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Inventory control in diversified manufacturing: the problem of uncertainty and their reduction

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THESIS

Inventory Control in Diversified Manufacturing: The Problems of Uncertainty and their Reduction

by

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Chapter 1

Introduction

Recently, businessmen have shown increasing interest in inventory control. In past centuries inventories were considered an indication of wealth; enormous stocks were looked on as beneficial. In fact, a man's wealth was usually assessed by the size of his flocks, herds, and granaries. Money was no more than another class of merchandise:

> "It is true that usually the measure of stock and riches is accounted by money; but that is rather in imagination than reality... The stock or riches of the kingdom doth not only consist in our money, but also in our commodities and ships for trade, and in our ships for war, and magazines furnished with all necessary materials."*
>
> "Riches, in respect to a nation, are the universal plenty of all necessaries, as food, raiment, houses, and furniture, provision for war, etc."**

Since the turn of the century, and especially since the 1920's, this attitude has changed. Wealth has become increasingly identified with money and a desire for liquidity has replaced the previous preference for large stocks. There

* 5, p. 20.
** 6, p. 21.

has been a strong tendency to hold the means to purchase goods rather than the goods themselves. Excessively large inventories are now viewed with alarm, whereas in former times no one would ever have doubted that they were beneficial.

A number of factors have contributed to the change in attitude toward inventories. The development of mass production and the resulting expansion of markets, increased complexity of products, and accelerated tempo of changes in styles and specifications, are some of these factors. The growth of the corporate form of organization has also focused attention on this area, for both the groups of professional management and diversified owners have demanded greater efficiency. Increases in taxes, both on property and profits, have also increased interest in improved inventory control.

Inventories represent approximately one-third of industry's working capital. As a result of this, imbalances can cause companies to suffer substantial losses; accordingly, the unfortunate consequences of "adequate" inventories are much more a topic of conversation among businessmen than such beneficial aspects as good customer service and greater profits. Many firms look upon inventories as a necessary evil rather than as an investment which offers the same profit potential as plant and equipment.

Very few companies are completely satisfied with their method of managing inventories. Of course, few give inventory management the same careful scrutiny that is given to the acquisition and utilization of new plant and equipment or to other assets of the business. Even fewer have developed a basic philosophy on inventory management in which they attempt to outline the specific purpose they hope to accomplish through their substantial investments in raw material, work-in-process, and finished goods. Inventory programs as a rule are based upon judgements of the current business situation, without much thought as to the full or long range consequences of chosen courses of action. Since the programs are limited to current conditions, decisions usually come too late to produce balancing effects. Quite often such decisions accentuate the swings between excessed and shortages.

This is probably a result of the inherent difficulty of sound management of inventories. As will be seen, a good system of inventory control requires a reliable forecast of business conditions and, in some instances, a good forecast by model. While progress has been made in improving the reliability of business forecasting, it remains a treacherous art. Even present forecast techniques, however, would help many companies manage their inventories more intelligently.

Much attention has also been given other facets of the inventory problem. The place of inventories in, and their effect on, the economy has received, and still is receiving a great deal of study. Particular emphasis is placed on the role of inventories in the business cycle. Indeed, the unwitting and tardily recognized build-up of excess stocks is often recognized as a major cause of the 1920-21 depression. Again in 1949 there developed an inventory recession. In this instance inventory accumulation declined from a rate of nine billion dollars annually in the last quarter of 1948 to a liquidation of inventories at the rate of 1.5 billion dollars in the fourth quarter of 1949 - a total decline of three billion dollars in investment in producers' durable equipment. This mainly accounted for the recession. Consumption expenditures declined by only three billion. Unemployment benefits increased from 80 million dollars per month in December, 1948 to 170 million dollars in December, 1949.*

Businessmen as individuals cannot, of course, expect to eliminate entirely the effect of inventory fluctuations. This introduces another area receiving attention today, that of control over inventories by forces other than business itself. The interests of entrepreneurs who are installing modern inventory control systems are sometimes in conflict with the best interests of society. The question arises as to whether or not social control over inventories is desirable. First of all, it should be stated that the objectives of social control of inventories might be of an entirely different sort than of private enterprise. For example, attempts might be made to use inventories in cyclical

* 2 , p. 532.

stabilization plans. Social control of inventories could also play an important role in attempts to construct and implement production programs for the economy as a whole as well as in the experimental programs in military inventory now under way. It is almost beyond the range of conceiveable possibility that social control of inventories could be accomplished at the present time. Indeed, the failure of the military services to establish effective inventory control has been to a large extent due to the sheer magnitude of the task. Social control over industrial inventories presents an enormously larger range of problems even than this. In addition, over and above the question of the feasibility of such control is an equally broad subject - the desirability of such control in a free enterprise system.

On a more practical level are many other problems receiving a good deal of attention today. The subject of inventory management organization is one of these problems. Smaller companies, of course, tend to place responsibility under one man, usually the treasurer or controller, while leaving actual control to the plant management. This tends to result in pressure to keep the inventory value low. As a company increases in size, inventory policy, administration, and responsibility center in one person. Recognition of the need for cooperative action has caused some companies to establish a committee to direct the inventory program. While most of these committees are merely watchdog or review groups, some come close to the actual administration of inventory objectives and exercise strong central control over inventory matters. Some companies intend their committees to be review groups only. While the deliberation of such committees produces a certain amount of coordination between sales, finance, and production, they rely on individual members to initiate action. Also, they often leave the actual administration of inventories to a lower level of management.

In contrast to the committee approach to centralized management of inventories, some companies create a regular department with a staff devoted exclusively to problems of inventory control and production planning. What motivates companies in this direction is the belief that committees cannot find enough time to direct inventory programs properly, and that committees do not become well enough informed to do the job adequately.

In divisionalized companies the most common practice is to place the main responsibility for inventory control on the division manager. Even when there is a headquarters organization created to carry out the inventory program, a division manager is usually a key member of this central organization. He is the connecting link between central management and plant management. Many company executives feel that the divisional level is the logical spot to place responsibility for inventory management. The division manager and his staff are in close touch with plant operations and can exercise a more intelligent control over inventory matters in accordance with the policies and objectives established by headquarters. In some organizations divisions are operated like separate companies, and the division managers are almost solely responsible for their division's performance. Within the division the actual control of inventories is often the responsibility of one member of the division manager's staff or of an intra-divisional committee. The division manager carries out his responsibilities for inventory management by reviewing performance and consulting member of his staff.

Another problem on the operating level is that of the mechanics of inventory control, record keeping systems. At the simplest level, of course, there is no record keeping; the entrepreneur or his stock keeper keeps the record in his head. From this sort of elementary system developed the two-bin system in which a second bin's contents represented safety stock and reorder point. Here again there is no record keeping as such; action is instigated by observation of the actual parts. Transferring balances to a ledger card, be it on the bin or collected into a central location, is a necessity for all but the simplest enterprise.

There are as many types of ledgers as there are companies. All contain at least one balance, most commonly a physical balance, to which are posted receipts and disbursements. Some show an available balance, a figure which differs from the actual balance by the quantity of pieces reserved for customers' orders. In addition to these, quantities on-order and in-process can be posted. Many prefer to include on-order quantities in the available balance. As circumstances require, historical data, costs, vendor information, minimum and maximum balances, order quantities, and other information of a permanent or semi-permanent nature may be shown.

The form these records take and the method of sorting them are varied and numerous. A sizeable industry has developed to fill this demand and the outgrowth of it, automatic data processing. The increasing complexity of inventory problems has led to the development of mechanical devices to replace some or all of the clerical functions involved in the inventory ledger. Punched-card equipment has been so readily adapted to inventory record keeping that entries are collected, sorted, and summarized much more rapidly than otherwise possible. The actual record file has not improved as noticeably but a number of alternatives have been devised. One is a ledger card of the same size and shape as the normal punched card, printed from information on a master punched card. Another is a more conventional appearing ledger, printed on a spirit duplicating device with information accumulated on a master punched card.

Enormously increased data-handling speed, flexibility, and capacity has been made possible by the development of electronic equipment. The first of these units designed used continuous-flow memory devices, such as paper or magnetic tape. With such machines it is necessary to pass half of a tape through the reading section to find a unit of information stored at its mid-point. This is not an important disadvantage, however, for the fantastic speeds at which such a machine operates allow it to process gargantuan amounts of data in a very short time. The very complexity of these devices and their resulting high cost, however, limit their use to all but a relatively small group of companies and even in these instances inventory records are less often mechanized than accounts receivable, payroll, and other financial records.

A more promising development, especially for the small concern, is the "Random-Access" memory device such as the IBM 305 RAMAC. In this machine a unit of information is available of the inquirer directly; the memory file consists of a series of spinning disks on which information is stored in the form of magnetized spots in tracks around the disks. An access arm can be directed to any track, reading the desired information immediately. The capacity and flexibility of this type of equipment, together with its speed and relatively moderate cost - in comparison with the larger equipment - augur well for an auspicious future for mechanized inventory ledger systems.

The foregoing represents a summary of some of the problems facing businessmen today in the area of inventory management. This study will concern itself not with those, except in passing, but with another area on the practical operating level. This is the recognition of the problems of uncertainty and their reduction, with the goal of improving operating efficiency. This is an area receiving some attention today, especially in the field of "Operations Research." This broad term covers an approach to generalized, sometimes indistinct, business problems through the employment of scientific methods. As such, there is often employed a good deal of mathematics. Inasmuch as this study will look at the problem from the viewpoint of business management, the mathematical approach will be held to a minimum.

The problems of uncertainty concern themselves with basic, day-to-day operations. They are involved in the formulation of policy by top management and in the day-to-day decisions at the operating level. In diversified manufacturing, some of the simplest of these can be solved, or at least greatly reduced, with techniques and knowledge available to businessmen today. As time passes and more study is given the area, progress will be made against some of the remaining problems. The most important of them, however, can never be entirely solved. This is the important point; recognition and reduction of these problems, as will be shown in this thesis, is the most that can be expected.

Statement of the various problems of uncertainty, and indications of the manner in which they may be reduced, will form the body of this paper. The order in which they are listed in the form of chapter headings is, as closely as possible, in ascending order of difficulty. As might be expected, the existing body of work on these problems is in inverse proportion to their complexity.

The purpose of this thesis, then, is to define the problems of uncertainty in inventory control in diversified manufacturing, indicate solutions where possible, and point out the most promising methods of reduction of problems where no solution is possible.

Chapter II

The Inventory Problem: Theory and Fact

Inventory Functions

Probably the most important reason for the existence of inventories up until the development of mass production industries was forward buying, or buying in anticipation of price changes. Speculation of this type was carried on not as an adjunct to the operation of a business but as its main reason for existence. This practice is still common, of course, especially in those industries concerned with trading in the commodities.

Inventories have developed to fill other purposes as processes have become more complex. The physical inventory of any business is made up of a number of stock-keeping items. Two physical objects are the same item from a control point of view if they are fully interchangeable; that is, interchangeable without adding any expense to either piece. A soap company must view the same brand and size of soap package in two warehouses as separate items because time and money are required to move them; they are not directly interchangeable. Similarly two shoes of different size on a store shelf, otherwise identical, are different items. A stock-keeping item is held in a stock point. A warehouse or factory stockroom will have as many as several thousand stock points, one for each item held. In a manufacturing plant stock points will hold raw stores, work-in-process, and finished goods. Material is transferred from one of these to the next by means of an operation; the same operation can change the category into which the item falls by the type of work performed on the object, such as machining, assembling, or simply moving.

Stripped to its essentials an organization can be seen, from an inventory point of view, as consisting of a number of stock points and a number of operations, together with a control system for these stock points and operations. Each stock point is fed by one or more of these operations and is drained by others, until the point is reached where the drain is the demand by customers on the finished products. In principle, a flow chart can be constructed showing the course of the flow from the sources of raw materials through the intermediate stock points to the customers. This flow is not steady in actual practice. Operations are constantly being switched from feeding one stock point to feeding another, or the rate of flow through them is being increased, decreased, or interrupted. The control system governs the size of inventories in the various stock points by governing the rate and direction of flow through operations. The inventories in turn make it possible for the individual operations to run efficiently and for the production system as a whole to operate smoothly to give service to the consumer of the finished product.

The Production Handbook states that inventories are accumulated for six main reasons:

1. Economies can often be made by buying or producing material in larger quantities than that required for a specific order.

2. Industry custom sometimes dictates that finished items be available "off the shelf."

3. Sometimes difficulties are anticipated in procurement because of possible strikes or periods of high demand in relation to supply.

4. Sometimes higher prices or costs are anticipated because of price increases in raw materials or labor rates.

5. Production schedules can be increased more rapidly when raw materials and parts are carried in stock.

6. The risk of not having raw materials and parts on hand when they are needed is reduced, thus minimizing the risk of shutting down production lines or not having work for production workers.*

Excluding the forward buying consideration, which has already been mentioned, this boils down to the fact that basically inventories serve to decouple successive operations in the process of making a product and getting it to consumers.

* 2, Section 4, p. 2.

For example, inventories make it possible to make a product at a distance from customers or suppliers, or to do two operations at a distance from one another, even if only across the plant. Inventories make it possible to produce without precise connection with and dependence on sales, or, alternatively, to release consumption from adapting to the necessities of production. Inventories free one stage in the production process from the next, permitting each to operate more economically. The essential point is to determine when the decoupling process stops earning enough advantage to justify the investment required.

This decoupling function has two aspects. The first of these is that of time inventories, required because it takes time to complete an operation and move a product from one stage to another. This can be thought of as process or movement inventory. The second aspect is that of organizational requirements, inventories created to allow one unit, be it a machine or an industry, to schedule its operations without direct reliance on another. Both aspects concern time; the second differs from the first in that more than time is involved.

Movement inventories arise because of the time required to move stocks from one place to another. The inventory balances to fill this purpose may not be recognized as such, or may be confused with others. The amount of movement inventory at any one point is equal to the product of the rate of demand, or sales, multiplied by the transit time through that processing point. For example, if it takes two weeks to move materials from a plant to a warehouse, and if the warehouse sells 100 units per week, the movement inventory is 100 units times 2 weeks, or 200 units.

The amount of movement stock changes only when the rate of sales or transit time changes. Since time in transit often is a result of the physical requirements of the method of transportation, improvement in the method of transportation will serve to decrease the size of movement inventory. This is especially true in the case of movement between distant points, such as plant to warehouse, or mill to plant. However, it is equally true in the case of movement inside a plant from one machining operation, or in a retail store from stockroom to display counter. Most manufacturing plants contain substantial stocks in movement from one location to another. In fact, movement inventories have been the center of much attention by manufacturing management in recent years as the amount of savings possible have become evident.

Organization inventories simplify organizational requirements; the more of such inventories carried between stages in a manufacturing-distribution process, the less coordination is required to keep the process running smoothly. Conversely, if inventories are at an efficient level, they can be cut only at the expense of more expediting and scheduling effort to work out the difficulties which unforeseen disruptions at one point may cause in the whole process. Despite superficial differences among businesses in the nature and characteristics of the inventory they maintain, the following three inventory functions are common:

1. <u>Lot size inventories.</u> These 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 to obtain quantity discounts, to avoid high shipping costs, and to hold down clerical costs connected with creating requisitions, checking receipts, and paying bills. Similar reasons lead to long production runs on equipment requiring expensive set-ups.

2. <u>Fluctuation stocks.</u> These are held to cushion the shocks arising from unpredictable variations in customer demand. Warehouses and retailers maintain stocks in order to be able to supply customers on demand even when the rate of demand may show irregular and unpredictable fluctuations. In turn, factories hold stocks to be able to replenish the warehouses and retailers whose purchases from the manufacturer vary, of necessity, equally widely. Short-term fluctuations in the mix of orders on a plant often make it necessary to carry stocks of parts or subassemblies to give assembly operations flexibility in meeting orders as they arise, while

freeing earlier operations, such as machining, from the need to make momentary adjustments in schedules to meet assembly requirements. Fluctuation stocks are also carried in semi-finished form to balance out the load among manufacturing departments when orders received during the current day, week, or month may put a load on individual departments which is out of balance with long-run requirements.

The more diversified the manufacturing establishment, of course, the more acute the problem. For a company making one product, in one size, style, color, etc., the main problem is to maintain efficient stock levels at only one point, that of sales or ultimate demand. For the company making more than one product but concerned only with standard parts, uncertainty is encountered not only at the point of sale but also back through the stage of final assembly further complicating the problem. To handle this situation the manufacturer must either stock larger quantities of his finished product, thereby increasing his inventory, or require his customer to wait for the period of time required to assemble the unit. Still more difficult is the problem involving custom design, or products infrequently in demand. Here uncertainty extends through all the stages of manufacture and large fluctuation stocks must often be carried in the form of raw material.

These fluctuation stocks are not essential in any stage. A business can get along without them if it is willing and able to make its customers wait until the necessary material can be ordered, received, and scheduled into production as circumstances permit. The pressure of competition, however, always serves to oppose the natural desire to hold inventories down. As the importance of rapid deliveries increases, so must fluctuation stocks and, accordingly, the cost of doing business. In some cases such stocks are patently uneconomical; no one stocks finished battleships. In most cases anticipating all fluctuations is uneconomical, if not impossible; back orders will occasionally occur. Fluctuation stocks are part of the price we pay for the general business philosophy of serving the customers' wants rather than having them take what they can get.

3. Anticipation stocks. These are used where goods are consumed on a fairly predictable but changing pattern throughout the year and where it is possible and 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 capacity requirements. For example, many products show a seasonally changing demand; conversely the situation is often found where materials, such as agricultural products, are produced seasonally, but the rate of consumption is relatively uniform.

As more and more of these types of inventory are carried less coordination and planning are needed, less clerical effort is needed to handle orders, and greater savings can be achieved in manufacturing and shipping. These gains are not achieved directly with the increasing costs of inventory, however. As inventories increase, even if they are kept well balanced, the gains from additional stocks become proportionally less. Indeed, it is often the case that more effort is required, both clerical and manual, to control the larger stocks. The amount of control costs per dollar of inventory may drop somewhat but the total control costs rise with the increasing inventory. Along with control costs, warehouse, obsolescence, insurance, taxes, and capital costs associated with maintaining inventories also climb at a rate with, or greater than, the inventories themselves. As will be discussed later, these are the costs which rise with increasing inventories. There are also costs which decrease with rising inventories. Arriving at a balance between these two sets of costs while keeping inventories consistent with other requirements is one of the primary functions of inventory management.

The lack of control over inventories in past years is in part due to the inherent difficulty of effective control, and in part due to the philosophy previously mentioned, that inventory is money and the more the merrier. This viewpoint is still widespread. Salesmen know well that the larger the inventory the shorter the delivery and, accordingly, the easier it is to make the sale. Foremen know that longer machining runs mean fewer difficult set-ups with their attendant problems. Factory superintendents know that inventory reduction can mean idle machines, underabsorbtion of overhead, and personnel and union troubles.

One of the most severe problems with which inventory management is concerned is relating inventory levels to changes in the sales pattern. In the short term the problem is one of having enough stock on hand to fill an individual order without excesses; in the long run it is to successfully anticipate savings in the cycle so as to be ready to meet a change in conditions when it arrives, not six months later. Actually, of course, changes in total inventories and in production tend to lag behind changes in sales activity both in periods of rising and declining sales.

To illustrate this point, consider the average medium-sized concern in such a cycle, a company which does not have an accurately detailed sales forecast. At the beginning of the cycle management looks forward to a good year. A rapid increase in orders builds the backlog high and delivery times worsen. To avoid losing its share of the market management decides to increase production. Purchases are stepped up and overtime begins. An unexpected delay occurs at this point, however. Vendors are in the same position as their customers. Delivery times on purchased items have increased. Shortages occur, interfering with scheduling through the factory. This is complicated by high labor costs arising from overtime and training and selection of new workers. Gradually service improves and in the general bustle of activity the danger spots are disregarded. When the peak is reached and sales start to drop off slightly, a high backlog of orders deceives management into maintaining the high level of production. When the need for action becomes obvious the same time lag manifests itself. Purchase orders have been placed and cannot be cancelled. Receiving and inspection personnel must be retained to process this material. Raw stores and work-in-process must be finished in order that they can be sold and turned into needed cash. The labor force must be maintained to process these materials. Working capital drops dangerously; banks become more insistent on reduction of short term loans. Generally speaking about one full turnover, or one complete cycle of goods processed, is required before anything like proper balance is restored. In the course of this unhappy sequence of events, the high profits accumulated during the period of good sales can be drastically reduced, or even lost completely.

Top managements of many companies that formerly gave little thought to the administration of their inventories are now taking steps to correct the situation. There are a number of reasons for this. For one thing, tight money has forced the conservation of working capital. Organizations that once had little concern as to the ability to finance inventory investment now have other demands on their money, such as plant expansion and general company growth. New sources of funds may be very costly or unavailable. This has been especially noticeable since the war in the general desire to increase and stabilize earnings by diversifying. Managements concerned with acquiring new operations and adding new divisions have found that inventories require strict regulation.

Serious and recurring imbalances in inventory have also embarrassed management. Most companies occasionally find themselves with serious inventory excesses or shortages and have to accept the reduced profits which usually accompany the adjustment. Such situations should be held to a minimum, of course. A survey by the National Industrial Conference Board finds a number of reasons quoted for the causes of such imbalances:

1. Lack of a controlling policy or program
2. Failure to delegate management responsibility
3. Failure to recognize that inventory is a company-wide problem
4. Tendency to place too much emphasis on historical information
5. Inability to forecast accurately
6. The natural inclination to hoard inventory
7. The difficulty of reflecting changes in the sales pattern in the purchasing and production programs
8. The need to accumulate inventories in advance of the selling season

9. Allowing too many items in the line, or special order selling

10. Failure to develop and maintain good sources of supply

11. Failure to find underlying cause of inventory imbalance.*

To this list could be added such factors as the lack of standardization of parts, the failure to maintain accurate and up-to-date inventory records, sloppy storekeeping, inadequate costing systems, and others. These will be taken up in more detail in later sections as they affect the major areas of uncertainty.

Another cause leading to more interest in tighter inventory control is the annual discovery of discrepancies between stated inventory values and year-end figures derived from a physical count. Such studies often reveal heavy oversupplies or large quantities of obsolete equipment which must be sold at a discount or written off; just as often are found serious shortages which must come out of the year-end profit.

A fourth cause is inability to follow an operating program or to maintain a desired inventory level, leading some companies to study the causes of failure and seek new methods of control.

* 9, p. 9.

Management, especially sales management, becomes increasingly concerned about service to customers, or the lack of it, in times of tight competition. For this reason tighter inventory control has received more attention also in this area.

Chapter III

Policy and Practice

While there are many areas of uncertainty in the field of inventory control which are difficult to define, grapple with, and resolve, there is one which is not. This is the problem of inadequate attention by top management and the lack of clearly stated policies and goals. It is one thing to favor good inventory control; it is quite another to provide the degree of management influence that appears necessary for the achievement of favorable results. Top managements' desires are not often supported by a written policy or the expression of long range fundamental beliefs which can serve as a guide to operating management. The feeling exists in some quarters that a rigid inventory policy is unnecessary or impossible to state. It is true, of course, that such a rigid policy can tend to reduce the flexibility of inventory management in dealing with new situations as they arise.

However, there are certain objectives around which inventory policies can be based. They can be formally stated and implemented in any number of ways. Devices to measure results against goals can be established. A company may place nearly all of its emphasis on one of these objectives with slight attention to the others or it may try to reach all of the objectives at once. As times passes and conditions change, so may an organization shift its major emphasis from one area to another.

One of the most frequently quoted management desires is good service to customers. The ability to fill customers' orders in a reasonable time, regardless of how varied the requests, is a major objective of all inventory programs. Naturally, companies differ in their interpretation of what constitutes satisfactory speed of service. Some companies strive for high stock levels even at a relatively high investment with its inherent danger of obsolescence. Other organizations weigh the penalties of delayed shipments more carefully against the financial requirements of a higher inventory.

Factors that cause some companies to give unusual weight to prompt service in planning their inventories are:

Competition. When price and quality are the same for competing products, the delivery time period may be the deciding factor in making the sale; at any rate, it will weigh heavily in the purchaser's decision. Many times delivery is more important than other factors, such as unique design features or a price differential.

Public Responsibility. Some organizations cannot fail to supply their products when needed because of their responsibility to the public. This can take two forms - a legal responsibility, as in the case of a public utility, or a moral responsibility, as in the case of an ethical drug manufacturer. In the first of these the law allows a monopolistic situation to exist, guaranteeing a market and controlling the price in return for the high degree of responsibility. In the second case, while there are no legally created monopolies, the consumer must pay for the inefficient operations resulting from the unusually high inventories by paying a higher price for drugs than would otherwise be the case.

Customer Service. It is sometimes important to be able to supply customers with replacement parts without delay. Failure to do so may have serious effects on future sales. This is often the case in the manufacture of expensive capital equipment. The power plant buying a huge generator expects to be able to obtain spare parts for a considerable length of time. The policy a company established as to the period when parts will be made available depends on the value of the original equipment, the availability of replacement equipment, the policies of competitive organizations, and the nature of the parts themselves. Obviously it would be uneconomical to forge one small part for a replacement order, yet it would be difficult to charge a customer the full cost of such a piece.

Some companies have the financial strength to provide prompt delivery even when it is not essential. Most, however, are forced to strike a reasonable balance between the desire to provide prompt service and other requirements of inventory management. In essence, a company tries to match the cost of carrying those inventories against the cost of those it doesn't have, a cost which manifests itself in terms of lost orders and customer dissatisfaction. A desire to give prompt service usually has its greatest impact on finished goods inventories since this is the point of ultimate demand. In many cases this is also the point at which the inventory is hardest to control because of the vagaries in customers' orders.

For those organizations which place heavy emphasis on the aspect of service to the customer, advance planning of operations and sales forecasts are of high importance. Greater emphasis is also placed on the reliability of sources of supply, and efforts are made to acquaint vendors with anticipated future requirements.

Another policy influencing the establishment of inventory control is also connected with an area outside the company - vendor relations. A reliable source of supply of raw materials and component parts is an important safeguard to steady production and good service and can go far in reducing uncertainty in the delivery of these parts and materials. There are a number of practices which should be avoided when possible:

1. Sudden changes in quantity requirements without giving proper advance notice to the vendor.
2. Frequent specification changes affecting open orders.
3. Tendency to order on a rush basis.

4. Incomplete information and specifications on the Purchase Order leading to expensive and/or inaccurate shipments.

5. The practice of ordering and then canelling all or part of the order, or of delaying the required date, without regard to the supplier.

6. Lack of interest in the vendors' production problems and his required lead time.

Many companies believe that by making an effort to keep good vendor relations the suppliers are more willing to extend themselves in providing service, as for example, in maintaining stocks of parts and materials. By keeping the vendor informed of its requirements ahead of time, as in effect it would one of its own manufacturing departments, the vendor has an opportunity to provide goods more rapidly when they are needed.

The idea of persuading vendors to carry inventory is not a new one, of course, nor is it commonly approved of by vendors. The average concern considers itself as having problems enough without unnecessarily taking on those of its customer, which is what it is doing when it ties up its own money in what otherwise would be its customers' inventory. All of the customers' worries of decreasing sales, obsolescense, deterioration and the like, are then the concern of the vendor. To quote a conversation between Mr. E. J. Andrysiak, Works Manager of McRay Refrigerator Co., and Mr. J. M. Kaufman, General Manager, Manufacturing, Fort Wayne division, The Weatherhead Company:

Andrysiak: "There are two basic ideas to work toward in controlling inventory. First find a vendor who will keep the inventory in his particular plant. Second, have the vendor back his truck up to your door and work out of the truck."

Kaufman: "Somewhere, some supplier is going to have a rough time. If you want us to carry your inventory and our suppliers are going to carry our inventory, the man in the mines is going to have a rough time."*

These two statements reflect the two common schools of thought on the subject.

A common alternative to the device of forcing the vendor to carry the customers' stock is the blanket order, which is an order for a large quantity of parts of material to be released at intervals over a relatively long period of time. This removes the financial burden from the vendor but still gives the customer the advantage of small shipments, resulting in a small inventory at any given instant, at a low quantity price. Should the customers' sales forecast prove seriously wrong, of course, he can be in trouble, for he is committed to accept a relatively large quantity of goods.

Vendors can do other things for a customer in addi-

* 12, p. 90.

tion to carrying stock. When relations are good, vendors may be more willing to advise on approaching price changes, to honor existing orders at an old price when a price does increase, to give more generous terms, or to provide quicker delivery. Manufacturers of specialty equipment can provide good customers with very valuable service from trained salesmen and engineers, materially reducing product development costs.

Owens lists some practices of the purchasing department which may result in the loss of vendor good will:

1. Refusal to see salesmen.
2. Telling salesmen that the company is not in the market at a time when ordersare actually being placed.
3. Making unreasonable and unnecessary delivery requirements.
4. Placing speculative orders with the intent of cancelling them if prices decline.
5. Attempting to obtain a low price which does not afford a fair profit to the vendor.
6. Playing one vendor against another by misrepresenting the prices asked or the terms offered by other vendors.
7. Using a quoted price on an inferior article to drive down the price on a better one.
8. Failing to accept delivery of merchandise.*

* 4, p. 524.

Two other important objectives of inventory management are closely related, the maintainance of economical rates of production and stable levels of employment. With careful planning and a certain amount of luck, inventories can be balanced against production. Most often, however, increases and decreases in inventory levels cause cutbacks and cancellations in production, resulting in higher production costs and lower morale.

An inventory policy geared to these aims is especially important in industries that are very price-competitive, and in those using labor forces which are hard to find or expensive to train. There is also a particular moral responsibility where a company is the sole or principal employer in a community.

The inherent difficulty of accurate forecasting in diversified manufacture makes a goal of a steady production rate tenuous indeed. Accordingly, many companies do not feel the results worth the effort.

Among financial people emphasis is liable to be placed on maintaining low inventory balances. More than any other group they are aware of the ease with which liquidity may be impaired by overly large inventories. This philosophy may be given more credence by top management in times of depressed sales when inventories resulting from excess optimism in better times may be the cause of reduced working capital. In better times, however, the objective is usually subordinated to that of providing good service to customers. Like so many other facets of inventory control, this is to a great extent a result of the complexity of the subject. Very rarely have financial men ever proposed sound methods of inventory control which take into account the opposing philosophies of customer service and low inventories. Because of the constantly changing conditions of business life, few companies have ever been able to impose dollar limits on inventories. A more common device, but one with many faults, is the inventory turnover, a sales-inventory ratio established as an objective. This subject will be more fully discussed later.

All companies attempt to avoid deterioration and obsolescence, but in some companies this is a more serious problem than in others. Manufacturers of perishable products or those affected by style changes are most affected, but even durable basic products like steel and copper can corrode if held too long in inventory. In addition to perishability and fashion changes, other things can result in obsolescence and scrap, such as, specification changes, introduction of new and better materials by the manufacturer, competitors, or vendors, over-production, inadequate or improper storage facilities, too large a product line, and decentralized manufacturing or distribution operations.

For proper inventory management all these objectives must be considered in the light of a company's individual requirements at a given moment. Indeed, the success of one objective depends on the others; good service cannot be achieved for the sales department without a sound production program. A sound production program depends on reliable information and cooperation from the sales department as well as good vendor relations.

Chapter IV

The Product Line

The problem of inventory control is relatively simple for the manufacturer who has one product. As the product line increases from such a utopian situation, the maintenance of proper inventory level becomes more difficult. Every part in every product complicates the situation.

Many forces combine to broaden a company's product line. The passage of time brings changes in customers' requirements and a demand for a greater variety of shapes, sizes, colors, accessories, etc. Technological improvements force changes in product design and construction. If for no other reason, a company must maintain competition's pace or eventually fail.

Generally speaking, inventory management is not concerned with the initial selection of additions to the product line. There are, however, a number of ways that the experience of inventory management can be employed.

Most notable of the contributions that the production man can make to product design is the encouragement of standardization. Today the use of standards is so well accepted that relatively little thought is given to their actual importance. Their development and application are an almost routine activity of business operations. Yet many companies are not availing themselves fully of the opportunities for increased efficiency and cost savings that standards make possible.

The essence of standardization is to many people a provision for uniformity. Objections to the creation of standards often stem from the preconception that the end result must be a deadly identity of products. It is true that the tool of standardization, when misused, can excessively restrict variety, retard innovation, and cripple the process of investing articles with esthetic or artistic values. Yet without standardization and simplification, the elimination of needless variation, the present level of American industrial efficiency could never have been reached. It is a fortunate fact that manufacturing standardization, which permits longer production runs, simpler tooling, faster production, better control of quality, and other production-increasing advantages, also permits industry to offer a richly varied array of goods. The use of standard tools, materials, and components does not automatically require that final products be of limited variety and reduced to a common level of quality or mediocrity of design. The family relationship between a Chevrolet and a Cadillac or a Ford and a Lincoln, which exists because some of their parts are the same, does not impair their individuality. Moreover, hundreds of combinations of standardized features, such as body style, color, trim, and optional equipment can and do appear in each line. Providing uniformity where it is desirable is one thing; providing uniformity for its own sake is another.

Fixity or permanence frequently is implied as a necessary characteristic of all standards, especially when their supposed retarding influence on progress is the subject of discussion. This misconception arises from failure to distinguish between industrial standards and other kinds of standards. Physical constants such as the units for time, length, or speed of light are the standards of science and are necessarily unvarying. Since the standards of science are ultimates, physical industrial standards finally depend upon them. Industrial standards themselves, however, usually are not, and should not be, treated as ultimates. They define knowledge as a point in time, usually by stating what is most suitable when judged by some set of criteria. When knowledge increases or criteria changes, the standards must and do change. A motor manufacturer, for example, may revise upward over time the service rating of an electric motor it produces as its design is improved and parts of greater durability are incorporated in it. If new service conditions are to be provided for, manufacturing standards may have to be made more severe at some points or made to emphasize different attributes of the motor, as might be the case if the motor's starting characteristics become more important than its heat dissipation.

Just as opponents of standardization misconstrue its purpose and effect, so do some of its strongest proponents.

Obviously there are limits beyond which it is not feasible to push standardization. For the individual company there are appropriate and inappropriate directions to take. It is as illusory to expect standardization to provide a universal answer to management problems as to expect that any other program will provide it. By their very nature, the standards evolved in industrial administration cannot be either perfect or perfectly comprehensive, any more than they can be permanent. To try to standardize too much or too minutely may be nearly as serious a mistake as not to standardize at all.

Opinions on the proper scope of industrial standardization differ somewhat, even among administrators who recognize its importance. At one extreme it may be argued that industrial standardization includes only those measures taken to define products, to develop related standards for materials, supply processes, and test methods, and to provide other guideposts which aid in the definition of products, such as standards of nomenclature, classification, and design, or drafting practice. At the opposite extreme it is argued that industrial standardization takes in all activities that result in standards, regardless of their application, such as standards of performance for personnel, standard administrative procedures, etc. While this latter definition may have merit, it does not, of course, bear on the subject of inventory control.

A commonly cited objective of standardization is to make possible the manufacture of better products in larger quantities and at lower costs. The role of industrial standardization is perceived as that of assuring the use in the company of the best available materials (not necessarily the most expensive), the best manufacturing methods, and the best equipment - in short, the optimum assortment of productive factors.

It is widely asserted that a standard, by definition, defines the best available solution to an operating problem, whether it applies to a material used for a particular purpose, a process employed to produce a given end result, a product to fill a specific need, or some other element in production. It follows, then, that widening application of standards should improve performance, reduce costs, raise average quality, and allow more general utilization of the equipment and methods of mass production. These advantages are valid for the individual company. Their effect is cumulative when inter-company integration of standards can be accomplished through agreement between suppliers and customers.*

In practice, standardization can serve to improve operations from the point of view of inventory management in four principal methods. One is the reduction of needlessly stringent quality specifications. Since quanlity standards normally are standards of practical adequacy and not descriptions of borderline positions, no dilution of quality is implied if quality refers to appropriateness and not perfection.

* 8, p. 9.

The reflection of reasonable standards of quality in production requirements is the paring of operations to the point where standards are met comfortably. As a consequence of product-quality standardization it may be possible to eliminate intricate production operations, operations of high precision handwork, and repeated close inspections; substitutions may be made for scarce, expensive, and hard-to-work materials; equipment set-ups may be simplified, and operators may be trained more easily.

The second promising area for results achieved from standardization is simplification, especially applied to product design and components. The savings industry has made through product design studies are enormous, and innumerable examples could be listed. For example, manufacturing companies often carry two types of free machining stainless steel bars, such as types 303 and 416; one of these could be dropped. For another example of needless duplication, leaded steels are often carried along with such others as SAE 1112 or 1113. The introduction of commercial standards by various organizations for such specifications as screw threads had done much to reduce needless variation.# Even these can be simplified, as, for example, by using only coarse threads. Every type of raw material or part eliminated means that more money can be invested in another, with the result that the inventory will be better balanced and reduced in total, while at the same time

See Appendix for list of such organizations.

the chances of an item being out of stock, and accordingly, of an order being held up, are reduced.

Two examples of savings by the International Harvester Company will illustrate the point. First, a statement from Mr. C. W. Anderson, Works Manager, Fort Wayne plant:

> "At one time, we had 87 different types of cabs for trucks assembled in Fort Wayne. Someone suggested that we could eliminate the fire wall from the assemblies made by our source in Springfield, Ohio. By assembling the fire wall in Fort Wayne, we could reduce the order to 27 different types of cabs. Now instead of carrying an inventory of 87 different types of cabs, and a two or three or five-week bank, we can work from a smaller bank of 27 types of cabs. This was not a cleancut "make-or-buy" decision affecting an entire assembly, but we decided to buy less of the assembly.
>
> "A similar case involved transmissions. We used to buy 87 different types of transmissions. Now we buy nine skeleton types or models of transmissions. We stock additional gears and components in our plant, and build variations of basic types."*

* 12, pp. 73 and 89.

The second example concerns engine inventories:

"A standardization program, coupled with shifts in sequence and location of assembly operations, is producing substantial economic advantages for International Harvester's Motor Truck Division plant at Fort Wayne, Indiana.

"The main advantage is the reduction of part numbers to be scheduled and purchased. This, in turn, reduced the inventory of engines normally held in stock to supply the truck assembly line. The need for stocking fewer engines reduced storage space requirements, and the handling and shuffling necessary to select from a large assortment when specific engines are required on the assembly line.

"The problem, simply stated, was one of ordering and scheduling three basic engines under literally hundreds of part numbers, and scheduling them for specified trucks on the assembly line. The Red Diamond engine, alone, had 404 part numbers assigned to specify variations. Standardization eliminated 264."*

The third way standardization can be used to reduce

* 13, pp. 81-82.

inventory problems, is to reduce needless variation in the product line. While improvements must be made if a company is to stay in business, it is not necessary that additions be made to the line needlessly. Unless a request for a new product is scrutinized carefully, a manufacturer is apt to find himself with an enormous variety of products, some of which do not earn their keep. The decision to produce a line of items implies a number of connected decisions pertaining to the items and their relationships. If, for example, the line of products is determined so that a minimum number of individual items will cover the range of sizes, grades, capacities, styles, or models included in the line, and so that maximum interchangeability among the items of standard component parts and materials is provided, design criteria are likely to be much more explicit, systematic, and satisfactory.

Even in the face of considerable pressure, intelligent planning may overcome problems of a widening product line. For example, when competition in major applicances became most severe, many manufacturers hit upon the notion of offering a variety of finish colors on their large appliances. Such a situation, of course, could make for a nightmare of scheduling and stocking problems. One manufacturer, Frigidaire, overcame its problem by making all the units with a standard white finish and, to stay abreast of competition, designed a series of colored panels which could be fixed to the appliance by the dealer. This gave the consumer a style choice without adding a single variation to the plant production.

The fourth major advantage of standardization to the manufacturer of a diversified product line is that it reduces the incidence of expensive engineering changes. Changes in a product after its initial release for production are to be expected in the normal course of events. The fewer such changes the better, however. Especially annoying are those changes which force obsolescence or junking of parts. Such changes are usually in the minority. When the change is such that supply of parts can be used up, a very careful plan must be constructed to insure the maximum utilization of the old parts together with a smooth transition to the new design without running out of stock in the process. As standardization improves the design features of the product, engineering changes are reduced.

Another subject requiring a statement of managerial policy is replacement parts. As products and parts become obsolete, replaced by improved designs, demand for the old unit is generally reduced to spare parts orders. The length of time that a company feels required to supply spare parts along with the degree of service it should offer have a direct bearing on the inventory. This policy is determined to a great extent by the initial expense and complexity of the equipment initially supplied. While the manufacture of some obsolete parts is not a problem, often times the high production tooling originally designed for the part severely complicates the manufacture of a small number of pieces for a replacement parts inventory. In addition, patterns, dies, and special tools must be stored and maintained to prevent deterioration. When such tooling is owned by a supplier, an additional problem occurs in the form of the vendor's unwillingness to store the tools for a long period of time.

Chapter V

Uncertainty in Manufacturing

Cost Factors

It can safely be said that there are two major areas of uncertainty in inventory control for any manufacturing concern, both of which are intensified for a company producing a diversified product. The first of these, and the most promising field of investigation, is uncertainty in the manufacturing operation.

There are a number of problems in manufacturing which are influenced by uncertainty. This may be so for a number of reasons. Perhaps the problem could be resolved by better reports or systems; perhaps personnel are insufficiently trained. More often than not, however, uncertainty is a result of a large number of complex, little-understood factors bearing on each other. Proper analysis of these factors can go far in helping management establish effective inventory policies and controls.

The subject of costs is one of the most basic in inventory discussions. Costs, and the balancing of opposing costs, lie at the heart of inventory control problems, as well as production problems. Furthermore, the cost elements essential to a production or inventory control problem are not those characteristically reported in accounting records. Accounting records can supply cost information but usually the accounting costs must be restated to arrive at cost figures valid for the problem at hand. At times costs must be derived by other methods, such as statistical means. On occasion it is a problem for inventory management not only to determine these costs but to demonstrate to top management how they differ from accounting cost figures and their proper use in inventory control.

Accounting costs are derived under principles of accounting developed over many years and are strongly influenced by tradition. In any company the methods and the degree of accounting skill and refinement will vary, but in all companies the basic objective of accounting procedures is to provide a fair, consistent, and conservative valuation of assets and show the flow of values in the business. Accounting methods have, accordingly, been devised in accordance with these objectives. Modern accounting is also affected by legal and tax considerations and the desire to reflect conservative values in the face of price-level fluctuations. The constant search by businessmen for better methods has resulted in the increasing use of accounting costs for control systems, but rarely has the need been recognized for questioning the techniques of cost definition for the purpose of inventory and production problems.

Accounting systems typically distinguish three types of costs: direct costs, indirect costs, and overhead. Direct costs are those which can be directly associated with a specific job, order, batch of material, or item, as, for example, raw materials or the wages of workers operating production equipment, such as machine tools, or of workers assembling equipment on a production line. Indirect costs include the cost of supplies used to service a machine or line, wages of process operators where operator time is not directly related to specific jobs, or auxiliary help, such as set-up men, sweepers, etc. Indirect cost items vary widely from plant to plant. Overhead items include factory overhead such as building and equipment depreciation and factory supervision and general overhead such as administration, selling, etc. The listing of overhead items, too, varies widely from one company to another, depending on individual requirements and tradition.

The methods by which these types of costs are recorded vary widely but are of two basic types. One of these is based on actual costs. In a system of this sort product costs are based on an accumulation of the actual direct costs reported from a job or in making an item during a given time period, as by labor time cards, periodic physical inventory counts, or material requisitions. Thus the cost of an item under an actual system will vary from batch to batch or from time to time. Under a standard cost system, product costs are based on "standards", or desired norms of direct labor and materials cost which remain fixed for substantial periods. Under a standard cost system, actual costs will also be collected to varying degrees of detail as a check on the reliability of the standards and as a control device. The standard costs are usually used to value material in in-process or finished inventory; differences or "variances" between actual and standard costs are considered as additions to or subtractions from current profits rather than being included as adjustments to inventory value.

Actual or standard cost systems may in turn be based on direct or absorption costing. Under direct costing, only direct costs are included in the value placed on products in inventory. Under absorption costing, the value includes not only direct costs but also allocated overhead charges, usually only factory overhead. A variety of overhead allocation bases are used; the establishment of fair methods of overhead allocation has received a great deal of attention by accountants.

Methods of overhead absorption are based first, on the assignment of expected overhead charges in total to work centers, and second on the allocation of the overhead charge in each work center to the work done in that center, based on an overhead rate. For example, the overhead may be assigned to products in proportion to the direct labor charge incurred on each. The overhead rate, or dollars of overhead charged per dollar of direct-labor costs, is conventionally set in advance, based on an expected level of activity at the work center. If, after the overhead rates are set, the actual level of activity exceeds the expected, more overhead will be charged to the product than was assigned to the center and overhead will be "overabsorbed." If actual activity is less than expected, overhead is "underabsorbed."

Since overabsorption results in artificially high costs and underabsorption the opposite, it is only natural that the tradition of conservatism in accounting would tend to favor the former. Accordingly, it is sometimes found to indicate a sound operation for reasons independent of inventory and production control. On occasion, however, the matter can affect production planning; for example, sometimes there is a tendency to balance production between two plants of different efficiencies to absorb overhead in the less efficient plant independent of other reasons. At the other extreme, production may sometimes be shifted to the plant operating at a high level because of its low average costs resulting from spreading plant overhead over a larger volume. Both of these fallacies should be avoided.

Contrasted with the principles and search for consistency underlying accounting costs, the definition of costs for production and inventory control may vary from time to time depending on circumstances and the length of time being planned. This reflects one of the uncertainties of cost recording and control from the inventory manager's viewpoint. Cost definition for production and inventory control purposes is based on two factors foreign to the common conception of manufacturing costs. First, these costs represent only part of product expenditures in the form of cash actually paid out or of opportunities for profit foregone. Overtime premium payments are out-of-pocket expenditures, depreciation of equipment 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. To the extent that storage space is rented, representing out-of-pocket expenses, or could be used for other productive purposes, representing foregone opportunity, 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 accounting value of the investment. The rate of interest charged on the out-of-pocket investment may be based either on the rate of interest paid banks, an out-of-pocket expense, or on the rate of profit that might reasonably have been earned by an alternative use of the investment, a foregone opportunity, depending on the situation. A bank rate could be used for short term seasonal inventories and an internal rate for long term growth requirements.

The second stipulation of production and inventory cost definition is that they shall represent only those 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.*

These definitions may seem unreasonably severe, as well as unnecessarily complex, at first glance. Fortunately, however, another difference between accounting and production costs has been proven by experience. While accounting systems

* 3, p. 27.

exhibit meticulous concern for precise detail, this is unnecessary for production cost analysis. As will be shown, inventory decisions are relatively insensitive to small variations in costs. Since it is absolutely impossible to determine many costs accurately, regardless of the detail of the accounting system, the use by inventory management of techniques relatively independent of precise costs becomes all the more important.

There are a number of types of costs which have to be considered in any discussion of inventory control. One of these is that group of costs dependent on order quantity. The most obvious of these, of course, is the quantity discount, a rate schedule varying with the quantity of items purchased. Quantity discounts are ordinarily quoted in price breaks, or brackets, volume limits within which fixed unit prices apply, or in terms of percentage allowances granted for orders of more than a stated quantity. The underlying logic behind this principle is that the supplier is allowed to distribute his fixed costs over a larger quantity of pieces. On contract bids or special inquiries purchasers often request estimates of price reductions obtainable with volume buying. Such data often is misleading since it may be compiled half-heartedly and carelessly, and will fail to give the buying an understanding of actual quantity breaks which might influence his ordering. Some suppliers are reluctant to give quantity discount figures, for the perceptive buyer can determine from them fixed and variable costs and profit, figures which the seller does not want disclosed.

Similar to the quantity discount is the set-up cost, a fixed cost per run incurred by a manufacturer. This is true in a factory operation, where machines must be adjusted before producing goods, as well as in an office, where clerical routines are performed on each sales and manufacturing order. Costs obtained from accounting data must be checked carefully where set-up is likely to be important. Variation in unit manufacturing cost cannot always be traced to the existence of a simple set-up cost for in machine tool operations several alternate manufacturing processes may be available. For a few pieces, set-up might be negligible as the pieces would be made essentially by hand. As the demand for the item increases, the method of manufacture will change, reducing the total time employed to make the piece, but the more intricate machinery used will call for longer set-ups. Very long runs may justify expensive special tools, such as the dies used to form automotive body panels.

Similar to set-up costs for a machine are learning or "shakedown" costs associated with hiring and transferring personnel. Output during the early part of a run may well be deficient in quantity or quality, and material may be spoiled. These costs may effectively be considered as additions to the direct set-up costs of the run. Another cost which should be considered is that of overtime, the premium paid for working over eight hours per day or forty hours per week. This premium, usually fifty percent of the regular rate, is ordinarily an out-of-pocket cost resulting from planning and scheduling decisions. In addition to the wages paid for overtime work, supervisory and other normally fixed costs may increase with the additional hours worked. There are also important indirect labor costs, such as social security, workmen's compensation, pension, and similar benefit payments to be considered. Too, overtime or extra shift operation may cause losses due to inefficiency, fatigue, unskilled supervision, or special rest benefits.

The cost of undercapacity operation may be encountered at times and is especially apt to be found in slack times where a basic labor force is considered necessary, independent of volume. Fortunately, this is not a common occurence in manufacturing organizations. A more frequent cost is that of hiring and training. Charges of this sort include interviewing, tests, physical examinations, and special training. The low productive efficiency of the new worker is also a type of training cost. Sometimes aggravating these costs is seniority rule which can result in a whole series of promotions, each incurring training costs, because of one job opening. Even layoffs can cause training costs where "bumping" forces the dismissal of a worker who might otherwise have been kept.

As has been pointed out, one of the common objectives of inventory control systems is proper customer service. An evaluation of the worth of customer service or, alternatively, the losses suffered from its lack, is an essential part of the derivation of an intelligent inventory control system. The cost of customer service limitations must be weighed against the production and capital costs incurred in improving service. It is normally very difficult to obtain a figure on the value of customer service from sales people, and it is not hard to understand their reticence. The usual reaction will be that customer service is of immense importance and that, if indeed any value can be put on it, it is very high. The most reasonable counter to such a statement is to show that it can be determined how much must actually be paid to achieve a given degree of customer service in terms of delivery time or other criteria. With such a demonstration estimates of the value of customer service drop markedly. In illustration of this point, a study made by the Bell Telephone Labs for one inventory item showed that, with an allowable frequency of being out of stock once a year, an inventory of $76,000 was carried; once every two years, $100,000; every five years, $134,000; every ten years, $167,000; and when policy stipulated never being out of the item, a total investment of $276,000 was required.*

In some cases certain limits can be placed on the value of customer service. In seasonal products, for instance, the cost of being unable to fill an order immediately will vary from time to time during the year. During peak sales periods

* 14, p. 20.

inability to fill an order immediately may cause the loss of the order resulting in a loss at least equal to the profit of the order. At other times, being out of stock may cost only the extra paperwork connected with the back order. In other cases it is not possible to arrive at a reasonable statement of the cost of being able to fill an order. For example, the possible loss of customers over a substantial period of time due to insufficient stocks might well be unestimable.

Clerical costs are one of the most difficult costs associated with production and inventory control to measure. Relatively little has been done in many companies to identify these costs clearly, to measure them, for example by time study or work sampling methods, or to identify the work units which originate clerical costs. Clerical costs include such items as the cost of making out a requisition and placing an order, the cost of time of personnel required for scheduling, and the cost of periodic inventory reviews for ordering purposes, among others.

One approach to measuring order-handling costs is to follow typical orders and requisitions through all the handling steps, noting the times required by individuals processing the item, the supplies used, and direct costs incurred such as telephone or postage. The time that individuals spend on handling an order may be estimated by watching to see how long it takes to process sample orders, by spot checks to see how much of the time an individual is working on orders, or by counting to see how many orders each person handles in one day. Order-handling time must be distinguished from other duties, of course, and fixed costs, such as machine rental, must be properly accounted for.

Since order-handling costs are difficult to measure and distribute to inventory they are generally not considered in evaluating order procedures. Inasmuch as they are part of order costs, however, they should not be ignored. As has been pointed out, production costs need not be precise to the penny. The important points are that they be roughly correct and that they accurately reflect the types of out-of-pocket costs which would be affected.

As for the costs of inventory itself, there are a number of types. Storage and handling costs include heat, light, stock handlers, trucking, loading and unloading. Taxes on inventory are sometimes overlooked as an inventory cost. Property taxes in some states are assessed on one day during the year against the inventory which is on hand on that particular day. This may create a distortion in inventory planning which can have considerable impact. Manufacturers strive to deplete their inventories by the assessment date and build them up thereafter.

Obsolescence costs are usually obtainable from historical records. Obsolescence is not a material factor with some firms and with others it is critical. In style goods and military products, for example automobiles, appliances, fighter planes, and clothing, changes occur at frequent intervals rendering present lines obsolete. As styles change, excess stocks must either be marked down or otherwise disposed of. Since all items may have different risks involved, these obsolescence charges should be categorized by product lines and prorated on such a basis.

Deterioration is another common occurrence with items stocked in inventory. Steel items tend to rust and have to be reworked or scrapped, silver tarnishes and must be reshined, rubber deteriorates completely and may become useless. Bearings and other moving precision parts are packed in grease and must be periodically cleaned and repacked. These costs again can be obtained from historical records and prorated as a percentage against the inventory. Repackaging and rehandling may occur, for example when as item is packaged in gross-size boxes and must be repacked in dozen-size boxes to fill an order.

A final cost to be considered is that of the capital invested in inventory. Since capital represents cash tied up which the company expects to get back, its cost is not its total amount but rather the value paid to obtain it. This may be based on the rate paid to borrow the investment or the cost of diverting capital from other possible uses, or both. This cost of capital invested in inventory is the product of three factors: the capital value of a unit of inventory, the time a unit of product is in inventory, and the charge or imputed interest rate placed against a dollar of invested cash. The imputed interest rate is less often considered by businessmen than the other two elements of this definition, especially in those cases where the investment is provided by the company's own reserves rather than by borrowing. To ignore this, however, is to say that cash would otherwise not be used at all. Of course, this is not the case; if nothing else the cash would be placed in bonds to earn a return. Barring the need for the capital, the money should be released to the stockholders.

Determination of the rate of return based on alternative uses of funds is not often easy. Some company managements have determined rates which they want their operations to earn. While it might be argued that a complete study of a company's operations would be required to establish a realistic rate based on alternative uses of capital, it is generally true that statements of the organization's financial and investment policies and estimates of current total return on investment will prove effective guides. Sometimes businessmen think of inventory as a short-term investment and thus relatively liquid and riskless inasmuch as it may turn over several times a year. While this may be true, it ignores the fact that at least part of that inventory is as permanent an 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.

Inventory in fashion lines or other types of products having high obsolescence risk is hardly riskless. Its value depends only on the company's ability to sell it. If sales are insufficient to liquidate the inventory built up, losses result and considerable risk may be entailed as a result of inventory investments. Inventory in stable product lines built up to absorb short term seasonal variations might be thought of perhaps as bearing the least risk, since this type of investment is characteristically short term. Even in these cases, however, if peak seasonal sales do not reach anticipated levels, substantially increased costs of storage and obsolescence may be incurred before the excess inventory can be liquidated over the time up to the next sales peak.

The rate of return may depend on the type of investment. For example, permanent investment as in facilities or relatively permanent base stock inventories may be financed internally at one rate, while seasonal inventory stock may be financed by a bank line of credit at another rate. Furthermore, depending on the nature of the financial arrangements, where the investment varies substantially from one time of the year to another, the capital cost of inventory investment may at times be appropriate where cash released during low inventory periods cannot be more profitably invested elsewhere.

Where tax rates are progressive, as in the case of an excess profits tax, a higher than average rate must be earned on the incremental investment to maintain the average over-all return. When tax rates are high, the cost of borrowed capital - a deductible cost - represents a substantially lower cost to stockholders than the cost of internally supplied funds imputed at similar rates. A substantially higher return must be earned on internal capital to maintain the same return on investment after taxes.

It is generally accepted that average or expected earnings, which are only the equivalent of capital costs, are not enough in risk bearing circumstances; something additional is required to compensate for assuming the risk. Manufacturing and merchandising organizations are, by definition, in business to bear the risks of these activities and to earn the resulting entrepreneur's profit. When the question of an appropriate rate of return to charge against investment is raised, company officers sometimes suggest a bank rate, i.e. 3 to 5 percent annually, when this rate is in fact inconsistent with financial policy. Such an inconsistency should be pointed out, since the use of a bank rate, when in fact the company is not inclined to use outside funds, would result in a much lower rate of imputed interest and a much higher drain on capital than is consistent with true company policy. When inventory or related facilities investment is normally financed internally, a rate of return between 10 and 30 percent is not unreasonable. In selecting a truly appropriate rate, there are a number of factors to be considered. First, as has been pointed out, the source of the funds may be internal or external. Second, is the question as to whether there are other purposes for which the money could be used and the rate of return from the alternative uses. Third is the length of time before the investment will be recovered. Fourth is the element of risk in the form of slow sales and obsolescence. The use of capital cost based on internal interest rates, or for that matter external interest rates, is not commonly found in accounting records. Nevertheless, it is implicit in many problems which arise in inventory control. Capital cost illustrates the type of operational cost which must be established entirely outside the normal accounting framework and is typical of the problems of cost uncertainty facing the inventory manager.

Determining the Length of the Run

The preceding discussion of the problems of cost determination for the inventory manager leads to one of the most actively discussed issues affecting the subject today, the problem of lot size. While methods are available for greatly improving the art, applying them is so inextricably tied up with areas of uncertainty that, generally speaking, little progress has been made.

The lot size problem arises because of the very reasons that businessmen find it necessary to carry inventory.

For example, raw materials are purchased in larger quantities than are immediately required in order to reduce order and clerical costs, to obtain a quantity price, and to hold down handling costs. Similarly, finished stocks maintained in warehouses usually come in shipments substantially greater than the amount sold in one order so as to reduce processing and shipping costs. In manufacturing, the length of time required to set up machine tools or to adjust automatic equipment has a similar effect on order quantity. The crux of the question, however, is this: as these factors exert their effect, inventories increase commensurate with the length of the run, at the same time, the cost of owning the additional stocks increases too, until they equal the savings obtained by the larger run.

An analysis of the costs previously discussed shows that they are, to the inventory manager, of two types. One set of these costs varies with the number of order that are placed in a given time period, and can be called procurement costs. Clerical and paperwork costs of this type would be found in Purchasing, Inspection, Requisitioning, Accounting, Receiving, and Stores Departments. Actual handling costs incurred would be found in receiving, inspection, trucking, and storekeeping. In addition to the costs of the supplies and materials used in the process of procurement should be included such expenses as telegraph and telephone charges incurred. Processing costs for placing an order are commonly estimated to run from $5.00 to $15.00.

When the item is placed into manufacturing, the procurement cost must include the cost of any set-ups, testing, blueprint study time, and any such factors as inspection and quality control. Essentially these charges apply whether the item is purchased on the outside or manufactured in one's own plant. In determining procurement costs, only those costs which are accrued as each order is placed are included. In other words, tool repair and resets are excluded from procurement costs.

In determining set-up costs on machines and equipment, it is frequently difficult to arrive at a fixed figure because of the variability involved. On a machine, previous set-ups may be utilized to reduce the actual set-up time. If order A follows B the set-up may be only 2 hours, whereas if A follows C the set-up may be 20 hours. Hence, the true set-up is largely dependent upon the sequence of the orders and the product mix of the time. In cases where orders are placed in the shop to take advantage of sequencing, the set-up costs should reflect these savings. In some companies orders are grouped as families and placed into production for stocking purposes. The first item run in the family will involve a full set-up and subsequent items only partial set-ups.

When the set-up variations are a result of random sequencing of jobs, the set-up costs to be charged are the average costs that have been experienced in the past. These may be obtained from cost variance reports when available, or other data.

The procurement costs, therefore, will include all set-up costs, direct and indirect, burden charges for the time involved, and any tooling or design work that will vary with the number of orders placed. Procurement costs will also include acceptance inspection and all paperwork costs relating to initiating the order. In short, procurement costs are all costs both in the office and the shop that occur with each placement of an order, as distinct from those direct costs of producing each successive piece.

The second type of costs affecting the lot size are commonly called carrying charges. These are the costs which vary with the number of items placed in inventory each time. These are usually computed as a percentage of the cost or value of the part and assumed to be fairly constant for any quantity. On rare occasions a firm will adjust this figure with the size of the inventory but such a variation is so difficult to determine accurately that it is of doubtful value.

The items included in carrying charges fairly generally are: 1. interest 2. taxes 3. insurance 4. storage and handling 5. maintenance of stock records 6. obsolescence 7. deterioration 8. repackaging and rehandling. This list is not all inclusive, of course, nor do all these elements affect all organizations. In each case the particular value for each specific item must be determined. W. Evert Welch states:

Interest	4% to 15%
Insurance	1% to 3%
Taxes	1% to 3%
Storage	0% to 3%
Obsolescence and	
Depreciation	4% to 10%
	10% to 34%

"Figures from 17% to 24% seem to have the most common acceptance but there is no reason for you to use anything but the results of your own determination."*

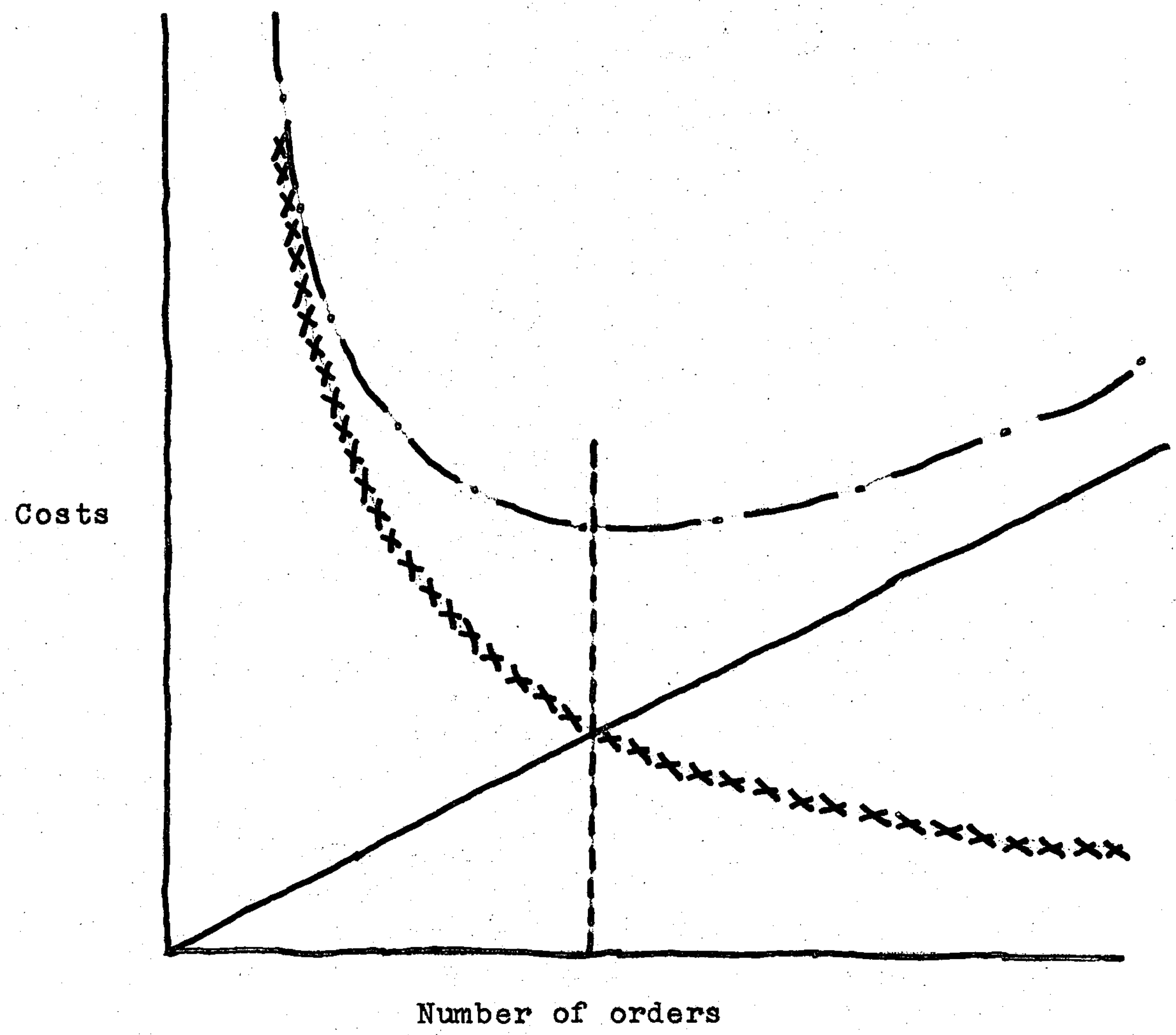
It is not often easy for a company to arrive at figures for their carrying and procurement costs that can be agreed on by all concerned, but it is important that the estimates be as accurate as possible.

When these two sets of costs are plotted on a chart such as on page 71, it becomes apparent how each cost reacts with volume. Since an order involves costs of both types, it follows that the low point on the total cost curve represents the lowest possible order cost for that item. The low point on the total cost curve is always at the point where the other two curves intersect; accordingly, the economical lot size for any item is that quantity for which the carrying costs and procurement costs are equal.

It will also be seen that the total variable cost

* 7, p. 64.

Interaction of Varying Costs Chart



Key

Procurement Costs

Carrying Costs

Total Costs

Minimum Cost Point or Economic Order Quantity

Compiled by the author

curve is one-half of a hyperbola and is relatively flat in the area of its minimum point. This flat area of the curve indicates that there is very little change in total variable cost as the order quantity is varied within the range. This concept permits the exercise of judgement in determining the actual order quantity. For example, if the economic order quantity should be found to be 2.8 months supply to be ordered at a time, it is possible to use a quarterly ordering policy without a significant increase in cost. Since the total variable cost curve is flatter to the right of the low point than to the left, it is more economical to increase the order quantity than to decrease it should a change be indicated. Knowledge of the flat around the minimum cost unit can be used to increase the inventory turnover, or it can be used to build stocks in anticipation of increasing usage or rising prices without materially increasing costs.

Since construction of a chart to determine the economic lot quantity for each item in a large inventory would be impractical, a better way to arrive at the same figure is through the use of an algebraic formula derived from this data. This formula is expressed as

$$Q = \sqrt{\frac{2RS}{KC}}$$

where Q = economic lot size

R = annual usage, in pieces

S = procurement costs

K = carrying charge, as a decimal

C = unit price

For various applications it may be more convenient to express usage in monthly rates or dollar value, or to express the order quantity in dollars. In so doing, however, it is important to be sure that the units used in the formula are consistent. The basic principles are:

1. The order quantity should be expressed in the same units as the usage rate, i.e. both in physical units or dollar units.

2. The usage rate and the inventory cost should be based on the same time and material units. If usage is expressed in physical units, the inventory cost should be per the physical unit. If usage is expressed in dollars, the inventory cost should be the cost per dollar in inventory.

When a large number of items are being ordered, as is often the case in a manufacturing concern with a diversified product line, it is not necessary to compute the order quantity individually for each item or order. Sometimes ordering tables can be used to short-cut the work of the computing minimum-cost order quantities. Such a table or set of tables incorporating various inventory charges and ordering costs can be readily computed by hand or mechanically and used as a reference to look up order quantities for individual items. For an example of this table see page 75.

When a single ordering table is appropriate, some companies have the table printed in semi-permanent form, e.g. on stiff paper, for referral by inventory clerks. In other cases the table may be printed on the back of the inventory ledger card on each item or on back of the requisition form for ready reference.

Another device for determining economic lot quantities quickly is the nomogram. This device, as shown on page 76, has the advantage over the ordering table in that it allows use of varying procurement and carrying costs. This is a necessity in computing economical manufacturing runs when set-up costs vary from one job to the next. In using nomograms one can expect some initial reaction to their non-linear scales, but with a little practice even the novice can read them with adequate accuracy. They can be printed in pads and each computation placed in the order file for a permanent record or, like the order table, the nomogram can be printed on the back of the requisition form.

There is one general characteristic of which inventory management should be acutely aware. Some items of any inventory have a much higher annual dollar usage than others, which causes a concentration of dollar usage in a relatively small percentage of the total items. Dollar usage is equal to the cost of the part multiplied by the number of items used during a year or other time period. It is commonplace to

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PURCHASED ITEMS - NO QUANTITY DISCOUNTS

Sample Order Quantity Table

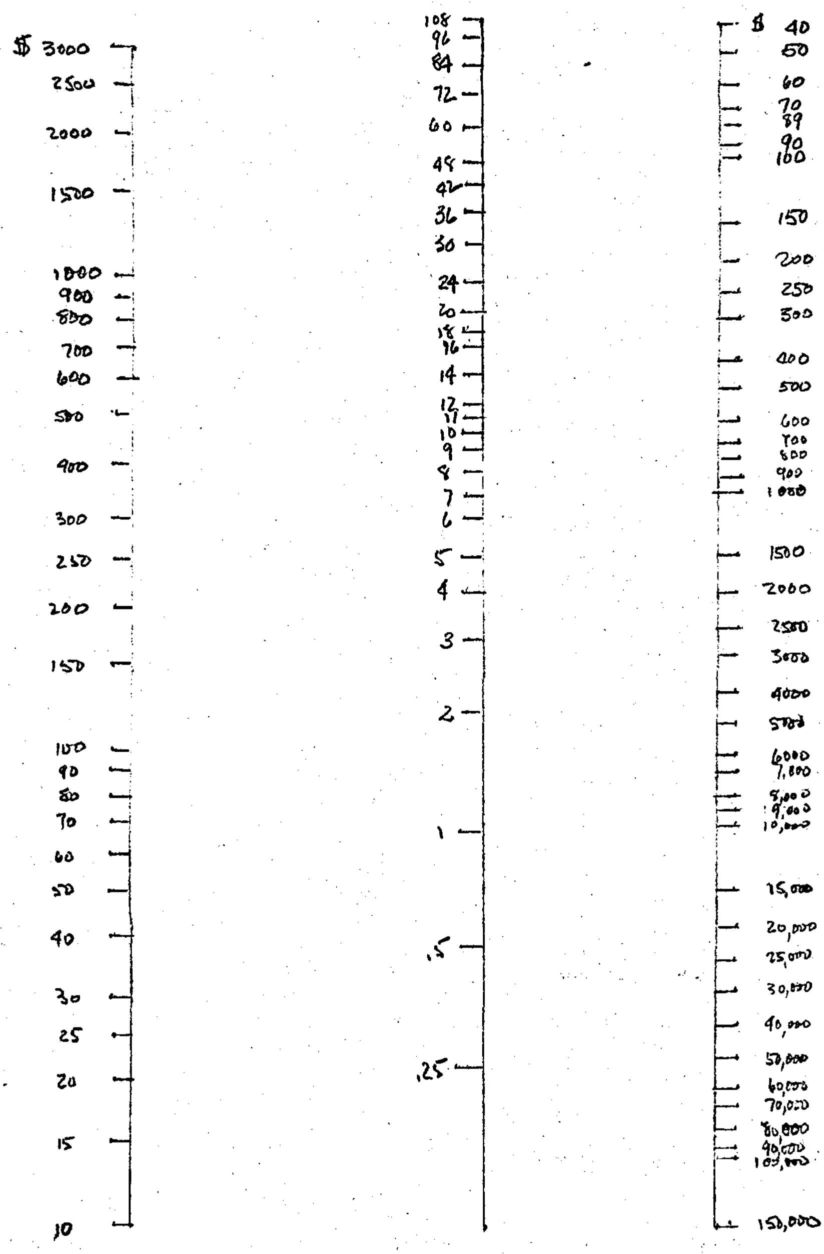
Order handling cost = $8.00 --- Unit costs from $.001 to $.10

YR = 1 YEAR ORDER QUANTITY

UNIT COST	MONTHLY USAGE																	
	1000	1300	1600	2000	2500	3M	4M	5M	6M	8M	10M	13M	16M	20M	25M	30M	40M	50M
$.001	YR	YR	YR	YR	YR	YR	YR	YR	YR	YR	105M	120M	135M	150M	165M	180M	210M	235M
.002	YR	YR	YR	YR	YR	YR	46M	53M	58M	66M	74M	86M	95M	105M	120M	130M	150M	170M
.003	YR	YR	YR	YR	YR	33M	38M	43M	46M	54M	61M	70M	76M	87M	98M	105M		
.004	YR	YR	YR	YR	27M	30M	33M	37M	41M	46M	53M	60M	66M	76M	85M			
.005	YR	YR	YR	21M	24M	26M	30M	33M	36M	42M	46M	54M	60M	66M				
.006	YR	YR	17M	19M	22M	24M	27M	31M	33M	38M	42M	50M	54M					
.008	YR	14M	15M	17M	19M	21M	24M	26M	29M	33M	37M							
.010	11M	12M	13M	15M	17M	18M	21M	24M	26M	30M	33M							
.013	10M	11M	12M	13M	15M	16M	19M	21M	23M									
.016	9M	10M	11M	12M	14M	15M	17M	19M	21M									
.020	8M	9M	10M	11M	12M	13M	15M	17M										
.025	7M	8M	9M	10M	11M	12M	13M											
.03	6M	7M	8M	9M	10M	11M												
.04	5M	6M	7M	8M	9M													
.05	4700	5M	6M	7M														
.06	4300	4700	5M															
.08	3700																	
.10	3300																	

Mason-Neilan Division
Worthington Corporation
Norwood, Massachusetts

Economic Order Quantity Nomograph



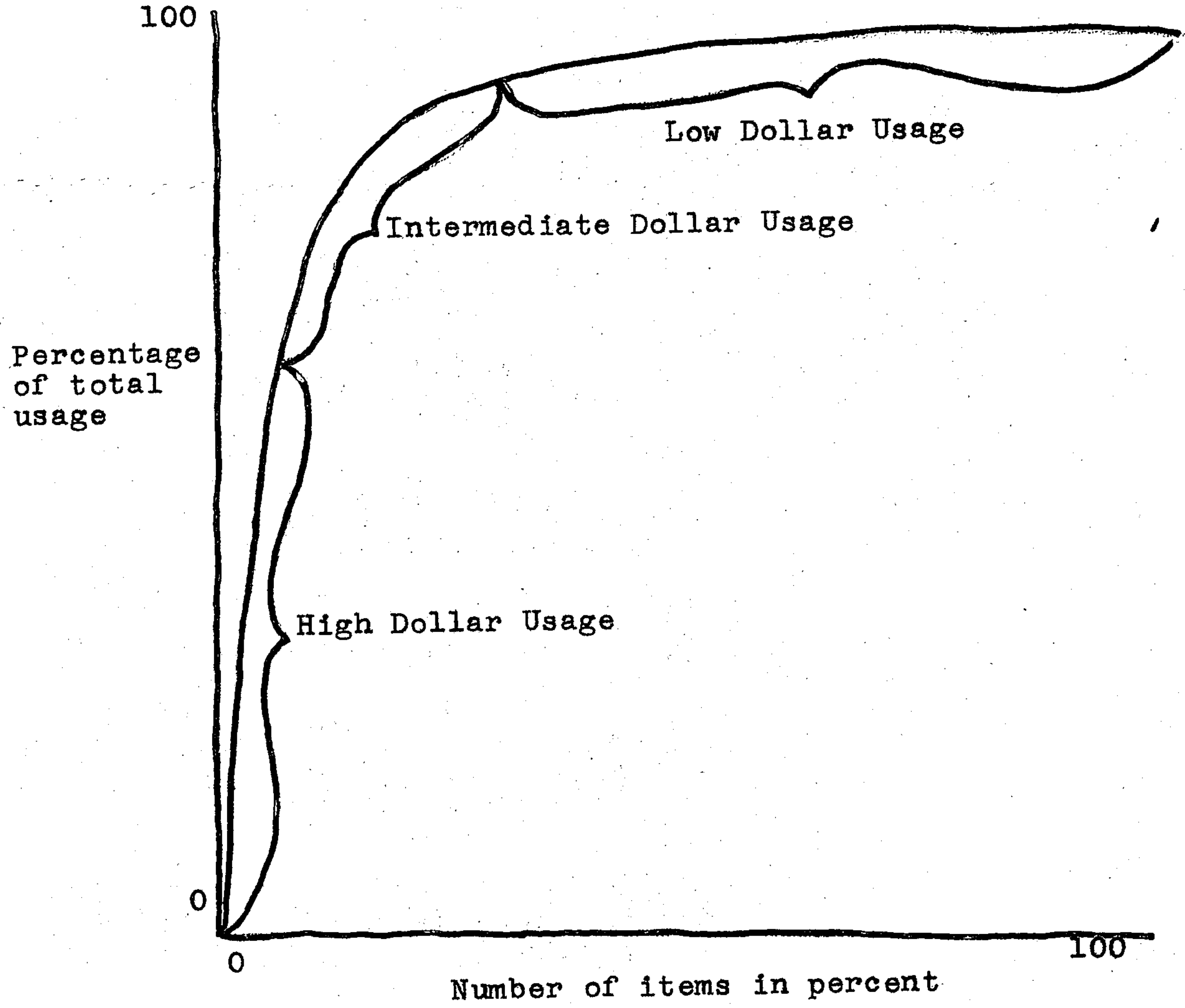
A line drawn from a point on scale S (Set-up or procurement cost) through a point on scale R (Monthly usage of an item at cost) will indicate on scale Q the number of month's supply to order.

Mason-Neilan Division
Worthington Corporation
Norwood, Massachusetts

find that 85% of the annual dollar usage in a given inventory is concentrated in 15% of the items making up that inventory. Exhibit 5-4, page 78, shows such a value distribution. Intuitive approaches to inventory control tend to lead toward similar emphasis on each item in the inventory. The inclination is to schedule, or make, or buy the low cost items on the same basis as the high cost items. A usage distribution such as that illustrated points up the fallacy in such a control system, and suggests different treatment for different segments of inventory. General Electric, in writings on the subject, refers to "A-B-C" distribution where certain high dollar usage items are classed as "A" items, the low value usage items as "C" items, with an intermediate classification designated as "B" items. The term "A-B-C" has caught on fairly broadly in industry. Some divisions of Westinghouse separate inventory into two classifications called "planned" and "probability" accounts, the names describing the different approaches to the high and low usage value items. Other companies making only two distinctions, have used the terms "blue chip" and "red chip" to designate the two categories. Others making three divisions have designated them "X-Y-Z". The more common "A-B-C" description will be used here.

When an A-B-C analysis is made it can be determined how attention will be divided among the inventory items. Often it is set up so that products in the A classification are to be carefully analyzed with respect to procurement and carrying

Usage Distribution Curve



Compiled by the author

charges and activity patterns. These products are all ordered by formula. Products in classification B are less critical and permit less accuracy. These parts, too, are ordered by formula. Products in classification C are usually ordered according to a stated policy, such as once a year.

Another problem encountered in this area is that of the families of parts which are of two types, related and non-related. Non-related products occur in families when they are brought together to form an assembly. Each part may have its own set-up and production process. These parts are related only by usage. An economic quantity can be calculated for each individual part in the assembly, thus creating separate stock levels for each part. If the parts are used solely in the assembly, it may be desirable to compute the economic quantity in terms of the assembly, using the combined procurement costs to obtain the assembly procurement costs.

An analagous situation occurs in the production of a product through several stages of manufacture. It is possible to compute the economic quantity for each stage, in terms of semi-finished parts, or the economic quantity can be calculated as the end product. The economic quantity in terms of work-in-process inventory requires a bank or storage area between machines. It has the advantage of stocking goods in the least expensive state and holds them ready for the next stage of production.

Work-in-process inventory also permits variations in the end product at little cost which might not be possible otherwise. In this sense one basic item in in-process inventory may be sufficient whereas finished inventory may require stocks of each variation of that item. Hence, work-in-process inventory will generally total much less than a finished good of a size to accomplish the same purpose. The disadvantages are the need for considerable storage space between the types of equipment and the longer lead time required to fill a customer's order. Both methods are used and should be studied carefully with respect to the specific situation before one plan is discarded in favor of another.

Related families are those products which are only variations of a type of product. One method for handling these has been considered; that is, the product can be brought up to the point of completion, just before the variations take place, and stored, or each variation can be produced and stored. Since related families work from the same or similar set-ups, the total set-up time is prorated to each item if separate order quantities are to be calculated.

The methods for determining an economic order quantity previously described are based on the assumption that the unit purchase price is fixed. However, where quantity discounts are allowed, i.e. where lower unit prices apply to orders above fixed limits, a decision has to be made whether to buy the minimum cost quantity at one price level or to increase the order size to the minimum size for a lower unit.

Discounts may be expressed in many ways. One common method is to state directly the unit prices applying to various quantities. Another is to state a price for the smallest quantity bracket, showing prices for larger quantities as percentage discounts of the first. A third method is to quote a set-up cost and a piece price.

The method of analyzing the discount for the best buy varies with the type of schedule presented by the vendor. When the supplier shows two prices, the solution is simple. The set-up cost, being the suppliers' procurement cost, is simply added to the purchasers' procurement cost and the calculation can be carried out. When the suppliers' set-up cost is not stated, the derivation of an economic order quantity is a little more difficult. There are a number of methods used in these circumstances. One of the simplest works as follows. Assume that in buying a casting the price is quoted at $5.00 each in quantities up to 1,000 and $4.90 each for a quantity of 1,000 to 2,000. The vendors' procurement cost can be determined with a little elementary algebra: let $\underline{x}$ be the cost per casting and $\underline{y}$ be the cost of procurement. Then $1000x$ is the cost of 1,000 castings and $2000x$ is the cost of 2,000 castings. By adding the set-up cost, y, the total cost of the order is reached. Hence, $1000\ x + y = \$5,000$. Similarly, $2000\ x + y$ is the total cost for 2,000 castings, or $9,800. These two discounts have provided two equations with two unknowns:

1. $1000\ x + y = \$5,000$

2. $2000\ x + y = \$9,800$

Solving these two equations simultaneously, we subtract the first equation from the second to get:

$$1000\ x = \$4,800$$

$$x = \$4.80$$

Therefore the cost per casting is $4.80. Since 1,000 castings cost $4,800, the procurement or set-up cost, y, is $200. This added to the purchasers' procurement cost will enable him to calculate an economic order quantity which will take into account the suppliers' discount schedule.

The foregoing has dealt with some solutions to one of the great problems of uncertainty in inventory management - how much to order. Another equally serious problem of uncertainty is less easily solved. This is the question of when to order, or the determination of reorder points.

In considering the subject, it is important to realize that an inventory of any item or material is made up of two parts, a working stock and a safety stock. The safety stock is a resevoir used in times of unexpected high demand or unusually long delivery time from a supplier.

A typical practice is to show a minimum point on the inventory ledger card such that stocks are reordered when they hit this level. The minimum point is based on the lead time or length of time required to obtain the stock plus an allowance as protection against unusual usage during the lead time, or safety stock. The cushion or protective stocks are set up in two ways. One method is to use a safety cushion equal to the usage in a stated period, such as a month or six weeks. Another is to use a percentage of the usage during the lead time. If, for example, an organization using a safety stock figure of 33% found usage during the lead time of an item to be 100, the safety stock would be 33. This is not to be confused with the reorder point. In the instance cited, the reorder point would be 133 pieces.

While common, reorder point and safety stock methods such as these have many failings. They are designed to prevent stock-outs, but they do not accomplish their objective well. As any production man will verify, stock-outs are a common occurence when reorder points are determined in such a manner. A more satisfactory solution is to base the reorder point on the probability of stock-outs. The reason for this is that sales or usage will seldom equal the estimate during the lead time; accordingly, more or less will be used than expected. The fluctuation of usage above or below the expected usage will usually follow a pattern known as a Poisson distribution. This has been found to be particularly appropriate to problems involving usage, its value is that it is valid under condition of very small as well as large usages.

The Poisson distribution may be described simply by referring to the scatter of a rifle. If the gun in mounted and fired a number of times, there will be a dispersion of shots around a center point. This dispersion can be shown to be a Poisson distribution. In the problem of reorder points, the average stock usage during the lead time gives the center point. By use of the Poisson distribution it is possible to predict the probably dispersion around this average and thus to predict the probability of using more than a certain amount of stock. By adding units into stock as a cushion, the probability of the dispersion exceeding the stocks on hand decreases. The cushion can, therefore, be determined on the basis of the probability of running out of stock. If the cost of a stock-out can be computed, the cost of carrying the safety stock can be compared with the cost of stock-outs.

Not all products require the same protection against stock-outs. Important customers and products may present situations requiring high protection. Stock-outs in other items, such as "cat and dog" lines, may be completely acceptable and expected by the customer.

Here, as in the determination of order quantities, the A-B-C type of analysis is valuable. Parts and products can be categorized as "critical", "major", and "minor" or some other classification applied. As has been shown, a high degree of stock-out protection is expensive. Careful analysis of each item will prove worthwhile. This analysis should take the form of determining the allowable stock-outs, in terms of the allowable percentage of times a stock-out will occur before replenishments are received. If, for example, an item is ordered once each week and the reorder point is so established that only once each year, or once in every 50 weeks, is the stock exhausted when the new order is received, the allowable percentage of stock-out is 1/50, or 2%. If the allowable occurence of stock-outs were once in every two years, the figure would be 1%.

The proper reorder point for any item can be determined by use of the formula:

$$C = A + D\sqrt{A}$$

where C = reorder point

A = average usage during the lead time

D = factor derived from Reorder Point Determination Table, page 86.

Like the economic order quantity, this formula can be expressed in graphical form allowing very rapid determination of the proper reorder point for any situation. Such graphs are available from industrial consulting organizations.

The potential benefits of this to a manufacturer of a diversified product line are enormous, perhaps equal to the savings derived from economic order quantity analysis. For example, in one case it was shown that a fixed reorder point system allowed about 18 stock-outs a year out of every 20 items carried in inventory. In other words, there would be almost one stock-out for every item in that inventory. Actually, it happens that while some items are out of stock many times during the year, others will hardly ever be depleted. By applying the method shown above, stock-outs were reduced to a small fraction of their former quantity, while at the

Reorder Point Determination Table

D	Acceptable % of stock-outs
4.0	"Never"
3.5	.023
3.0	.135
2.8	.26
2.6	.47
2.5	.62
2.4	.82
2.33	1.00
2.17	1.50
2.06	2.00
1.96	2.50
1.89	3.00
1.82	3.50
1.76	4.00
1.65	5.00
1.56	6.00
1.48	7.00
1.41	8.00
1.35	9.00
1.29	10.00
1.16	12.50
1.04	15.00
1.00	15.87
0.85	20.00
0.68	25.00
0.53	30.00
0.39	35.00
0.26	40.00
0.13	45.00
0.00	50.00*

* 14, p. 24.

same time reducing safety stocks as much as 30%. Results such as these are truly worthwhile, both in savings in inventory investment and improved customer service.

Chapter VI

Variations in Sales Patterns

A manufacturing company that has an inventory justifies this investment on the grounds that it will be sold; it is anticipating demand. This basic concept underlies the fact that all inventories are the result of a sales forecast, whether stated or implied. Any company is in business primarily to serve its customers' needs in some way. Its survival depends on its ability to adapt its operations to customers' needs, to demonstrate or stimulate the needs, and to service them adequately and efficiently when they arise. The demand forecast is the link between the evaluation of external factors in the economy which influence the business and the management of the company's internal affairs. A forecast demand of some type exists at least implicitly whenever the company management makes a decision in anticipation of future demand, whether this decision is to build a new plant or to manufacture another run of a particular item to restore inventory balances.

Forecasting is not easy; for the manufacturer of a diversified line of industrial goods, it may be impossible. Alexander, Cross, and Cunningham point out:

> "The estimating of sales can usually be done much less accurately for an industrial good than for a consumers' good. This is because of the relatively small number of possible buyers

of industrial goods and the large lots in which they habitually purchase. The ultimate users of the average consumers' good are numbered in the millions. The failure of any one of them, or even of a considerable number of them, to behave as expected is not likely to cause very much inaccuracy in the figure estimated. In the case of an industrial good, a change in the patronage pattern of a single large customer may cause a highly significant variation from the estimated sales figure. Moreover, changes in the patronage pattern of ultimate consumers usually occur slowly, except, for example, in fashion goods, while the introduction of a new process or a new material may cause a sizeable shift in the use of an industrial good within a short space of time.

"The estimator of the sales of a consumers' good can often find some statistical series, such as personal income payments, or sales of some other article, which varies with the sales of the product whose volume he seeks to forecast. By gearing his estimates to the projection of this series, he can arrive at highly accurate forecasts. Such series are usually much less useful, often entirely worthless, to the forecaster of the sales of an industrial good because of the possible erratic behavior of a few important individual customers. As a result of these factors, while it is not unusual to hear of firms making consumers' goods which forecast their sales within a few per cent of the actual figure, such accuracy is very rarely possible in estimating the sales of industrial goods."*

The difficulty of forecasting is no reason that it should not be attempted. Once it is recognized that forecasts are not merely desirable but basically necessary, it must be decided what forecasts must be made. This concerns the type of forecast, the detail which is necessary in the forecast, the frequency with which it should be made, and the time period which must be covered.

Business tend to make mistakes in both directions in forecasting; they go into insufficient detail or they become too detailed. The former tendency is illustrated by gross-dollar demand or dollar demand by broad product groups or customer groups. The difficulty with formal forecasts of this type is that they simply do not tell what the demands on the various operations are.

The second tendency, that of going into too much detail, often follows as a reaction to the difficulties encoun-

* 1, p. 504.

tered from insufficiently detailed forecasts. The company then goes too far in attempting to detail the forecasts to make them useful to manufacturing, without thinking out what detail is most needed. For example, the manufacturing department of a company making metal products had over the course of time built up a list of 125 detailed breakdowns of the sales forecast that it wanted. The sales department objected strongly to these breakdowns, maintaining that their forecast of the over-all dollar demand was good, the forecast by product group was reasonably good, but the forecasts in detail by various combinations of size, shape, and material were necessarily terrible. This debate led naturally to a good deal of frustration and bickering, with the manufacturing department saying that the sales department's forecasts were no good and the sales department maintaining that manufacturing department demands were unreasonable. Both sides failed to realize that the manufacturing department did not need forecasts by individual products except over a very short span to control finished-stock safety levels, and these could be obtained with adequate reliability by crude statistical devices. But the manufacturing department did need forecasts of demand in terms of activity in major operating centers if it was to have any hope of meeting sales service requirements at reasonable cost.

The time period a sales forecast much cover depends on the inventory turnover of the company making the forecast; in other words, on the lead time necessary to make an adjustment to anticipated change in sales patterns or volumes. Such a forecast is short range for the purposes of planning, management must consider more than this. There are, to begin with, seasonal fluctuations which in one way or another affect most businesses. The oil companies have different patterns of demand in summer and winter and there are many other examples. This type of fluctuation tends to be highly regular, so one can usually prepare for it.

A second major type of business fluctuation is the business cycle. There are all sorts of business cycles, the one most commonly thought of is the so-called "inventory cycle", which in the postwar period has averaged from two to three years in length. This cyclical variety of fluctuation is more difficult to forecast. Both the timing and the magnitude tend to be more irregular. Moreover, the impact on business varies noticeably from industry to industry.

Finally, there is a truly long-run pattern of change in the economy. This is the rate of change which derives from basic growth factors - population change, productivity increase, and the like. It is convenient to think of this long-run rate of change as being represented by some growth curve, and it is about this curve that cyclical variations occur.

During normal periods, these are the major regular varieties of change in the level of economic activity and, therefore, the major determinants of demand for the goods sold. There are, of course, always random developments which no one can really foresee. Such things as wars, earthquakes, and fads occur, and have major effects on the business climate of many firms.

If one so chooses, he may identify the need for short-, medium-, and long-range forecasting with seasonal, cyclical, and trend movements, respectively. This, however, would be a great simplification. The long and the short run for most firms depend primarily on the nature of their business. For firms using raw materials whose prices vary drastically in the space of days or weeks, a couple of months may be a long run. For firms whose capital installations take several years to complete, anything under two years may be a short run.

Whatever the situation of the individual firm, the distinction between long and short run is usually meaningful, and - within the context of the problems which the firm faces - little confusion between the two is likely to arise. Frequently, problems have aspects of both the short and the long run about them.

Once the decision has been made as to what is required of the sales forecast, the second point to be settled is how it will be made. Once again the problems of the company itself will determine the methods used.

Where product or product group forecasts are made as a basis for production planning, these must be exploded or converted into demand for the various types of manufacturing activity and purchased material the company wishes to control. Explosion of end-product demand into parts and time requirements is one of the fundamental techniques in production planning and control. It is used not only to convert end-product or product group forecasts into parts demand forecasts, but also to convert actual demand or shipment reports into usage of components.

One way to make explosions is to start with a parts and operations list or bill of material, showing the type and amount of materials, parts, and sub-assemblies which go into a single unit of the item. Operation centers and unit operating can also be shown. The unit, material, and time requirements are multiplied by the forecast quantity of the item to give the total demand resulting from the forecast.

When manufacturing operations call for several stages of part and sub-assembly manufacture, the bill of material can show either the parts and sub-assemblies used directly and the operations required to complete the end product, or the parts and operations list can carry requirements back, breaking sub-assemblies into their component parts. This latter method, while involving more work to determine the lowest level of components involved for every sub-assembly in the final product, eliminates the pyramiding of parts resulting from the artificially large demand often shown by the first method.

Using bills of material to explode parts requirements is readily performed on punched-card equipment. A punched-card master requirements file is set up containing a deck of cards showing the materials and operations required to make each end item. Each card in the file shows how many of a specified item are needed in a specified end-product or how much time in a specified operating center is needed. To compute part and time requirements:

1. A card is punched for each end-product, showing the quantity forecast in as much detail by time period as is needed.

2. These cards are used to select corresponding detail part and time cards from the master file. The fore-cast quantity cards are collated with the selected part and time cards, and end-product total quantities are transferred. Unit requirements are extended by total forecast quantities.

3. Extended part and time cards are sorted by part and operating-center number and added to obtain total require-ments of each material or operating center.

The most common approach to forecasting is the easy, though highly subjective, one of surveying the sale's organi-zation and soliciting opinion. The advantage to this approach, besides being simple and direct, is that it is made by the people closest to the situation and that it takes into account all the intangibles that more formal systems cannot. On the other side of the coin this technique suffers from the fact that it is always colored by human weaknesses of optimism or pessimism. Recent events tend to make field people weight their forecasts improperly; if sales have taken a short-term dip, the situation for the coming year looks dark, or if sales have improved or a few good customers have been landed in the recent past, the view may be overly optimistic.

This tendency is exaggerated as the forecast passes from salesmen to district manager to home office to management. Each succesive supervisor may add or subtract a percentage to the figure he has been given, as he is impressed by the immediate situation. The difficulty also always exists that where an estimate is arrived at presumably based on collective opinion, the final result may depend far more on the opinions of one or two influential or persuasive individuals than the group from which it was drawn. Such individuals may or may not be more perceptive than their fellows.

The two approaches to forecasting which are most objective and which show the most promise are the use of the sciences of economics and statistics. Improper application of these techniques has given them a bad reputation in some companies but this is not a failing of these methods as such. Some companies have found it possible to correlate sales in their industry or company with such economic indices as the Federal Reserve Board Index of Industrial Production, various estimates of personal income, disposable income, the F. W. Dodge indices of construction contracts awarded, etc. When an index can be found to which sales are closely correlated, but with a lag, correlation techniques may be highly useful. If the lag is long enough, the reported index figures can be used as a basis for forecasting future demand. Where the lag is insufficient for forecast requirements, correlation with the reported index leaves the company with the need to predict the index itself. Even so, in the hands of an economist such correlations may be very useful.

A number of other statistical techniques have been found useful. For example, a number of methods exist for developing seasonal indices of demand based on past experience. These are often useful in breaking down broader forecasts based on field opinion or economic studies into an expected pattern of sales month by month. Extrapolation of sales trends, for example, is a rather commonly used approach. This has obvious dangers since extrapolation depends on conditions holding in the future which have caused the past trend. Trend extrapolations have been particularly useful in making short-run forecasts for adjustment of production levels and establishing reorder points. Beyond such relatively simple techniques lie some of the newer forecasting techniques such as the waiting-line, or queuing, theory, linear programming, game theory, and non-numerical logic.

The final provision in a properly planned forecasting program is control and review to insure that the effort being applied is worth the results. The quality of the forecasts can be checked by comparing it against results. This checking process will enable the forecaster to improve his accuracy. The quantity or detail of forecasts is also worth checking. All to often some of the information originally thought necessary is no longer needed, even though it is produced month after month.

Chapter VII

Conclusion

This paper, as has been stated, has examined several of the problems of uncertainty encountered in inventory control in diversified manufacturing. These problems generally have been stated in order of increasing difficulty. The methods for recognizing, defining, and solving these problems with their relative advantages and disadvantages have also been shown.

It is certain that progress will be made in these areas in the future. Two devices that will certainly come into greater use are now under investigation. Operations analysis techniques have focused new light on production scheduling and inventory control problems. These problems are being found so complex and dynamic that they are well suited for operations research projects. The solutions often seem to be in mathematical models or simulations. Inventory control models and production control simulations have been constructed to include many of the variables that should be considered. These models assign logical mathematical weight to the many factors which are usually considered only intuitively. Mr. H. Ford Dickie, of General Electric, explains their work in this area:

> "We are now completing mathematical models of key portions of their manufacturing operation. With these models we can develop better

scheduling and flow plans for these shops. Our three-fold objective here is meeting schedules, keeping men and machines well utilized, and doing both with minimum inventory.

"These models are representations of typical manufacturing job shops. But they are explanatory rather than descriptive. By this I mean that we use them to predict how various plans of operating this shop might affect our three key result areas - meeting schedules, utilizing men and machines, and keeping inventory at minimum. Consequently we can make these manipulations without disturbing the shop. In effect, we operate in parallel with it. Here's the opportunity to solve problems where men and machines in complex relationships, experiencing irregularities, are too complicated for mathematical solution. . . . For example, we try to balance the improved utilization of men and machines against the increased cost of carrying the higher inventory."*

The second of these promising developments in a sense makes the first possible. This is the electronic computer. The speed and capacity of these machines make it possible to use the new operations analysis methods which would be imprac-

* 11, p. 72.

tical to approach with manual devices. While the cost of such machines is high, their use can sometimes be justified by allocating time between such groups as engineering, accounting, and production. Again to quote Mr. Dickie:

> "On two mathematical models we are using large-scale computers. This way, we get rapid and economical runs in our "cut-and-try" development of quantitative scheduling and manufacturing control plans. In fact, the availability of the large computer made it feasible to do this much needed research. . . . I think you'll need access to some kind of computer - although not necessarily a large one. There are several reasonable solutions.
>
> "First, consider an original research or development simulation. If a large computer is required, as it may well be, you can rent time at any number of computer installations. The manufacturers offer service-center facilities. Others who have computers (industries, universities, etc.) often will rent time on their machines, especially second- or third-shift time. Once this development has been checked, simulation to be used in shop control may feasibly be reduced so it is suitable for running on a medium sized computer. . . .

"This type of approach should lead to a fundamental change away from the inconsistent rule-of-thumb intuitive production planning and scheduling based largely on experience. It should make available logically derived, consistent, quantitative-formula schemes of control. We believe this may be as important an advancement as has been made in production control in many years."*

The other advantage of the modern electronic equipment is the instantaneous access to large quantities of stored information which improves the accuracy and flexibility of inventory ledgers.

Undoubtedly other methods will be devised to improve inventory control in years to come. The necessity for understanding and defining the elementary problems, however, is and will continue to be the basis for intelligent operation.

* 11, p. 72.

Appendix

The following is a partial list of societies, associations, and other organizations that participate in the formulation of industrial standards in the United States.

Aluminum Association
American Association of Engineers
American Brush Manufacturers' Association
American Bureau of Shipping
American Ceramic Society, Inc.
American Drug Manufacturers' Association
American Electro-Platers' Society
American Gage Design Committee
American Gas Association
American Gear Manufacturers' Association
American Institute of Architects, Department of Technical Services
American Institute of Bolt, Nut and Rivet Manufacturers
American Institute of Chemical Engineers
American Institute of Consulting Engineers
American Institute of Electrical Engineers
American Institute of Mining and Metallurgical Engineers
American Iron and Steel Institute
American Ordnance Association
American Petroleum Institute

American Pharmaceutical Manufacturers' Association

American Railway Car Institute

American Railway Engineering Association

American Rocket Society, Inc.

American Society of Agricultural Engineers

American Society of Civil Engineers

American Society of Mechanical Engineers

American Society for Testing Materials

American Specification Institute

American Standards Association, Inc.

American Welding Society

American Zinc Institute

Asbestos Textile Institute

Asphalt Institute

Association of American Battery Manufacturers

Association of American Railroads

Brass and Bronze Ingot Institute

Conveyor Equipment Manufacturers' Association

Copper and Brass Research Association, Inc.

Farm Equipment Institute

Gray Iron Founders' Society, Inc.

Industrial Safety Equipment Association

Institute of Makers of Explosives

Institute of Radio Engineers, Inc.

Instrument Society of America

Lead Industries Association

Machine Screw Nut Bureau

Malleable Founders' Society

Manufacturing Chemists' Association, Inc.

Mellon Institute of Industrial Research

Metal Powder Institute

National Aircraft Standards Committee

National Association of Bedding Manufacturers

National Association of Fan Manufacturers

National Association of Flat Rolled Steel Manufacturers

National Association of Pipe Nipples Manufacturing

National Association of Purchasing Agents

National Association of Radio and Television Broadcasters

National Board of Fire Underwriters

National Screw Machine Products Association

Society of Automotive Engineers, Inc.

Society of Motion Picture and Television Engineers

Socket Screw Products Bureau

Special Tool, Die, and Machine Shop Institute

United States Cap Screw Service Bureau

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