Chapter One

Inventory Management

1.1 Introduction

Dear learner, well come to the topic of inventory management. It is really applicable in every walk of life whether organizational or personal. Every family went to the flour mill or market to buy one quintal of teff/wheat or others depending on their interests. Farmers produce at the rainy season and have their own inventory of different crops to be used on the other coming seasons and to sell the extra to the market. People of rural Christians used to fetch water on every Friday to be used on Saturday and Sunday. The oil mill around your locality buys more oil seeds at the harvest season and used it according to their utilization rate. This shows that inventory is applicable in every organization.

All Organizations know, inventory is one of the most expensive assets of many companies, representing as much as 40% of total invested capital. But don't forget that all organizations don't have the same level of inventory requirements. A flour factory has more level of inventory either as input (grain) or finished goods (flour) than a school. Operational managers at these organizations have long recognized that good inventory control is crucial, for example.

On the one hand, a firm can try to reduce costs by reducing on hand inventory levels. On the other hand customers become dissatisfied when an item is frequently out of stock. For example, assumes that there is a restaurant that always brings bread from a bakery. Now the bakery is unable to deliver the required quantity at the required time to the restaurant. This leads to the loss of revenue for both businesses as customers shouldn't satisfied and join other competitors to get their demands. Thus companies must strike a balance between inventory investment and customers service levels. As you would expect, cost minimization is a major factors in obtaining delicate balance.

Organizations have some types of inventory planning and control system. A bank has method to central its inventory of cash. A hospital has methods used to control blood supplies and pharmaceuticals. Government agencies, schools, and of course

virtually every manufacturing and production organizations are concerned with inventory planning and control.

- ***Dear learner, thinks of other organizations that have inventory? What will happen if they don't have the required quantity of inventory at the desired time?***

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Objectives

Dear learner, when you complete this chapter you should be able to:

- Define the term inventory
- Describe and explain the function of inventory
- Describe the objective of inventory management
- Contrast dependent and independent demand
- Explain the views of different departments towards inventory

1.2 Definition

An inventory is an idle resource that possesses economic value and kept for the purpose of future production or sale. Inventories are usually in the form of raw materials, semi - finished goods used in the production process, or finished products ready for delivery to consumers.

Example; The oil seeds in an oil mill factory is a raw material to be used in the production of oil while the inventory of barrel of oil is a finished stock to be sold in the future when demand arises.

- ***Why we study inventory Management?***

Inventory is usually associated with manufacturing & distribution activities. But unused labor or capital is also an idle resource, and in this sense it is essentially an inventory although we do not formally refer to it as such. Service industries are often unable to inventory their final products, although they must manage their raw materials and supplies inventories just as any other organization. An airline company, for example, may have the seating capacity to provide a transportation service but lack the demand necessary to create the end product (final inventory) of a transportation service.

- ***What type of inventory your organization use and what is the purpose of this inventory?***

Adequate inventories facilitate production activities and help to assume customers of good service. On the other hand, Carrying

inventories increases working capital on goods that sit idle - not earning any return on investment. The major problem of inventory management thus consists of trying to achieve an optional balance between the advantage of having inventories (or the losses that may be expected from not having adequate inventories) and the costs of carrying them.

• ***Is there any inventory which is stocked for many months/years in your organization? What is the cost of this piled up inventory to the organization?***

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Thus inventory management is a discipline concerned with the management of different inventory items for the smooth running of an organization. Good inventory management is essential to the successful operation of most organizations. There are a number of reasons for this. One is the amount of money inventory represents; another is the impact that inventories have on the daily operations of an organization. Some organizations do not recognize the role that inventories play or even if the recognition is there, what is lacking is an understanding of what needs to be done and how to do it.

The types of items firms' stock range from small things like pencils, paper clips paper screws, and nuts and bolts to large items like machines, trucks, construction equipment, and so on. Types of inventory organization carries relates to the kind of business it engages in. That is, Manufacturing firms carry supplies of raw materials, purchased parts, partially completed items, and finished goods as well as spare parts for machines, tools & other supplies. Departmental stores carry clothing, furniture, carpeting, stationery, appliances, gifts, cards, toys, paints, sporting sheets, and pillowcases and more. Supermarkets stock fresh and canned foods, packaged and frozen foods, house hold supplies, magazines, baked goods, drug items, and miscellaneous items. Thus, all organizations are in need of inventories regardless of their nature of activities. Profit making, non Profit making, service giving, merchandising, manufacturing, even philanthropic organizations have to keep an adequate inventory level either to minimize waste or to maximize profits as in the case of profit making organizations or to provide a better service to the public at large in the case of non profit making

organizations. There fore, we can safely say that the need for inventories is not confined to only one sector of the economy.

- ***List out the type of inventories that your organization has and what is the effect if adequate level of inventory is not available at the required time?***

1.3 General inventory consideration

1.3.1 Functions of inventory

Inventories exist with in an organization for many reasons and serve many purposes. The major reasons for holding tangible inventors include:

I. Decoupling production Process: -

After each production and distribution stage, inventories serve to increase the rationality of the production distribution system by decoupling its parts. This is achieved by providing

inventories between the various steps from the procurement of raw materials through the various production operations in to finished product inventories and moving from the point of manufacture through whole sale distribution to retail outlets. By providing inventories at selected steps in the manufacturing - distribution system, a firm obtains a certain degree of independence for the steps following or '' down stream'' from these inventories. If for example one production operation becomes inoperative because of break down, the succeeding operation can continue as long as the in-process inventory ahead of it exists. Even though the firm that makes the product is closed, retail customer service can be maintained if there are inventories at the retail level.

II. **Stabilizing employment: -** Inventories can effectively serve to mitigate the problem of minimizing major changes in the size of the work force under conditions of fluctuating demand. If for example it is believed that demand for a firm's product or products will decrease in the near future, the additional costs involved in inventorying excess production may be entirely or in part off set by avoiding layoffs which could adversely affect the firm's state of unemployment, compensation costs and results in a loss of employee skills and experience that will be needed when product demand picks up.

III. **Taking advantage of quantity Discounts: -** The willingness of a firm to held larger inventories of supplies and purchased parts may gain the firm the advantage of lower prices. The fixed costs of ordering will also be shared by a larger number of units if price increases are considered imminent. Since lead times are judged as being erratic, increasing inventories of key or critical items may represent a sound and prudent managerial philosophy.

IV. **Buffer inventories: -** The purpose of inventory is to protect against the uncertainties of supply and demand. ***Buffer*** inventories or, as they are sometimes called, safety stock, serve to cushion the effect of unpredictable events. The amount of inventory over and above the average demand requirements is considered to be buffer stock held to meet any demand in excess of the average. The higher the level of inventory, the better the customer service—that is, the fewer the stock outs and backorders. It should be recognized that while protection against stock outs may be available when demand suddenly increases, an increased expense stemming from this inventory must be borne when demand is stack. A stock out exists when a customer's order for an item cannot be filled because the inventory of the item has run out. If there is a stock out,

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the firm will usually backorders the materials immediately, rather than wait until the next regular ordering period.

V. Delayed deliveries and unexpected increases: - If demand increases the risk of shortages is natural. Delays can be due to weather conditions, supplier's stock outs, deliveries of wrong materials, quality problems, and so on. Holding safety stocks, which are stocks in excess of anticipated demand, can reduce the risk of these shortages.

VI. **To meet anticipated customer demand: -** An anticipated future demand is the reason for holding anticipation inventory. Rather than operating with excessive overtime in one period and then allowing the productive system to be idle or shut down because of insufficient demand in another period, inventories can be allowed to build up before an event and consumed during or after the event. Manufacturers, wholesalers, and retailers build anticipation inventories prior to occasions or holidays when

demand for specialized products will be high. It is only when inventories get out of hand that they become an unnecessary burden: If they are managed properly, they permit quick and economic customer service.

- **From the above functions of inventory which are applied in your organization?**

VII. **To smooth production requirements:-** firms that experience seasonal patterns in demand often build up inventories during off -Season periods in order to meet overly high requirements that exist during certain seasonal periods. Therefore inventories are used to smooth out seasonal demands by leveling out production. This helps to minimize overtime, manning up & training costs, etc for seasonal peaks.

VIII. **To take advantage of order cycles:** In order to minimize purchasing and inventory costs, it is often necessary to buy these necessities storing some or all of the purchased amount for later use. Similarly, it is usually economical to produce in large, rather than small quantities. Again, the excess output must be stored for later use. Hence, inventory storage enables a firm to buy and produce in economic lot sizes with out having to try to match purchases or production with demand that acceptable customer service is achieved, and the disruptive and costly effects of machine breakdowns, strikes, etc. are kept to a minimum. Production leveling involves planning plant capacity at an economically desirable level-usually by producing is whether demand for items in inventory is independent or dependent (derived). Dependent demand items are typically subassemblies or components parts that will be used in the production of a parent or finished product. That is dependent demand is that industrial

customers, including government & institutions, do not purchase goods & services because of their own personal needs or desires, but rather to produce other goods and /or services for their own customers. Generally speaking, these items (i.e. independent demand) are sold or at least shipped out, rather than used in making another product. In such cases, there is usually no way to precisely determine how many of these items will be demanded during any given time period because demand typically includes

elements of randomness. Therefore, forecasting plays an important role in stocking decisions, where as for dependent demand items, stock requirements are determined by reference to the production plan.

Example: Manufacturers of synthetic fibers sell tire cord to tire manufacturers who intern sell tires to the auto industry and to ultimate consumers as replacement products. Where the sales of original equipment tires follow the same pattern as vehicle production, and replacement tires sales closely parallel vehicle registrations. Neither the auto manufacturer nor the individual car owner is purchasing tire cord, but their tire purchase determines the amount of tire cord that is purchased by the tire industry from the synthetic fibers industry. When new car sales are down, auto production drops. When that happens, auto manufacturers need fewer tires & this in turn means that tire sales to the auto industry are down. If replacement purchases of tires by consumers are not enough to offset the decrease in auto production, the tire manufacturers will require less tire cord from their suppliers. Thus, the ultimate consumer in buying or not buying new automobiles has an indirect effect on the demand for tire cord. In other words, the demand for tire cord is derived from the consumer demand for new automobiles. Hence, it is safe to say, dependent (derived) demand is volatile, i.e. very often, relatively small fluctuations in the ultimate consumer household demand bring about much larger fluctuations in the demand for capital goods used to produce the products sold into the consumer market.

- **If a carpenter buys certain amount of nails to produce a furniture then:**
  - **Is the furniture independent or dependant demand**
  - **Are the nails independent or dependant demand**

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1.3.2 Types of inventories

Inventories are usually classified in different forms, some of which corresponds directly with the inventory function but some of which do not. For this discussion inventories are classified into two categories, namely;

A) Direct and

B) Indirect Inventories

• **Is a lumber which is used to fabricate a table or a cupboard direct or indirect inventory?**

A) **Direct inventories: -** The inventory of those items, which become a component of finished goods, is termed as direct inventory. Direct inventories are categorized as follows;

i) **Inventory of raw materials: -** Raw material inventory has been purchased but not processed, i.e. it requires further processing before they are used in any assembly or as a finished product. They are a major input and their shortages can be holding up the production. They are also useful for seasonal fluctuations, changes in production rate and act as buffer between procurement and manufacture. These items can be used to decouple (i.e. separate) supplier variability in quality, quantity or delivery time so that separation is not needed.

ii) **Work in process (progress (WIP) Inventories: -** These types of inventories consist of materials actually worked on and inventories lying between machines or operations. Work-in-process inventories are waiting to be processed with in the operations systems. Decoupling inventories are an example of work-in-process. That is, they are all the items that have left the raw materials inventory but have not yet been converted or assembled into a final product. They minimize the production loss, which may occur due to different production rates at different centers and braked down at any center. They also help in replacing wastage and maintaining uniform production, even though sales may vary. WIP exists because of the time it takes for a product to be made (called cycle time)

iii) **Finished products inventory: -** Stock of finished goods between production and marketing is known as finished product inventory, i.e. completed product awaiting shipment. This type of inventory is essential to assure a free flow of supply to the

consumer, to allow stabilization of the level of production, and for sales promotion. Finished goods may be inventoried because future consumer demands are unknown.

B) **Indirect inventories:** Inventory of raw materials that do not form an integral part of finished products is called indirect inventory. This may include item such as lubricants, grease, oil, petrol, maintenance materials etc. These are also termed as

maintenances, repair, and operating supplies (MRO) they are consumed in the production process but which do not become parts of the finished products. Their primary purpose is to keep machinery & process productive. They exist because the need and timing for maintenance and repair of some equipment are unknown. Although the demand for MRO inventories is often a function of maintenance schedules, other unscheduled MRO demands must be anticipated.

- **Is Gum or glue used in the fabrication of a table or a cupboard direct or indirect inventory?**

As you can see from the discussion, inventory system and the operations system with in an organization are strongly interrelated. Inventories affect customer service, facility and equipment utilization, capacity, and labor efficiency. There fore, the plans concerning the acquisition and storage of materials, or "inventories" are vital to the production process.

The ultimate objective of any inventory system is to produce decisions regarding the level of inventory that will result in a good balance between the purpose for holding inventories and the costs associated with them.

1.3.3 Inventories in profit and non-profit organizations

- **Do all organizations require inventory to function smoothly?**

All organizations are in need of inventories regardless of their nature of activities. Profit making, service giving, merchandising, manufacturing organizations have to keep an adequate inventory level.

Profit making organizations needs to keep an adequate inventory level either to minimize waste or to maximize profits.

Non-profit making organizations need to keep adequate inventory level to provide better service to the public at large.

The type of items firms' stock range from small things like pencils, paper clips, paper, screws, and nuts and bolts to large items like machines, trucks, construction equipments and airplanes.

Naturally the type of items a firm carries in inventory relate to the kind of business it carries on. Example, manufacturing firms

consists of raw materials, purchased parts, partially completed items, finished goods, and spare parts.... etc
Merchandising firms like department stores, supermarkets, etc carries food stuff items, beverages, cosmetics, fresh and canned foods, garments (clothing), house hold items, stationery, gifts, cards, toys, sporting goods etc.
Hospitals stock drugs, surgical supplies, blood supplies, sheets and pillowcases etc....

1.3.4 Views of Different Departments towards Inventory

It is stated that, inventories make possible smooth and efficient operation of a manufacturing organizations by decoupling individual segments of the total operation. Purchased Part inventories permit activities of purchasing and supply personnel to be planned & conducted some what independently of shop production operations. By the same token, these inventories allow additional flexibility for suppliers in planning, producing, and delivering and order for a given Part.
Thus, well-planned and effective controlled inventories can contribute to the effective operation of a firm and a firm's profit. The basic challenge is to determine the inventory level that works most effectively with the operating system or systems existing within the organization - and that realistically is the most feasible in dealing with given suppliers and material market.
If the inventory issue is viewed through the eyes of various operating department managers, an interesting situation appears. The marketing manager tends to favor larger inventory stocks to assure rapid assembly and delivery of a wide range of finished product models. This capability obviously can be used as an effective sales tool. The production manager is inclined to go along with the marketing manager, but for quite a different reason. He/she argues for higher inventory levels because they allow more flexibility in daily planning, unforeseen problems in producing a given component can be mitigated if productive efforts can easily be transferred to another component for which the required raw materials are on hand. Likewise, a reasonable inventory of the required items ensures against production shutdowns due to delivery problems, supplier problems, and stock outs, thus avoiding the incurrence of high production down

time costs. These arguments might be against the Just in time model that we will discuss later.
The financial officers of the firm, on the other hand, argue convincingly in favor of very low inventory levels. They point out that the company's need for funds usually exceeds availability and

that reduced inventories free solely needed working capital for other uses. They also note that total indirect inventory carrying costs drop proportionately with the inventory level. The purchasing & supply manager is the final participant; he/she is concerned with the size and frequency of individual orders. Purchasing often favors a policy of placing fewer & larger order. Unless contractual arrangement with routine delivery-release systems can be worked out with suppliers, fewer & larger orders usually increase the total inventory level. At the same time, however, they tend to minimize operating problems with suppliers, and in some cases they may reduce unit material prices. Large volume buying also permits more efficient utilization of buying personnel and more effective advance planning for major activities such as market studies, supplier investigations, and so on.

- **What is the reason for the purchasing department to favor higher inventory level?**

Thus it is clear that each department executive supports his/her position with legitimate justification. However, certain conflicts do exist between the objectives of the various departments. Concepts & techniques useful in analyzing this problem to arrive at sound policy decisions are the focal points of inventory management.
Finally, it should be noted that well managed inventories help to reduce both the direct expenses of a business plus its investment base (and keep customers happier too), and the business return on investment can be dramatically improved. This is true because inventory is a controllable item, which means we have unexcelled opportunity to do something about the impact of inventories on costs, capital, investment, customer service, profits & return on business investment. In the words of Kannan "the consumption of material could be as high as 50-70% in the

cost of the product & control on this material inventory directly effects on profits of a company.

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Summary

Inventory management is among the most important operations of management responsibilities because inventory requires a great deal of capital and affects the delivery of goods to customers. Inventory management has an impact on all business functions, particularly operations, marketing, accounting, and finance.

The primary purpose of inventories is to uncouple the various phases of operations. Raw materials inventory uncouples a manufacturer from its vendors; work-in-progress inventory uncouples the various stages of manufacturing from each other, and finished –goods inventory uncouples a manufacturer from its customers. The other functions of inventories are stabilizing employment, getting quantity discount, buffer inventories, and meeting an anticipated demand.

A crucial distinction in inventory management is whether demand is independent or dependent. Independent demand is influenced by market conditions outside the control of operations. Finished goods inventories and spare parts for replacement usually have independent demand. Dependent demand is related to the demand for another item and is not independently determined by the market. When products are built up from parts and assemblies, the demand for these components is dependent for the final product

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Chapter 2
Forecasting

2.1 Introduction

Dear learners in chapter one, we define inventory, types of inventory and its benefit to any organizations. In this chapter we will discuss about forecasting. We practice forecasting formally or informally in our daily life. We hear the weather forecast by the metrology people and central statistics authority forecast the number of Ethiopian population in 2020. All th+ese and other forecasts have an impact in our daily or future life. Then dear

learner please be brave and go through all the notes and apply to enhance your personal or organizational success.
Inventories are not stockpiled for previous years' orders: rather they are used for economically handling present and future demands.
To calculate order quantities, safety stocks, or in-process inventories requires that we make assumptions about upcoming demands. These demand assumptions are really forecasts, whether we call them that or not.
Every day managers make decisions without knowing what will happen in the future. They order inventory without knowing what sales will be, purchase new equipment despite uncertainty about demand for products, and make investments without knowing what profit will be. Managers are always trying to make better estimate of what will happen in the future in the face of uncertainty. Making good estimates is the main purpose of forecasting.
Inventory control is therefore built upon an unseen and almost unknowable foundation: a prediction of the future. All is not lost, however: all business decisions are implicitly based upon expectations of the future, such as the expected sales level next week or next year. If inventory control forces us to do a better job of planning a head, the happy results go far beyond the maximizing of raw materials discounts or the minimizing of plant changeovers.

- **Do you involve your self in forecasting? In what area?**

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Forecasting is the art and science of predicting future events. It involves estimation of the occurrence, timing, and/or magnitude of uncertain future events or levels of activities. Forecasting may involve taking historical data and projecting them into the future with some sort of mathematical model. It may be a subjective or intuitive prediction or it may involve a combination of these-that is, a mathematical model adjusted by a manager's good judgment. Successful forecasting requires blending art and science. Experience, judgment, and technical expertise will all play a role in successful forecasting.

The purpose of forecasting activities is to make use of the best available present information to guide future activities to ward system goals

Furthermore, there is no need for such forecasts to be 100% correct in order to obtain useful results. Fortunately, there are many techniques available that can provide useful forecasts for inventory control purposes. Many of these forecasting methods are based on solid historical patterns; others take history and update it based on current trends.

In business, forecasts are the basis for capacity planning, budgeting, sales planning, production and inventory planning, manpower planning, purchasing planning, etc. Forecasts play such as important role in the planning process because they enable managers to anticipate the future and to plan accordingly.

It should be noted that business forecasting pertains to more than predicting demand. Forecasts are also used to predict profits, revenues, costs, productivity changes, prices and availability of energy and raw materials as well as other variables.

In spite of the use of sophisticated models in forecasting, forecasting is not an exact science. Instead, successful forecasting often requires a skilful blending of art and science. Experience, judgment, and technical expertise all play a role in developing useful forecasts.

Objectives:

When you complete this chapter, you should be able to:

- Describe the techniques of qualitative forecasting techniques
- Describe the techniques of quantitative forecasting techniques
- Compare and contrast qualitative and quantitative approaches
- Outline the steps in forecasting techniques

2.2 Common Features to all forecasts

- **Is your organization practice forecasting? Is the forecast and the actual result matches?**

There are a wide variety of forecasting techniques in use. In many respects they are quite different from each other. Nevertheless, there are certain features that are common to all and it is important to recognize them.

1. Forecasting techniques generally assume that the same underlying causal system that existed in the past will continue to exist in the future.
2. Forecasts are rarely perfect: actual results will usually differ from predicted values. The inability to precisely predict how an often-large number of related factors will impinge upon the variable being forecasted and the presence of randomness preclude a perfect forecast. So allowances should be made for inaccuracies.
3. Forecasts for groups of items tend to be more accurate than forecasts for individual items because forecasting errors among items in a group usually have a canceling effect. Opportunities for grouping may arise if parts or raw materials are used for multiple products or when a service is demanded by a number of independent sources.
4. Forecast accuracy decreases as the time period covered by the forecast (i.e. the time horizon) increases. Generally speaking short-range forecasts must contend with fewer uncertainties than longer-range forecasts, so they tend to be more accurate.

Elements of a Good Forecast

1. The forecast should be timely
2. The forecast should be accurate and the degree of accuracy should be stated
3. The forecast should be reliable (consistent)
4. The forecast should be expressed in meaningful terms. Different users may need different terms (Financial in dollars, marketing in units by products, operations by units, human resources by skills, etc)
5. The forecast should be in writing
6. The forecasting technique should be simple to understand and use.

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Forecasting time horizons

• Would you plan for the next one year or next 10 years? Is the accuracy of forecast equal for both?

A forecast is usually classified by the future time horizon that it covers. Time horizon falls in to three categories:

1. **Short-range forecast**. This forecast has a time span of up to one year but is generally less than three months. It is used for

planning purchasing, job scheduling, workforce levels, job assignments, and production levels.

2. **Medium-range forecast.** A medium-range, or intermediate, forecast generally spans from 3 months to 3 years. It is useful in sales planning, production planning and budgeting, cash budgeting, and analyzing various operating plans.

3. **Long-range forecast**. Generally 3 years or more in time span, long-range forecasts are used in planning for new products, capital expenditures, facility location or expansion, and research and development.

Steps in the forecasting process

- **What parameters have to be considered to forecast in your organization?**

There are five basic steps in the forecasting process: -

Determine the purpose of the forecast and when it will be needed. This will provide an indication of the level of detail required in the forecast, the amount of resources that can be justified, and the level of accuracy necessary.

Establish the time horizon that the forecast must cover, keeping in mind that accuracy decreases as the length of the forecast period increases.

Select a forecasting technique

Gather and analyze the appropriate data and then prepare the forecast. Identify any assumptions that are made in conjunction with preparing and using the forecast.

Make the forecast

Monitor the forecast to see if it is performing in a satisfactory manner. If it is not, reexamine the method, assumptions, validity of data, and so on, modify as needed, and prepare a revised forecast.

2.3 Methods of forecasting

- **Is your organization's forecasting practice start from top management or lower level management? Which practice is best?**

Forecasting is some time done by a top-down method. In other cases, the reverse, a bottom-up method is used. And in still other cases, past experience is extrapolated into the future by using mathematical and statistical procedures.

Top-down forecasting

The top down method often starts by using forecasts of general business conditions made by economists in the government and in large companies and universities. Such forecasts appear frequently in government and private publications. Other, more detailed & customized, forecasts are purchased from organizations, which specialize in economic forecasting (forecasting economic trends, using statistical and mathematical procedures). The experts may say, for example, that next year's gross national product will be birr 11 billion. In a company making kitchen stoves, the question then becomes: How will this affect us? The forecaster in the company must first translate general forecasts in terms of his/her industry's future business. Then he has to estimate his company's share, and, finally, how many of each product the company will be able to sell each month.

Bottom – up forecasting

The bottom – up method begins with individual end – product demand expectations. How many of each end product does it appear that the company can sell next year? Or how many hours of service will be demanded? In this method the forecaster receives estimate from sales people and from dealers and customers. He/she also looks at past sales patterns. Finally, he/she adds up the different product forecasts and gets a total, which is the aggregate forecast.

Actually, companies use both top-down and bottom-up methods at the same time and combine the resulting projections into a single forecast. But before settling on a final forecast, they may also use the "jury of executive opinion" (Delphi) approach to adjust judgmentally the more technically determined forecasts. The forecasts are adjusted up or down according to what the organizations top people think about the future.

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Neither top-down nor bottom-up methods are, however, very useful for forecasting how many of each of the thousands of individual products to make. Here, the most common method is simply to extrapolate past demands for each item into the future by mathematical and statistical procedures. At first this does not sound very practical because these mechanistic forecasts do not

consider outside factors and thus may not always be very good forecasts. As the same time, however, the other methods of forecasting described above are much too complex to be used for each individual item of the thousands of items in normal inventories. Extrapolations and calculations of future needs by computers, using mechanistic methods, are perhaps the best that one can do for individual items or demands for service.

2.4 Approaches to forecasting:-

• Would you use your experience or use some mathematical manipulation in your forecasting? Which one is best?

There are two general approaches to forecasting, qualitative and quantitative. **Quantitative forecasts** use a variety of mathematical models that relay on historical data and/or causal variables to forecast demand. **Qualitative forecasts** incorporate such variables as the decision maker's intuition, emotions, personal experiences, and value system in reaching a forecast. These factors are often omitted or down played when quantitative techniques are used because they are difficult or impossible to quantify.

2.4.1 Overview of qualitative forecasting

• What are the methods that you use in qualitative forecasting?

Qualitative techniques are subjective or judgmental in nature and are based on estimates and opinions. When a forecast must be prepared quickly, there is usually not enough time to gather and analyze quantitative data. At other times, especially when political and economic conditions are changing, available data may be obsolete, and more-up-to date information might not yet be available.

Similarly, the introductions of new products, as well as the redesign of existing products or packaging, all suffer from the absence of historical data that would be useful in forecasting. Besides, subjective opinions may be adequate for less consequential or relatively certain situations. In such instances, forecast based on

judgment and experiences are commonly used. The following are types of qualitative forecasting.

• **What is the difference between qualitative and quantitative forecast?**

Executive opinions:

A small group of upper level managers (E.g. marketing, engineering, manufacturing, and financial managers) may meet and collectively develop a forecast. This approach is often used as a part of long rang planning and new product development. It has the advantage of bringing together the considerable knowledge and talents of these top management people. However the risk is that the view of one person will prevail as well as the possibility that diffusing responsibility for the forecast over the entire group may result in less pressure to produce a good forecast.

Sales force composite:

The sales staff is often a good source of information because of its direct contact with consumers. Thus, these people are often aware of any plans the customers may be considering for the future. There are however, several drawbacks to this approach. One is that sales people may be unable to distinguish between what customers would like to do and what they actually will do. Another is that sales people are some times overly influenced by recent experiences. Thus, after several periods of low sales, their estimate may tend to become pessimistic, while after several periods of good sales, they may tend to be too optimistic. In addition, if forecasts are to be used to establish sales quotas, there will be a conflict of interest because it would be to the sales person's advantage to provide low sales estimates.

• **What is the difference of between executive opinions and sales force composite methods of forecasting?**

Consumer Surveys:

Since the customer is the one who will ultimately determine demand, it would seem natural to solicit input from customers. In some most cases, however, there are either too many customers or no way to identify all potential customers. Because of these and similar factors, organizations that seek consumer input usually resort to the use of consumer surveys which enable them to sample consumer opinions. The obvious

advantage of such surveys is that they can tap information that might not be available elsewhere. On the other hand, surveys require a considerable amount of skill to handle currently. A great deal of care is necessary to construct a survey, administer it, and correctly interpret the results in order to obtain valid information. In addition, even under the best of conditions, surveys involving the general public must contend with the possibility of irrational behavior patterns.

Opinions of managers and staff:

A manager may use a staff to generate a forecast or to provide several forecasting alternatives from which to choose. At other times, a manager may solicit opinions from a number of other managers and/or staff people. The Delphi method is useful in this regard. It involves circulating a series of questionnaires among those individuals who possess the knowledge and ability to contribute meaningfully. Responses are kept anonymous, which tends to encourage honest responses. Each new questionnaire is developed using any information extracted from the previous one, thus enlarging the scope of information on which participants can base their judgments. The goal is to achieve a consensus forecast.

• Compare and contrast consumer survey and opinions of managers forecasting?

The first step in the Delphi process is the establishment of a small group of individuals who will design the study. This group is the Delphi committee. They will first decide the channel of communication, (mail, hand delivery, computer), the size of the group to be queried, and the participants.

Next the initial questionnaire must be developed. It must be constructed in such a way that it elicits opinions. Unambiguously, this is essential in order to achieve a true consensus from the group. The initial questionnaire must introduce the desired purpose and scope and focuses on the desired points, factors and opinions. Protesting of the questionnaire to ensure its validity is very important. Next, the questionnaire is distributed to the participants for their initial inputs and returned to the Delphi committee, which then compiles the results. Using this information, the committee develops and distributes a second questionnaire. This second

questionnaire usually asks respondents to expand on key factors or place priorities on key items. This questionnaire receives

cursory presetting to eliminate ambiguities along with the results of the initial questionnaire. The intent of including the initial results is to exert pressure to conform; since it is human nature to conform, the feed back these results provide helps the process. The process is repeated with a third questionnaire. If there is to be a consensus, it will usually be achieved by this point. Hence, the process usually terminates after the third questionnaire. At that point the forecast can be made, assuming consensus has been reached. Other wise the process may be started all over, perhaps with new participants, a revised questionnaire, or a completely different approach to the problem (e.g. a face -to-face meeting of a few key experts).

The reasons for considering a Delphi approach are:

- A group of experts can provide needed judgmental input.
- More individuals are needed than can effectively interact in a face-to- face situation, and /or the individuals cannot be conveniently assembled in one place. Time and cost can be factors.
- It is desirable to preserve the anonymity of the participants.
- There is controlled feedback between rounds and a statistical summary of group responses.

However, it has its own weaknesses such as:

- The questions may contain ambiguous phrasing so that panel members reach a false consensus.
- Panel membership may change, especially if the process requires a long time.
- The “experts” may not be experts.
- Preserving anonymity removes accountability and responsibility.
- Results are difficult or impossible to replicate.

2.4.2 Overview of quantitative methods

• What are the methods that you use in quantitative forecasting?

Quantitative forecasting methods use historical data. Quantitative methods fall in to two categories: Time series models and associative/causal models.

2.4.2.1 Time serious models

A time series is a time-ordered sequence of observations taken at regular intervals over a period of time (e.g. hourly, daily, weekly, monthly, quarterly, and annually). The data may be measurements of demand, earnings, profits, shipments, acquirements, output etc. Forecasting techniques based on time series data are made on the assumption that future values of the series can be estimated from past values. In other words, they look at what has happened over a period of time and use a series of past data to make a forecast. Example if I want to predict weekly sales of a dry cell, we use the last weekly sales of a dry cell in making a forecast.

Time series analysis will have a variable which is dependent and another independent variable which is time. The time is independent variable because it doesn't dependent on the other variable. The other variable becomes a dependent variable when it depends on time.

Time serious models include the following techniques to forecast:

a. Naive forecasts
b. Moving averages
c. Exponential smoothing
d. Trend projection

• **Assume demand bread for a bakery in may and June of 2000E.C is 50,000 units and 48,000 units respectively. If the weight for May is 0.4 and that of June is 0.6.; what is the forecasted demand for July of the same year for the bakery?**

a) Naive forecasts

The simplest way to forecast is too assume that demand in the next period will be equal to demand in the most recent period.

Example: if the actual demand of umbrella is 60 units on Monday, the forecasted demand for Tuesday will be 60 units. Does this make sense? At least it provides a starting point against which more sophisticated models that follow can be compared.

b) Simple Moving averages

Moving average forecast uses a number of historical actual data values to generate a forecast. Moving averages are useful if we can assume that market demand will stay
25
fairly steady overtime. A 4-month moving average is found by simply summing the demand during the past 4 months and dividing by 4 with each passing month, the most recent month's data are added to the sum of the previous 3 months data, and the earliest month is dropped. This practice tends to smooth out short-term irregularities in the data series.
Mathematically, the simple moving average, (which serves as an estimate of the next period's demand) is expressed as;
Moving average= Σdemand in previous n periods
N
Where **N** is the number of periods in the moving average.
There are two problems with this approach. First, it requires keeping all of the past data, no matter how long the time series records are kept. Second, it will become weighed too much toward in the distant past (be too smooth) and fail to be responsive to any changes in recent data.
A way to achieve a compromise between the smoothing and responsiveness goals is to use the forecasting method called the **n** period moving average. Only the data for the previous n periods are kept, and the forecast is the average of these **n** periods of data. Less data are maintained, and the amount is kept constant by dropping off the oldest piece of data every time a new one is made available. By using an average, a smoothing effect is still seen, but, because a smaller amount of data is averaged, the method will be more responsive to any changes in recent data.
Example1: Given in table 2.1 the number of admission at Gishabay Clinic over the past ten weeks. The administration would like to predict the number of admissions for the coming week.
26
Table 2.1
Gishabay Clinic admission
Week Number
Admissions

1
2
3
4
5
6
7
8
9
10
22
21
25
27
35
29
33
37
41
37
Total= 307

Overall, the admission pattern seems to be increasing, but there have been weeks when admissions did drop. Notice that the average over the ten weeks is 30.7(i.e. 307/10). There are times when the average of all of the data may be a reasonable forecast, but, in this case, it appears that the more recent data are well above the overall average. Therefore, a reasonable method for forecasting is to use only the more recent data. This minimized the lag. By "more recent" we mean either last week's data alone, or the data from only the last two weeks, or the data from the past three or four weeks. The general procedure is to average the data from the last n weeks (or months or years). For example, the following forecasts would be made for N ranging form 1 to 5

N Forecasts

1 37
2 $(37 + 41)_{1}/_{2} = 78/2 = 39$
3 $(37 + 41 + 37) /3 = 115/3 = 38.33$
4 $(37 + 41 + 37+33) /4 = 145/4 = 37$

5 (37 + 41 + 37+33+29) /5 = 177/4 = 35.4
27
Of course if N=1 the method simply uses the data of one week to predict admissions for
the next, while the overall average is the predictor in this example N= 10 (because we
have ten weeks worth of data.)
The table uses the three-week moving average to present forecasts for all of the data.
Note that the computations cannot begin until week 4, because three weeks of data are
needed for forecasting.
Computation of three-week moving average for Gishabay Clinic data is as follow:
Table 2.2
Week Actual admission For casting admission using three-week moving average
1
2
3
4
5
6
7
8
9
10
11
22
21
25
27
35
29
33
37
41
37
?

(22+21+25)/3 = 88/3 = 22.67
(21 + 25 + 27)/3 = 73/3 = 24.33
(25 + 27 + 35)/3 = 87/3 =29
(27 +35 +29)/3 = 91/3 = 30.33
(35 + 29 + 33)/3 = 97/3 = 32.33
(29 + 33 + 37)/3 = 99/3 = 33
(33 + 37 + 41)/3 + 111/3 + 37
(37 + 41 + 37)/3 = 115/3 = 38.33

Example 2: Compute a three-period moving average forecast given demand for shopping
spare parts for the last five periods

Table 2.3

Period Age Demand
1 5 42
2 4 40
3 3 43
4 2 40
5 1 41

Solution MA_3 =
3
41+ 40 + 43
= 41.33
28

If actual demand in period 6 turns out to be 39, the moving average forecast for period 7
would be

MA7 =
3
39 + 41+ 40
=40

Note that in a moving average, as each new actual value becomes available, the forecast
is updated by adding the newest value and dropping the oldest and then recomputing the
average consequently, the forecast “moves” by reflecting only the most recent values.

The advantages of a moving average forecast are that it is easy to compute and easy to

understand. A possible disadvantage is that all values in the average are weighted
equally. For instance in a 10-period moving average, each value has a weight of 1/10.
Hence, the oldest value has the same weight as the most recent value. If a change occurs
in the series, a moving average forecast can be slow to react, especially if there are a
large number of values in the average. This problem is solved by using weighted moving
average.
In summary, moving average presents three problems:
1. Increasing the size of **N** does smooth out fluctuations better, but it makes the
method less sensitive to real changes in the data.
2. Moving averages cannot pick up trends very well. Because they are averages,
they will always stay with in past levels and will not predict changes to either
higher or lower levels. That is, they lag the actual values
3. Moving averages require extensive records of past data.

• Actual demand for a product for the past three months was as follow:

Three months ago 400 units

Two months ago 350 units

Last months 325 units

a. Using a three month moving average, make a forecast for this month

b. If 300 units were actually demanded this month, what would your forecast be for
the next month?

C) Weighted moving average

In the simple moving average method, each observation in the time series receives the same weight. When detectable trend or pattern is present, *weights* can be used to place more emphasis on recent values. One possible variation, known as ***weighted moving averages***; involves selecting different weights for each data value and then computing a weighted mean as the forecast.

In most cases, the most recent observation receives the most weight, and the weight decreases for older data values. This practice makes forecasting technique more responsive to changes because most recent periods may be more heavily weighted.

In the example of the three-week moving average, the forecast for week 11 is given by (37 + 41 + 37) /3 Note that this is the same as taking the admission for each of the last weeks, multiplying each by a weight of one-third, and adding the products-37 (1/3) + 4 (1/3) + 37 (1/3). There is no reason that the admissions data must be multiplied by the same weight. In fact, it is quite reasonable to weight the data from last week more than the data from two weeks ago. The n-period weighted moving average does just this. Different weights are assigned for the different periods. The weights assigned should add to 1. For example, if the clinic has decided that the weights to be used are 0.5, 0.3, and 0.2, then the forecast for week 11 is given by

0.5 (last week admission) + 0.3 (admission two weeks ago) + 0.2 (admissions three weeks ago)

= .5 (37) + .3 (41) + .2 (37)

= 18.5 + 12.3 + 7.4

= 38.2

It should be clear that the largest weight is usually for the most recent datum. Table 2.3 presents the three-week weight moving averages, which use weights of 0.5, 0.3 and 0.2. Based on past data, the weights 0.5, 0.3 and 0.2 are worse than the equal weights of one third. The assignment of weights is given to the forecaster, provided they are positive and sum to 1.

30

Three week weighted moving average for

Gishabay Clinic data

Table 2.4

Week

Actual admission

Three week weighted moving average for

Gishabay clinic data

1

2

3

4
5
6
7
8
9
10
11
22
21
25
27
35
29
33
37
41
37
?
.5 (25) + .3 (21) + .2 (22) = 23.2
.5 (27) + .3 (25) + .2(21) = 25.2
.5 (35) + .3 (27) + . 2(25) = 30.6
.5 (29) + .3 (35) + .2 (27) = 30.4
.5 (33) + .3 (29) + .2 (35) = 32.2
.5 (37) + .3 (33) + .2 (29) = 34.2
.5 (41) + .3 (37) + .2 (33) = 38.2
.5 (37) = .3(41) + .2 (37) = 38.2

The weighted moving average has a definite advantage over the simple moving average in being able to vary the effects of past data.

For example, a super market may find that in a four-month period the best forecast is derived by using 40 percent of the actual sales for the most recent month, 30 percent of two months ago, 20 percent of three months ago, and 10 percent of four months ago. If actual sales experience was as follows;

Month 1 Month2 Month3 Month4 Month5

100 90 105 95 ?

The forecast for month 5 would be:

Fs=0.40(95)+

=38+31.5+18+10
=97.5
Suppose sales for month 5 actually turned out to be 110; then the forecast for month 6 would be
F6=0.40(110)+0.30(95)+0.20(105)+0.10(90)
=44+28.5+21+9
=102.5
31
The weighted moving average has a definite advantage over the simple moving average in being able to vary the effects of past data. However, it is more inconvenient and costly to use. And the choice of weights is somewhat arbitrary and generally involves the use of trial and error to find a suitable weighting scheme

d) Exponential smoothing

In the previous methods of forecasting (simple and weighted moving average), the major drawback is the need to continually carry a large amount of historical data. each new piece of data is added in these methods, the oldest observation is dropped, and the new forecast is calculated. In many applications, the most recent occurrences are more indicative of the future than those in the more distant past. If this premise is valid-that the importance of data diminishes as the past becomes more distant-then exponential smoothing may be the most logical and easiest method to use. Exponential smoothing is a sophisticated weighted moving average forecasting method that is still fairly easy to use. The reason this called “exponential smoothing” is because each increment in the past is decreased by (1-α), or
Most recent weighting= α $(1-\alpha)_0$
Data 1 time period older=α $(1-\alpha)1$
Data 2 time periods older=α $(1-\alpha)2$
Data 3 time periods older=α $(1-\alpha)3$
Exponential smoothing is the most used of all forecasting techniques. It is an integral part of virtually all computerized forecasting programs, and is widely used in ordering inventory in retail firms, wholesale companies, and service agencies.
The major reasons that exponential smoothing techniques have become so well accepted are;
1. Exponential models are surprisingly accurate
2. Formulation an exponential model is relatively easy.

3. The user can understand how the model works.
4. There is very little computation required to use the model
5. Tests for accuracy as to how well the model is performing are easy to compute.
32
In the exponential smoothing method, only three pieces of data are needed to forecast the future: ***the most recent forecast, the actual demand that occurred for the forecast period, and a smoothing constant alpha***. This smoothing constant determines the level of smoothing and the speed of reaction to differentiate between forecasts and actual occurrences. The value for the constant is arbitrary and is determined both by the nature of the product and the manager's sense of what constitutes a good response rate. For example, if a firm produced a standard item with relatively stable demand, the reaction rate to differentiate between actual and forecast demand would tend to be small, perhaps just a few percentage points. However, if the firm were experiencing growth, it would be desirable to have a higher reaction rate, to give greater importance to recent growth experience. The more rapid the growth, the higher the reaction rates should be.
The equation for a single exponential smoothing forecast is simply
New forecast= Old forecast +α (Actual – Old forecast)
$F_t = F_{t-1} + \alpha (A_{t-1} - F_{t-1})$
Where
F_t= the exponentially smoothed forecast for period t
F_t-1=the exponentially smoothed forecast made for the prior/previous period
A_t-1=the actual demand in the prior/previous period
α = the desired response rate, or smoothing constant.
This equation states that the new forecast is equal to the old forecast plus a portion of the error (the difference between the previous forecast and what actually occurred)
To demonstrate the method, assume that the long-run demand for the product under study is relatively stable and a smoothing constant of 0.05 is considered appropriate. Assume that last months forecast (f_t-1) was 1050 units. If the actual demand

were1000 units rather than 1,050, the forecast for this month would be:

$F_t = F_{t-1} + \propto(A_{t-1} - F_{t-1})$

$= 1{,}050 + 0.05(1{,}000 - 1{,}050)$

$= 1{,}050 + 0.05(-50)$

$= 1{,}047.5$ units

33

Because the smoothing coefficient is small, the reaction of the new forecast to an error of 50 units is to decrease the next months forecast by only 2 ½ units, i.e. (1050- 1047.5)

Example: In February a car dealer predicted demand March 142 autos, but in March demand was turned out153 autos. Using a smoothing constant chosen by management of auto dealer $\alpha = 0.2$, forecast April demand.

New forecast (April demand) $= F_t = F_{t-1} + \alpha\ (A_{t-1} - F_{t-1}))$

$= 142 + 0.2(153 - 142)$

$= 144.2$

Then the April demand is 144 autos.

Exponential smoothing requires that the smoothing constant alpha (α) be given a value between 0 and 1. If the real demand is stable, we would like a small alpha to lessen the effects of short term or random changes. If the real demand is rapidly increasing or decreasing, we would like a large alpha to try to keep up with the change. It would be ideal if we were able to predict which alpha we should use. Unfortunately, two things are going against us; first, it would take some passage of time to determine the best alpha that would fit our actual data. This would be tedious to follow and revise. Second, because demands do change, the alpha we pick this week may need to be revised in the near future. There fore, we need some automatic method to track and change our alpha values.

2.4.2.2 Associative forecasting techniques

In the previous section, we saw that demand could be related to time; that is, the demand changed as time changes. While a relationship existed, we could not say for sure that time caused the changes in the demand. There are factors other than time that are often related to demand and, in fact, these factors often cause, or at least precede, the demand changes.

Associative or explanatory forecasting models incorporate one or more variables that are related to the variable of interest and, therefore, they can be used to predict future values of that variable. It is associative techniques rely on identification of related variables that can be used to predict values of the variable of interest. Unlike, time series forecasting associative forecasting models usually consider several variables that are related to the quantity being predicted. Once these related variables have been found, a statistical

model is built and used to forecast the item of interest. This approach is more powerful than the time-series method that uses only the historic values for the forecasted variable.

Many factors can be considered in an associative analysis. For examples, the sales of Vestel TV might be related to the company's advertising budget, the company's prices, competitor's prices and promotional strategies, and even the nation's economy and unemployment rates.

In this case, TV sales would be called the dependent variable and the other variables would be called independent variables. The manager's job is to develop the best statistical relation ship between TV sales and the independent variables. The most common quantitative associative forecasting model is linear regression analysis

X- Y graph

The most widely used associative models in forecasting are called regression models, and the discussion here will concentrate on them, with particular emphasis on simple linear regression models.

Simple Linear regression analysis

Regression can be defined as a functional relationship between two or more correlated variables. It is used to predict one variable given the other. A simple linear regression model consists of two variables that are taught to be related. Example we can expect that

- An extended period of rain will increase sales of umbrellas
- The cost of a text book may depend on the number of pages
- The yield from a land depends on soil conditions, amount and timing of rain and fertilizer applications.

One of these is the variable to be forecasted, and it is referred to as the dependent variable; its value “depends” on (is a function of) the value of another variable. The other variable, which will be used to “explain” or predict the value of the dependent variable, is referred to as an independent variable. From the above example umbrella/yield of crop is dependent variable while rain/fertilizer is an independent variable. The relationship is
35
usually developed from observed data. In order to make a forecast, the two variables must
be expressed in a linear equation of the form

Y = a + bx

Where
Y= the dependent variable
x= the independent variable (in time series analysis, X is unit of time)
a= value of y when X=0
b= slope of the line
Linear regression is useful for long-term forecasting of major occurrences and aggregate
planning. The major restriction in using linear regression forecasting is, as the name
implies, that past data and future projections are assumed to fall about a straight line.
For example; the marketing manager of a shoe company has developed the following
equation to predict the demand of shoes (dependent variable) based on the amount of
television advertising (independent variable) during the holiday week:

Y= 3.57 + 3.78x

Where
x= television advertising in thousands of birr in preceding week
y= sales of shoes in thousands of birr
Thus, the marketing manager must feel that advertising expenditure is a major factor in
determining sales of this product. According to the equation, if adverting expenditure is
birr 1(thousands), sales will be about

3.57+ 3.78 (1) = 7.35 thousands = birr 7350

Note: It is conventional to represent values of the predicted variable on the y-axis and
value of the predictor variable on the x axis. The coefficient of a and b of the line are
computed using these two equations

$$b=\frac{n(\Sigma xy)-(\Sigma x)(\Sigma y)}{n\Sigma x^2-(\Sigma x)^2}$$

$$a=\frac{\sum y - b\sum x}{n}$$

or

$$a=\bar{Y}-b\bar{X}$$

Where n= number of paired observations

Example

Meta brewery factory sell draft to the Addis Ababa Market. The companies have found that its sales volume of draft is dependent on the Addis Ababa area construction employees. That is as the number of construction employees' increase they generate more money and use more drafts. The following table lists Meta brewery's revenues and the amount of money earned by wage by construction employees in Addis during the past six months.

Table 2.5a

Sales of Meta draft

Payroll (00,000), y	**(000,000), x**
2	1
3	3
2.5	4
2.0	2
2	1
3.5	

7
Meta brewery's management wants to establish a mathematical relationship to help predict sales. First it needs to determine whether there is a straight line (linear) relationship between construction employees' wage and sales, so it plots the known data on a scatter diagram. It appears from the six data points that there is a slight positive relationship between the independent variable (wage) and the dependent variable (sales) as wage increases, Meta brewery's sales tend to be higher.
We can find a mathematical equation by using the least squares regression approach
37
Table 2.5b

Sales, Y	**wage,** X	$\mathbf{X_2}$	**XY**
2	1	1	2
3	3	9	9
2.5	4	16	10
2	2	4	4
2	1	1	2
3.5	7	49	24.5

$\Sigma y=15.0$
$\Sigma x=18$
$\Sigma x_2=80$
$\Sigma xy=51.5$

$\bar{X} = \frac{\sum x}{6} = \frac{18}{6} = 3$

$\bar{Y} = \frac{\sum Y}{6} = \frac{15}{6} = 2.5$

b=
$\sum$
$\sum$
-
-
-
$_{2}\,_{2}\,x\ nx$
$XY\ n\ xy$
=
( )( )( )
( )($_{2}$) 80 6 3
51.5 6 3 2.5
-
-
=0.25
a= -
-
Y b
-
X = 2.5-(0.25)(3) = 1.75
The estimated regression equation, therefore, is
Y= 1.75 + 0.25 (wage)
If the housing agency predicts that the employees wage will be birr 6 million next month,
we can estimate sales for with the regression equation
Sales (in hundreds thousands) = 1.75 + 0.25(6)
=1.75 + 1.50
=3.25
Or sales = Birr325, 000
38

2.5 Accuracy and control of forecasts

• Is the forecast and the actual result the same in your organization? If there is a mismatch what do you do next?

Accuracy and control of forecast is a vital aspect of forecasting. The complex nature of most real-world variables makes it almost impossible to correctly predict future values of those variables on a regular basis. Consequently, it is important to include an indication of the extent to which the forecast might deviate from the value of the variable that actually occurs. This will provide the forecast user with a better perspective on how far off a forecast might be.

Moreover, because some techniques provide more accuracy than others in a given situation, the decision maker needs a measure of accuracy to use as a basis for comparison when choosing among different techniques. Finally, some forecasting application involve a series of forecasts, where as others involve a figure forecast that will be used for a one-time decision. When making periodic forecasts, it is important to monitor forecast errors to determine if the errors are with in reasonable bounds. If they are not, it will be necessary to take corrective action.

Forecast error is the difference between the value that occurs and the value that was predicted for a given time period. Hence,

Error=Actual-forecast

et= At--Ft

Positive errors result when the forecast is too low, negative errors when the forecast is too high. Forecast errors influence decisions in two some what different ways. One is in making a choice between various forecasting alternatives, and the other is in evaluating the success of the failure of a technique in use. We shall begin by examining ways to summarize forecast error overtime, and see how that information can be applied to a choice among forecasting alternatives. Then we shall consider methods for controlling forecasts.

• What is the difference between positive and negative errors?

Forecast errors

In using the word error, we are referring to the difference between the forecast value and the actual vale occurred. In statistics, these errors are called residuals. As long as the

forecast value is with in the confidence limits, it is not really an error. But common usage refers to the difference as an error.

Demand for a product is generated through the interaction of a number of factors too complex to describe accurately in a model. There fore, all forecasts certainly contain some error. In discussing forecast errors, it is convenient to distinguish between source of error and measurement of error.

Source of error

Errors can come from a variety of sources. One common source that many forecasters are unaware of projecting past trends into

the future. For example, when we talk about statistical errors, in regression analysis, we are referring to the deviation of observations from our regression line. It is common to attach a confidence band (that is, statistical control limits) to the regression line to reduce the unexplained error. But when we then use this regression line as a forecasting device by projecting it into the future, the error may not be correctly defined by the confidence band. This is because the confidence interval is based on past data; it may not hold for projected data points and therefore, cannot be used with the same confidence. In fact, experience has shown that the actual errors tend to be greater than those from forecast models.

Errors can be classified as bias or random. Bias errors occur when a consistent mistake is made. Sources of this bias include the failure to include the right variable; the use of wrong relationships among variables; employing of the wrong trend lines; a mistaken shift in the seasonal demand from defined as those that cannot be explained by forecast model being used.

Measurement of the accuracy of forecast

There are two aspects of forecast accuracy that have potential significance in deciding among forecasting alternatives. One is the historical error performance of a forecast, and the other is the ability of a forecast to respond to changes. Two commonly used measures for summarizing historical errors are the ***Mean absolute deviation (MAD)*** and the ***mean square error (MSE).***

MAD is the average error in the forecasts, using absolute values. It is valuable because

MAD, like the standard deviation, measures the dispersion of some observed value from

some expected value.

MAD is computed using the differences between the actual demand and the forecast

demand without regard to sign. It is equal to the sum of the absolute deviation divided by

the number of data points, or stated in equation form,

MAD =

n

$\sum$ *Actual - forecast*

The mean squarer error (MSE) is the average of squared errors. The formula used to
compute MSE

MSE=

( )

1

2

-

$\sum$ -

n

Actual forecast

The sample standard deviation, **s**, equals the square root of MSE. The following example illustrates the computation for the following data. Compute MAD
and MSE for the following data

Table 2.6

Period Actual Forecast Error /Error/ Error2

1 217 215 2 2 4

2 213 216 -3 3 9

3 216 215 1 1 1

4 210 214 -4 4 16

5 213 211 2 2 4

6 219 214 5 5 25

7 216 217 -1 1 1

8 212 216 -4 4 16

Using the figures shown in the table

MAD =

n

$\sum e$ =

8

2 + 3 +1+ 4 + 2 + 5 +1+ 4

=

8

22

=2.75

41

MSE =

1

2

-
$\sum$
n
e
= 10.86
8 1
76
=
-
From a computational standing point, the difference between these two measures is that
one weights errors evenly (MAD) and the other weights errors according to their squared
vales (MSE).
One use for these measures is to compare alternative forecasting methods. For instance,
using either MAD or MSE, a manager could compare the results of exponential
smoothing with values of 0.1, 0.2, and 0.3, and select the one that yields the lowest MAD
or MSE for a given set of data.
In some instances, historical error performance is secondary to the ability of a forecast to
respond to changes in data patterns. Choice among alternative methods would then focus
on the cost of not responding quickly to a change relative to the cost of responding to
changes that are not really there (i.e. random fluctuations).
Overall, the operations manager most settles on the relative importance of historical
performance versus responsiveness and whether to use MAD or MSE to measure
historical performance.

Controlling the forecast

It is necessary to monitor forecast errors to ensure that the forecast is performing
adequately. This is accomplished by comparing forecast errors to predetermined values,
or action units. Errors that fall with in the limits are judged acceptable, and errors outside

of either limit signal that corrective action is needed.
There are a variety of possible sources of forecast errors, including the following:
2. The model may be inadequate due to (a) the omission of an important variable,
(b) a change or shift in the variable that the model can not deal with, or (c) the
appearance of a new variable
3. Irregular variations may occur due to severe weather or other natural
phenomena, temporary shortages or breakdowns, catastrophes, or similar
events.
4. The forecasting technique may be use incorrectly or the results misinterpreted

5. There are always random variations in the data. Randomness is the inherent
variation that remains in the data after all causes of variation have been
accounted for.
A forecast is generally deemed to perform adequately when the errors exhibit only
random variations. Hence, the key to judging when to reexamine the validity of a
particular forecasting technique is whether forecast errors are random. If they are not
random, investigate to determine which of the other sources is present and how to correct
the problem.
Forecasts can be monitored using either tracking signals or control charts. A ***tracking signal*** focuses on the ratio of cumulative forecast error to the corresponding value of
MAD:
Tracking signal (TS) =
$$\frac{\sum (Actual - Forecast)}{MAD}$$

A tracking signal is a measurement that indicates whether the forecast average is keeping
pace with any genuine upward or downward changes in demand. As used in forecasting,
the tracking signal is the number of mean absolute deviation that the forecast value is
above or below the actual occurrence. Thus, if we compute the tracking signal and find
equal to minus 2, we can see that the forecast model is providing forecasts that are quite a
bit above the mean of the actual occurrences.
The table below illustrates the procedure for computing MAD and the tracking signal for
a six month period where the forecast had been set at a constant 1,000 and the actual
demands that occurred are as shown. Compute the MAD, the running sum of forecast
errors (RSFE), and the tracking signal from forecast and actual data given. In this
example, the forecast, on the average was off by 66.7 units and the tracking signal was
equal to 3.3 mean absolute deviations.

Table 2.7a

MONTH	DEMAND	FORECAST	ACTUAL DEVIATION (RSFE)
1	1000	950	-50 -50
2	1000	1070	+70 +20
3	1000	1100	+100 +120
4	1000	960	-40 +80
5	1000	1090	+90 +170
6	1000	1050	+50 +220

Table 2.7b

ABSOLUTE DEVIATION	SUM OF ABSOLUTE DEVIATION	MAD	TS=RSFE MAD
50	50	50	-1
70	120	60	.33
100	220	73.3	1.64
40	260	65	1.2

90 350 70 2.4
50 400 66.7 3.3
MAD, for month 6, MAD=400÷6=66.7
Tracking signal (TS) =
MAD
RSFE
, for month 6 is =
MAD
RSFE
=
66.7
220
= 3.3
Acceptable limits for tracking signal depend on the size of the demand being
forecast(high volume or high-revenue items should be monitored frequently) and the
amount of personnel time available (narrower acceptable limits)cause more forecasts to
be out of limits and there fore require more time to investigate).
In a perfect forecasting model, the sum of the actual forecast errors would be 0; the errors
that result in overestimate should be offset by errors that are underestimates. The tracking
signal would then also be 0, indicating an unbiased model, neither leading nor lagging the
actual demand.
Using forecast information
A manager can take a reactive or a proactive approach to a forecast. A reactive approach
views forecasts as probable descriptions of future demand, and a manager reacts to meet

that demand (e.g., adjusts production rates, inventories, the workforce) conversely, a proactive approach seeks to actively influence demand (eg. by means of advertising, pricing, or product, service changes)
Generally speaking, a proactive approach requires either an explanatory model (eg regression) or a subjective assessment of

the influence on demand. It is possible that a manager might use two forecasts: one to predict what will happen under the status two forecast are unacceptable

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Summary

Developing a forecast system is not easy. However, it must be done because forecasting is fundamental to any planning effort. In the short run, a forecast is needed to predict the requirements for materials, products, services, or other resources to respond to changes in demand. Forecast permit adjusting schedules and varying labor and materials. In the long run, forecasting is required as a basis for strategic changes, such as developing new markets, developing new products or services, and expanding or creating new facilities.

Designing a forecasting system involves determining what to forecast, which forecasting techniques to use, and how forecasting systems can assist managerial decision making. Demand forecast are crucial input to planning decisions within operations and other parts of business. Forecasting is generally classified as quantitative and qualitative.

Qualitative or judgmental methods of forecasting are most useful when historical data are not available or are not reliable in predicting the future. Qualitative methods are used primary for long or medium range forecasting involving process design, facilities planning, and marketing program. Sales force estimates, executive opinions, market research, and methods are qualitative/judgment methods.

Quantitative methods utilize an underlying model to arrive at forecast. The basic assumption for all quantitative forecasting methods is that past data and data patterns are reliable predictors of the future. Past data then processed by a time series or causal model to arrive at a forecast.

All forecasts tend to be inaccurate; there fore, it is important to provide a measure of accuracy. It is possible to compute several measures of forecast accuracy that helps managers to evaluate the performance of a given technique and to choose among alternative forecasting techniques.

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CHAPTER THREE

Inventory classification and stock taking

3.1 Introduction

The inventory of a typical firm is diverse. Therefore initial planning and subsequent control of such an inventory is accomplished on the basis of knowledge about each of the individual items and the finished products. The starting point for sound inventory management is the development of a complete recording system, followed by different analysis.

Good inventory control policies are meaningless if management does not know what inventory is on hand. Accuracy or records is a critical ingredient in production and inventory system. Record accuracy allows organizations to focus on those items that are needed, rather than settling for being sure that "some of everything" is in inventory .Only when an organization can determine accurately what it has on hand can it make precise decisions about ordering, scheduling, and shipping.

To ensure accuracy, incoming and outgoing record keeping must be good as must be stockroom security. A well-organized stockroom will have limited access, good house keeping, and storage areas that hold fixed amounts of inventory; Bins, sheet space, and parts will be labeled accurately.

Inventory in a warehouse is equivalent to cash. Hence strict control is fundamental to avoid embezzlements and wastage of inventory. Hence stock taking is vital part of inventory control. Sometimes inventory/stock might become useless because of deterioration or obsolescence. Hence immediate actions are required to minimize the loss for the organization.

Objectives:

Dear learner, when you complete this chapter you should be able to:-

- Identify and define ABC analysis
- Understand and describe other inventory classification methods
- Explains costs related to ordering inventory
- Describe costs related to holding inventory
- Describe the function and principle of store.

- Explain the methods of different stock taking methods

Describe reasons of inventory wastage and means of minimizing it
Describe or explain just in time philosophy
Explain pull system or push system

3.2 Inventory classification

3.2.1 ABC classification system or the value volume Analysis

• ***Do all inventories in a warehouse have similar value in your organization?***

Maintaining inventory through counting, placing orders, receiving stock, and so on takes personnel time and cost money. When there are limits on these resources, logical move is to try to use the available resources to control inventory in the best way. In other words, focus on the most important items in inventory. This means that all inventories cannot be controlled with equal attention. Some inventories are simply too small or too unimportant to warrant intensive monitoring and control activity. In addition, implementing new inventory management systems priority ranking must be developed to allow management to decide the order in which to include the inventories items in the control system. Because it is important to recognize that all inventory items don't have the same importance. Items differ in terms of holding costs, shortage costs, prices, annual volume, the need for security and so on. Example in a firm that sells small but expensive items, such as Camera generate more profit and carry a higher loss due to theft than say a children's toys.

Too many mangers apply perpetual inventory control systems universally across every item maintained in stock when a partial control system would be much more practical. Partial inventory systems minimize the expense involved in analyzing, processing, and maintaining records, a substantial cost of any inventory control system. The ABC method is one such approach, focusing control efforts on that small percentage of items that account for the majority of the firm's sales.

ABC analysis divided on hand inventory into three classifications on the basis of annual Birr volume. ABC analysis is an inventory application of what is known as the Pareto principle. The Pareto principle states that there is a "critical few and trivial many". In

the nineteenth century Pareto, in a study of the distribution of wealth in Milan, found that15 to 20 percent of the people controlled 75—80*% of the total annual inventory value/wealth. This logic of the

few having the same greatest importance and the many having little importance has been broadened to include many situations and is termed the Pareto principle. This is true in our everyday lives (most of our decisions are relatively unimportant, but a few shape our future) and is certainly true in inventory systems (where a few items account for the bulk of our investment). If the annual usage of items in inventory is listed according to birr volume and that a larger number of items accounts for a small birr volume. Then one idea is to establish inventory policies that focus resources on the few critical inventory parts and not the many trivial ones. It is not realistic to monitor inexpensive items with the same intensity as very expensive items.

The letters “A,” “B,” and “C” refers to different classes of items

A. high value items: The 15 to 20 percent or so* of the items that account for 75 to 80 percent of the total annual inventory value i.e., it account for a high birr usage volume.

B. Medium value items: the 30 to 40 percent of the item that account for approximately 15 percent of the total annual inventory or those items that are moderately important and account for a moderate birr usage volume.

C. low value items: The 40 to 50 percent of the items that account for 10 to 15 percent of the annual inventory or those items that is least important and account for a low birr usage volume.

Quite often, items are classified on the basis of annual birr value (i.e., unit price X annual volume). The birr usage volume that an item accounts for measures the relative importance of that item in the firm's inventory. Note that value is not necessarily synonymous with high unit cost. In some instances a high-cost items that generates only a small Birr volume can be classified as an A item.

To determine annual birr volume for ABC analysis, we measure the annual demand of each inventory item times the price per unit. The next step is to arrange the products in descending

order based on the computed birr usage volume. Class A item are those on which the annual birr volume is high although such items may represent only about 15% or less of the total inventory items, they roughly represent 70%-80% or more of the total Birr usage. Class B items are those inventory items of medium annual birr volume. These items may roughly represent about 30% of inventory items and 15% to 25% of the total value. Those with low birr volume are class C, which may roughly represent only 5% of the annual birr volume but about 55% or more of the total inventory items.

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Graphically, the inventory of many organizations would appear as presented in the figure below.

Figure 3.1:

Figure 3.1:

* Percentage of the A, B, and C categories and their inventory value may vary according to situation.

The purpose of classifying items according to their value is to establish the proper degree of control over each item held in inventory, clearly, it is wasteful and in efficient to exercise the same level of control over **C** items as **A** items. Items in the **A** classification should be controlled under a perpetual inventory system with a much detail as necessary. Analytical tools and frequent counts may be required to ensure accuracy, but the extra cost of tight control for these valuable items is usually justified. The manager should not retain a large supply of reserve or safety stock because this ties up excessive amounts of money in inventory, but she/he must monitor the stock closely to avoid stock outs and lost sales.

- **Which inventory is categorized as A, B and C in your organization?**

Control of **B** items should rely more on periodic central systems and basic analytical tools such as economic order quantity (EOQ) and reorder point analysis. The manager can maintain moderate levels of safety stock for these items to guard against shortages, and

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can afford monthly or even bi monthly merchandise inspections. Because **B** items are not as valuable to the business as **A** time, less rigorous control systems are required.

C items typically comprise a minor proportion of the firms' inventory value and as a result, require the least effort and expense to control. These items are usually large in number and small in total birr value. The most practical way to control them is to use uncomplicated records and procedure. Large levels of safety stock for these items are acceptable because the cost of carrying them is usually minimal. Substantial orders sized often enable the business to take advantage of quantity discounts without having to place frequent orders. The cost involved in using detailed recording and inventory control procedures greatly outweigh the advantages gleaned from strict control of C items.

One practical technique for maintaining control simply is the two-bin system, which keeps two separate bins full of material. The first bin is used to fill customer orders, while the second being is filled with enough safety stock to meet customer demand during the lead-time for the order; the manager uses the safety stock in the second bin to fill customer demand. A variation of this technique is the level control system. Here, the manager fills the bin with the usual amount of safety stock and marks the level with a brightly colored line. When the supply of material reaches the colored line, s/he orders enough stock to refill the bin.

ABC analysis procedure

1. Compute the annual usage value of each and every item of all the products using the formula: Annual usage (Annual consumption) X (unit price)
2. Arrange the items in the descending order of the usage value computed in step1
3. Observe how your classification fits into A,B & C

Examples of ABC analysis

Example 1: A business firm has organized its 10 inventory items on an annual birr-volume basis, shown below are the items (identified by stock number), their annual demand, unit price, annual birr volume, and the percentage of the total represented by each item. In the table below, we use to show these items grouped into ABC classifications.

Table 3.1

Item stock number

Percent of number of items stocked
Annual unit Annual
Volume X cost = Dollar
(units) volume
Percent of annual Dollar volume
Class
#10286
11526
20
1000
500
$90,000
$154,00
90,000
77,000
38.8%
33.2%
A
A
#12760
#10867
#10500
30%
1,550
350
1000
17
42.86
12.50
26,350
15,001
12,500
11.3%
6.4%
5.4%
B
B
B
12572

#14075
#01036
#01307
#10572
50%
600
2000
100
1,200
250
1417
.60
8.50
.42
.60
8,502
1,200
850
504
150
3.7%
.5%
.4%
.2%
.1%
C
C
C
C
8,550
$232,057
100.0%

Policies that may be based on ABC analysis include the following

1. Purchasing resources expended on suppliers' development should be much higher for individual **A** items than for **C** items.
2. **A** items as opposed to **B**& **C** items, should have tighter physical inventory control: perhaps they belong in a more secure area, and perhaps the accuracy of inventory record for **A** items should be verified more frequently.

3. For casting **A** items may warrant more care than forecasting other items.

Better forecasting, physical control, supplier reliability and an ultimate reduction in safety stock can all result from appropriate inventory management policies, ABC analysis guides the development of those polices.

In summary, a business owner minimized total inventory costs when she/he spends time and effort controlling items that represent the greatest inventory value. Some inventory items require strict, detailed control techniques, while others cannot justify the cost of

72%
23%
5%
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such systems. Because of its practicality, the ABC inventory system is commonly used in industry. In addition the technique is easily computerized, speeding up the analysis and lowering its cost. The following table summarizes the use of the ABC control system.

Table 3.2

Features	**A items**	**B items**	**C items**
Level control	Monitor closely & maintain tight control	Maintain moderate control	Maintain loose control
Reorder	Based on forecasted requirements	Based on EOQ calculations & past experience	When level of inventory
Record keeping	Keep detailed records of receipts and disbursements	Use periodic inspections and control procedures	No records required
Safety stock	Low level of safety stock	Moderate levels of safety stock	

High level of safety stock
Inspection frequency
Frequent monitoring schedule changes
Periodic checks on changes in requirements
Few checks on requirements
Purchasing supply source
Centralized as many as possible
Combination two/more reliable sources
Decentralized two reliable sources
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Example 2: Dashen plastic factory adopts the ABC method for classifying items in inventory. Currently, the factory has 14 items. Following are the data related to the items and assuming that you are the inventory, control officer in the factory, classify the item into the three classes.

Table 3.3

Item No
Annual usage
Unit cost
1
2000
5.00
2
2500
3.00
3
900
10.00
4
5375
20.00
5
4500
8.00
6
3000.
9.00
7
387
5.00
8

150
10.00
9
4990
3.00
10
7000
20.00
11
8440
4.00
12
1300
2.00
13
2880
3.00
14
1255
6.00
58

Solution

Item Annual consumption vale
(Annual usage) X (unit cost)

1. ..... 5000.00
2. ..... 7500.00
3. ..... 9000.00
4. ..... 107500.00
5. ..... 36,000.00
6. ..... 27,000.00
7. ..... 1935.00
8. ..... 1500.00
9. ..... 14970.00
10. ..... 140,000.00
11. ..... 33,760.00
12. ..... 2600.00
13. ..... 8640.00
14. ..... 7530.00

Total 407,935.00

Solution continued
Table 3.4b
Order of ranking
Consumption value
Percent of consumption value
Percent cumulative value
Class
10
4
5
140,000
107,500
36,000
34.32
26.35
8.82
34.32
60.67
69.49
A
11
6
9
1
33760
27,000
14,970
10,000
8.28
6.62
3.67
2.45
77.77
84.39
88.06
90.5
B
3

13
14
2
12
7
8
9000
8640
7530
7500
2600
1935
1500
2.21
2.12
1.85
1.84
0.64
0.47
0.37
92.72
94.84
96.69
98.53
99.17
99.64
100%
C

3.2.2 Other method of Analysis

VED (Vital, Essential, Desirable) Analysis

When the inventory is classified according to its criticality, i.e., according to the cost of incurring a stock-out, the technique is called VED analysis. The V class items are vital without which the production in an industry will immediately stop. The E class items are essential. Non-availability would affect the performance (efficiency), but without which the system would not fail. The 'D' class items are desirable without which the production is unaffected, but it is good if they are available, for

the state of efficiency and less fatigue. VED analysis can be used in the case of special raw materials that are difficult to obtain.
70
20
10
60

SDE analysis

This type of analysis is useful in the study of those items, which are scarce in availability. The 'S' class items are scarce items, e.g. imported items, which are generally in short supply. The 'D' class stand for difficult items, which are available in the market but not always traceable or immediately supplied, and 'E' class items are easily available in the market.

HML analysis

This type of analysis is similar to ABC analysis except that cost per item (per unit) is taken. Maximum or highest (H) cost are given top priority, then M (medium cost items) and finally L (the low cost items).

FNSD Analysis

Items are classified in the descending order of their usage (movement) value, namely 'F' class standing for fast moving items, 'N' class for normal moving items, 'S' class for slow moving items and 'O' class for dead items, which are transferred to disposal cell.

This method is used to combat obsolescence in all types of inventory. The analysis also helps in arranging stocks in the stores a deciding the distribution of inventory items. The cut off point for F, S and D items are usually in terms of the number of issues over the past year(s).

- **What is difference between SDE and HML analysis?**

XYZ Analysis

The XYZ classification has the closing inventory as the basis of classification. Items with high closing inventory are classified as 'X' items those with moderate closing inventory as 'Y' items and those with low closing inventory as 'Z' items. The classification is done usually once a year, during the annual stocktaking.

The XYZ analysis helps in identifying the items that are being stocked extensively. One can combine ABC analysis with XYZ

analysis, which helps in timely prevention of over stocking of items. We can also combine XYZ analysis with FNSD analysis.
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• ***From the above inventory classification technique which one can fit to your organization?***

Summary of selective Inventory management

We have described some commonly used technique of selective control. It depends upon the situation; need and nature of the inventories carried by an organization to decide which selective control technique must be chosen. For instance, a spares consuming organization would rely more on VED analysis. Moreover, in many situations it is advantageous to combine two techniques. For example, we can combine XYZ - FNSD analysis to reduce obsolescence of stocked items.

We now summarize the above discussed selective control techniques according to their basis of classification and chief uses.

Table 3.5

Classification technique	***Basis of classification***	***Main use***
ABC	Consumption value	Controlling raw material & work in progress inventories
VED	Criticality	Controlling the inventory level of spare parts
SDE	Scarcity	Controlling the inventory of scarce items
HML	Cost	Controlling the over consumption at departmental level
FNSD	Consumption or movement rate	Controlling obsolescence
XYZ	Closing inventory value	Controlling over stocking and under stocking of items

3.3 Inventory control systems

Generally speaking, three basic systems can be employed in controlling inventories:

1. The cyclical ordering system
2. The order point, or fixed order quantity system and
3. The material requirements planning

3.2.1 Cyclical ordering system

• What is the basis of ordering material in your organization?

This is also known as periodic review system or fixed order interval system which is a time based system which involves scheduled periodic reviews of the stock levels of all inventory items, When the stock level of a given item is not sufficient to sustain the production operation until the next scheduled review, and order is placed to replenish the supply. The frequency of reviews varies from firm to firm. It also varies among materials within the same firm, depending upon the importance of the material, specific production schedules, market conditions, and so on. Order quantities likewise vary for different materials. For administrative convenience, however each material's order quantity is usually chosen from a small number of predetermined coverage periods. (For example, all order quantities may represent operating coverage for two weeks, four weeks, eight weeks or twelve weeks).

Stock level can be monitored by physical inspection, by a visual review of perpetual inventory cards, or by automatic computer surveillance. In operations where a small number of materials are involved, the simplest and most accurate method is a periodic physical count of the stock. Where this is not practical, a perpetual inventory record for each material can be maintained by posting receipts from invoices and disbursements from stores material requisitions. If this procedure is closely controlled, the inventory record for each material should at all times be in reasonably close agreement with the actual stock balance.

The cyclical ordering system is well suited for materials whose purchases must be planned months in advance because of established and infrequent production schedules maintained by

suppliers. It also works better for materials which exhibit an irregular or
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seasonal usage and whose purchase must be planned in advance on the basis of sales estimates.
The system can, of course, be used for all materials in an inventory; used in this manner, however, it possesses three distinct disadvantages;
1. It compels a periodic review of all items; this in itself makes the system somewhat inefficient. Because of difference in usage rates, many items may not have to be ordered until the succeeding review. Conversely, the usage of some items during the period may have increased to the point where they should have been ordered before the current review date. Consequently, this system must be augmented with a minimum balance figure which signals the need for an early reorder in the case of a sharp usage increase.
2. The system demands the establishment of rather inflexible order quantities in the interest of administrative efficiency. Theoretically, there exists an optimum economic order quantity of each item, depending upon its price structure, its rate of usage, and attendant internal costs. However, because all items must be fit reasonably well into a limited number of ordering cycles under this system, actual order quantities may deviate substantially for the optimum. For a given material, the net effect frequently is an increase in the total inventory costs associated with that item.
3. The cyclical ordering system tends to peak the purchasing work load around the review dates. This disadvantage can however, be avoided to some extent by regulating the frequency of reviews.

3.3.2 Flow control system

• ***What are the criteria to order inventory in your organization with respect to time or quantity?***

The flow control system method of managing inventories represents a special variation of the cyclical system. This special method is applicable in continuous manufacturing operations, which produce the same basic product in large quantities day

after day. Most materials used in such an operation are purchased on term
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contracts and scheduled for daily or weekly delivery throughout the term. The production cycle is often a day or less in duration, and, in effect, material flows through the plant in continuous streams.
Inventory floats consequently can be kept quite low, thus requiring a minimum investment in production inventory. In such an operation, stores personnel daily review visually the level of all material stock and report any imbalance to the purchasing or production control department. Changes in production scheduled must be relayed immediately to buyers so that delivery schedules can be revised accordingly,

Order point system: Fixed order quantity system (Q-System)

A second basic type of inventory control system- the order point system - is based on the order point and order quantity factors, rather than on the time factor. This system is also called the fixed order quantity system or maximum- minimum systems. The design of this system recognizes that each item possesses its own unique optimum order quantity, and in practice, the system permits more effective utilization of this fact.
The operation of an order point system requires for each inventory item:
1. The predetermination of an order point, so that when the stock level on hand drops to the order point, the item is automatically flagged for recording purposes. The reorder point is computed so that estimated usage of the item during the reorder lead time period will cause the actual stock level to fall to a planned minimum stock level by the time the new order is received. Receipt of the new order then increases the stock level to a planned maximum figure.
2. The predetermination of a fixed quantity to be ordered each time the supply of the item is replenished. This determination typically is based on a consideration of price, usage rate, and other pertinent production and administrative factors.
The automatic feature of the system is achieved most commonly by maintaining a perpetual inventory record for each item

carried in stock. An inventory clerk, or a computer, continues to post all material issues until the balance of an item falls to its

order point. At this time, the clerk or the computer notifies the purchasing department. If the system operates correctly, purchasing replenishes the stock so that inventory levels for all items automatically remain between the planned minimum and maximum levels. The person responsible for inventories takes no action until the reorder point is reached.

• ***What is the difference between cycle order and order point ordering system?***

The major advantages claimed for the system are;

1) Each material can be procured in the most economical quantity.

2) Purchasing and inventory control personnel automatically devote attention to the items that need it only when required, and

3) Positive control can easily be exerted to maintain total inventory investment at the desired level simply by manipulating the planned maximum and minimum values.

However, the system possesses several limitations. It functions correctly only if each of the materials exhibits reasonably stable usage and lead-time. When these factors change significantly a new order point and a new order quantity must be determined if the system is to fulfill its objectives. Consequently, the system becomes extremely cumbersome to operate effectively when applied to materials with unstable usage patters and lead times. As with any system using perpetual inventory record, errors in posting and in the issuance of stores requisitions occasionally distort book balances and may lead to undetected material shortages.

• **What are the difference between cyclical ordering and flow control system?**

3.3.3 Two-Bin system

A variation of the basic order point system is found in the operation of the simple two-bin system. The distinguishing feature of this system is the absence of perpetual inventory record. In practice, the stock is physically separated into two

bins or containers. The lower bin contains a quantity of stock equal to the order point figure. This, typically, is
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just enough stock (or lightly more) to last from the date a new order is prepared until the incoming material is received in inventory. The upper bin contains a quantity of stock equal to the difference between the maximum and the order point figures. At the out set, stock is used from the upper bin; when this supply is depleted, it signals the clerk that the reorder point has been reached. At this point an order is placed, and material is used from the lower bin until the new stock is received. Upon receipt of the new order, the proper quantities of material are again placed in the two bins. This method demonstrates very simply the fundamental concept, which underlies the basic order point system.

- **Is two bin system or flow control best to control inventory in your organization?**

The two-bin system is widely used in handling low value hard ware and supplies whose usage is not recorded on a perpetual record. The major advantage of the method is the obvious reduction of clerical work. Issues do not have to be posted to determine the proper reorder time. Receipts, however, are usually posted to reveal significant changes. In some cases, additional requirements of storage facilities and perhaps some practical difficulty in keeping the two stocks properly separate is required.

Finally, it should be pointed out that none of the systems or their adaptations discussed so far are mutually exclusive. Several or all of them, may be used advantageously for different materials in a single firm. Question of how much to order and when to order will be discussed in detail in chapter four.
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3.4 STORAGE PRACTICE

- ***What is the role of storage in any organization?***

Once materials are acquired they do not directly enter in to production nor are provided to user departments immediately. They should be stored until time of requirement, for storage guarantees continuity to supply or uninterrupted service to user departments. The main objective behind the stores functions is to

render service to user departments. The very nature of the storage system is thus to act as a buffer between acquisition and other various consuming departments.

The store function is responsible for receipt, physical upkeep and maintenance, and distribution of larger sums of moneys in the form of stocks. The management of inputs and outputs flow will require a good deal of consideration of physical factors for the proper storage of materials depending up on their characteristics and volume of transaction. The accounting, reporting and verifying system should be devised. The stores function must be managed and operated in a highly efficient way.

- ***What are the facilities required in a store?***

The stores should be considered as a temporary location for materials need for operational purposes and should be planned, organized and operated in such a way that the life time of each stock item is as short as possible consistent with economic operation. The only good reason for carrying operating stocks is that the material needed is obsolete, redundant, or surplus material is simply money sitting on a shelf requiring more money to be spent on its custody. In general depending on the nature of the materials if demand is steady or highly predictable, then we should store for very short periods, when demand is not highly predictable then storage for longer periods may be required.

In a mass production unit, vast quantities of materials and component parts have to be provided every day. Large sums of moneys are involved and it is essential to organize the stores functions so that the investment is kept to the minimum. A big automobile factory can use hundreds of thousands worth of material each week. From the stores point of view the most important thing to keep the quantities of incoming goods as near as possible to the departments and the machine shops and assembly shops will use them daily. Shortages must be avoided or production lines will have to stop. At the same time too much must not be delivered or/it will clop up the warehouses and perhaps also the

production area, apart from the fact that excess deliveries will tie up more capital. So the emphasis is on the manufacturing schedule and everything is governed by that fact. For bulky or

expensive materials or components, the flow will have to be managed hourly and this demands a very high degree of cooperation and efficiency.
Storage is thus established with the following objectives:
1. Prevention of waste and /or misappropriation of materials
2. Reduced need for material handling equipment
3. Provision of better storage facilities
4. Ready accessibility of major materials permitting efficient service to users.
5. Awareness of limited shelf-life items with view to stock turnover in time to prevent deterioration.
6. Efficient space utilization and flexibility of arrangement.
Any managerial function is exercised to achieve a specific objective for which it is set. Similarly in achieving the above-mentioned objectives, storage performs the following functions:
1. Receive the materials, check quantities and quality against purchase orders, invoices and specifications, certifies deliveries and reports shortages, deficiencies in quality and partial deliveries, and prepare receiving reports.
2. Provide adequate and proper storage, and preservation.
3. Prepare and maintain bin cards, periodically checks inventory records against actual stock.
4. Minimize obsolescence, surplus, and scrap through proper codification, standardization and preservation.
5. High light stock accumulation discrepancies and abnormal consumption and effect control measures.
6. Ensure good housekeeping so that material handling material preservation, and stock receipt and issue can be done accurately.
7. Assist in verification and provide supporting information for effective purchase action
8. Keep and maintain store areas in a clean and orderly condition so as to facilitate handling and preserve all safety regulations and security measures.

Storage Cost and Operational Efficiency
• ***What are the costs associated with the inventory in a store?***
In the accounting sense, inventory represents stocks of materials either acquired or use in production or produced for subsequent

use in production or sale. They are obviously termed as raw materials inventories, in process or work in progress inventories, or semi finished and finished goods inventories etc. Besides, there are also some stocks of materials which are not directly related to the production process, but have always to be kept in stock, for example fuels and lubricants and other consumables. There are still others, which are required for tolling jigs and fixtures etc, which are necessarily stocked for use in the production process but are not incorporated in the final product. Besides, there are some others, which are stocked for the purpose of packing conveniently, grouped under packing materials. Where there is an urgent need for giving after sale service to customers, some spares and parts inventories are also always kept in stock. All these require investment of large sums of money in the form of tied up capital, requiring different idle periods in stores or other stock points, till the time of requirement. The financial significance of the flow of materials, therefore, is attributed to the need for measuring operating performance or income derived over a particular period of time.

Lying ready for use in the company store is a kind of time bomb which will do its damage at or following, the time of issue. The possible outcomes range from at best the inconvenience and costs of user returning to defective material for replacement, through the range of delays from minor production stoppages to the failure of a product in service, with possible serious damage, loss of customer good will or heavy warranty claims. Therefore all incoming materials are checked for:

Warehousing and Stores Security

- ***Can firms avoid store to minimize cost?***

The area for stores activities is refereed to by various names, including stockroom, storeroom, and warehouse. The basic stores function is to store material temporarily, ideally if a company would have no stores function, material would flow smoothly form receipt through all operations and then to a customer. In many companies, the practice of total materials management has effectively reduced the stores function by minimizing

inventories. However, very few companies have eliminated the stores function. Having raw materials supplies, work-in-process, and finished goods inventories enhances company operations and permits economies such as those obtained through quantity discounts, as well as optimum utilization of labor and equipment. Normally, finished goods inventory is part of the physical distribution organization.

3.5 Stocking taking

Stocktaking or physical inventory is the process of counting, weighting or otherwise measuring all items in stock and recording the results.

- ***People count and check their cash properly, but they are not applying the same practice for materials in a store. Why?***

Stock represents cash and, invariably, cash is looked after very carefully. A cashier is appointed to control it: it is locked up in safes when not in use. The cash office is fitted with a counter and grille to make sure that no one other than the cashier's staff has access to the money. Every time cash is received on it is counted, and the balance on hand is checked at frequent intervals. Cashbooks are kept in detail to record all transactions and, if any of the checks made discloses a discrepancy, the most searching inquires are pursued to find explanation. Cash is regarded as so important that, in the event of any substantial deficiency arising, it is normal to call in the police.

Now since stock is equivalent to cash, it follows that it should be carefully protected, counted and checked in a similar way, but it is not unusual to see organizations where the arrangements of stock items display a looseness' and lack of system which would be tolerated in the cash office, in spite of the fact that the value of stock is frequently very much grater than that of cash held.

Stock taking, involves many valuable and expensive man hours to arrange and carryout, plus a great deal of management time needed to investigate the almost inevitable list of discrepancies. However, the cost and effort are more than justified by the following benefits:

a) Verification and accuracy of stock record needs: stock record and stock control systems will be tested. Verification by physical

counts will act as a form of performance check on these systems and adjustments needed can be made.
b) Computerized recording systems (if any) can be verified. Computers are only as the data supplied to them, so, data being supplied from stock records and stock control must be accurate and relevant.
c) Supports the value of stock shown in the balance sheet by physical verification: financial repots (including the balance sheet) produced by the organization's auditors will demand some form of physical stock verification to back up the value of stock shown within the balance sheet. Stock valuations which are not backed up by a physical count have little relevance to the critical auditors and the organization's accountants.
d) Discloses the possibility of fraud, theft or loss: the security aspect of stores management demands that regular and physical checks be made to ensure that any possible theft or fraud is quickly detected and investigations carried out.
e) Reveals any weaknesses in the system for the custody and control of stock: stocktaking is an indicator of overall stores efficiency and management control. The number and size of stock taking discrepancies is a good indication of efficiency. A high incidence of stock discrepancies usually warrants a close look at the personnel and systems involved.
f) Accurate stock levels shown within the stock records system backed up by a regular physical count will ensure that all requirements of the user departments are covered by existing stock levels and will be issued promptly and efficiently. This avoids the common situation of stock shown in the records system not being physically present.

Methods of stocktaking

• ***Is there a practice of stock taking in your organization?*** **How many times in a year?**

Stock taking is the works of finding out by stores staff the physical balance or ground balance of the various items by means of counting weighing, measuring or estimating.
Stock taking enables to know whether there are any discrepancies in the postings; whether any pilferage is taking place; and whether the materials are in good condition. It also

helps the preparation of the final inventory for balance sheet purpose. Stock taking methods are mainly:

- Spot checking
- Periodic stock taking
- Annual stock taking
- Continuous stock taking

a) Spot-checking: this is used in connection with the security and anti-theft aspect of stores management. Spot checks are designed to verify the stock held, without a prior warning, which could provide time for stock to be replaced illegally. The system also acts as a deterrent against those who contemplate theft, knowing that sudden check could heralds an investigation.

To get the maximum benefit from the labor involved, spot-checked should be mainly, but not entirely, confined to stock items of high value, and it may be worthwhile to check the major items several times in the course of the year.

Blind stock taking: This is the name given to the system where by the person taking stock is given no prior information about the vocabulary numbers, descriptions, stock record balances or locations of the items he/she is to check, and is not allowed access to stock record cards or bin card. The theory is that the check will be more reliable as the stock taker has no knowledge of what is supposed to be in stock.

He/she has to locate and identify stores for himself, he is obliged to count every item, and he/she is not open to any temptation to skimp his work by accepting identifications or quantities as appearing on the stoke record cards.

This system is laborious and slow, it requires more staff and, unless the personnel concerned are experienced and have a good knowledge of the physical characteristics of the stock held, errors are likely to arise because of faulty identification.

A modification of blind stock taking procedure is to provide the stock taker with locations and identifications, but to withhold from him the quantity balance on the stock records. This is a reasonable compromise and speeds up the work substantially. It must be said, however if a major stock taking operation is to be done in a short space of time, the quickest method is to give the stock taker all available information including quantity balances

on stock records. This assumes, of course, that he is a conscientious and trust worthy employee.

- ***What action is taken if the quantity of inventory at the ware house is different from the records?***

This would have three main advantages:

- Where a stock taker finds a major discrepancy on his first physical count, he/she can recheck straight away.
- Where he finds trifling discrepancy, he can ignore it an avoid unnecessary adjustments and,
- It simplifies clerical work where the stock agrees with the card balance.

b) Periodical Stock Taking: Periodical stock taking is quarterly or half-yearly checking of the entire stock in one or two days. This is applied in places where the stock comprises a few but expensive items. The method followed is similar to the annual stock taking, i.e., physical stock of various items is recorded on inventory sheets or inventory card and then compared with the bin card balance. While inexpensive items may be checked once a year, expensive and attractive items should be checked three or four times a year. The physical balance obtained at the end of the financial year will form the inventory for final accounts.

- **What is the difference between spot and periodic spot checking?**

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c) Annual stock taking: by this method, the whole of stock is covered at the same time at the end of given period, usually the end of the financial year. Theoretically stock should be taken at the close of business on the balance sheet date, but in a large concern it may be quite impossible to do all the work in one day, and the operation has to be extended over several days. The stocking need not be done only once a year; it may be carried out as often as seems desirable.

For a satisfactory stocktaking a good deal of preparation is necessary. First of all, a program should be drawn up and agreed with all concerned, including the finance department and the auditors; secondly, stock taking sheets or cards have to be prepared in advance; thirdly, all personnel concerned must be instructed of their duties. The arrangements made should deal with all aspects of the job and, in particular, the following points:

1. Appoint one person to control the whole operation.
2. While stocktaking is in progress, do not open the stores houses for normal business.
3. After the end of the working day before the operation begins, no more issues should be made and no receipts recorded until the stock taking is complete. The numbers of the last receipt and issue vouchers should be noted and all documents up to and including these number posted to the records. At this point all the records can be ruled off and no further postings are made until the results of the stock taking have been entered.
4. Take all normal stock including packages, scrap, residues, items on loan and goods under inspection.
5. Have stock taking sheets under the control of one individual, consecutively numbered and issued to the staff on duty as required. No duplicates should be allowed and, at the end of the job, all stock taking sheets must be accounted for.
6. Record separately damaged, deteriorated or used items
7. Make each person taking stock responsible for a particular section or clearly defined area of the store house of stock yard, and record every thing that is to be

found in that area. Stock takers should proceed in an orderly manner, and mark each bin or as it is dealt with to avoid the chance of checking any item twice, and to ensure that nothing is missed.
8. Any items held which are not the properties of the business ought to be marked or labeled in advance.
9. List separately any goods, which have been received by not yet taken on charge (eg. still under inspection).
10. Special arrangements must be made to include in the total list of stock all items belonging to the business, which are not on the premises at the time of checking. Their concerns free-issue stocks in the hands of suppliers, goods sent out for repair or processing, or stocks at outlying operational sites. It is usual to write to the holders of such stock to obtain written confirmation that these items are in their possession.
11. Return to store all items issued on loan either internally or externally before the stocktaking begins.

12. Show the method of check i.e. count, weight, measurement or estimation on the stock sheet for each item.
13. Record quantities in terms of the normal unit of issue for the stock concerned. This can be ensured by inserting the appropriate unit of issue on the stock sheets before distribution.
14. The method of pricing should be known and if possible, it is desirable to enter all prices in terms of units of issue on the stock sheets in advance.
15. Where several widely dispersed stockholding points exist, stores in transit at the date of stocktaking must be taken into account.

- **What is the difference between annual and periodic stock taking?**

Stock sheets

The following is typical of the information which should appear on the sheets or cards used for stock taking:
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i. Serial number of stock sheet
ii. Date of stock taking
iii. Location
iv. Vocabulary number
v. Description
vi. Unit of issue
vii. Quantity of stock found
viii. Price per unit of issue
ix. Value of stock found
x. Stock taker's signature
xi. Remarks column for comments about conditions of stock or any other special notes.

- **By observing your organization stock card/sheet which of the above mentioned elements are included and which are left out?**

When the physical aspect of the work has been completed, all stock sheets should be collected and arranged in classification order, the value of each entry extended and a total shown. By adding up these totals the value of stock in each classification can be obtained. The sum of these classification totals will give the grand total value of stock on hand as verified by physical examination.

Precautions must be taken to make sure that all stock sheets are returned and that the arithmetic is checked. Where stock records are kept, the next step is to compare the individual entries on the stock sheets with the appropriate record cards and they enter the actual quantity found at the stock taking date on the records. where this quantity does not agree with the balance shown on the record card, two points would be noted:

a) The physical stock-taking figure is the factual one and, therefore, takes priority and the balance on the card must be amended.

b) Major discrepancies require investigation to discover, if possible, why they have arisen. All established surplus and deficiencies should be valued and written on or written off respectively to ensure that the balance on the control accounts are adjusted to agree with the total value of stock verified by the physical stock taking.

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The periodic stock taking has advantages such as, the sock-taking is usually carried over on a non-working day (as the store must be closed during a count) and therefore the stock checkers have item to count carefully and check discrepancies. A complete stock enables discrepancies which are brought to light to be investigated and, accurate stock evaluation figures can be provided for the annual balance sheet and accounts.

However, the system has certain limitations such as, the stores must be completely closed to ensure and accurate count. Besides, it is very costly and involves a great number of staff from both inside and outside the stores. Over time for week ends and working days can be very expensive.

d) Continuous stock taking

• In what conditions annual stock taking differ from continuous stock taking?

This is the method where by stock is taken continuously through out the year in accordance with a predetermined program so that each item is physically verified at least once in the course for the year or more frequently if required. This can only be done if complete stock records are kept showing receipts, issues and balances on hand (i.e. if there is a perpetual inventory). The program should be so designed that a certain number of stock

items are taken on every working days. It may be thought necessary to certain valuable or fast moving stocks examined more frequently than other items. It is also wise to arrange that the operation is scheduled to a month or so before the end of the financial year so that, if work is delayed owing to unforeseen circumstances, there is time in hand to complete it before the year end.

The method of physical check are the same as those employed for periodic stock taking, buy there are significant differences in other respects as follows:

i. There is no need to close down the stores or the works which stocktaking is in progress.

ii. The normal positing for receipts and issues on stock records can continue with out interruption.

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iii. The work can be done by a few specially appointed, experienced and trained stock takers completely independent of store keeping staff.

iv. Stock taking results may be entered on the stock records from day to day as they arise, and any discrepancies disclosed can be thoroughly investigated in detail. This is an important advantage, because one of the main weaknesses of the periodic stock taking method is that all the discrepancies are declared at once, and time to deal with them properly is necessarily limited.

v. Assuming that the continuous program of stock taking has been satisfactorily completed according to plan, the balances on the stock control accounts can be accepted for balance sheet purpose without any special year end physical check, and there need be no delay in the preparation of the final accounts, as far as stock is concerned.

- ***Which type of stock taking is applied in your organization?***

Team work: It is common practice for stock taking to be done by teams of two people for the following reasons:

□□Where quantities are not large, the counting or weighing can be done by one person and the clerical work by the other.

□□Where large items have to be measured or weighed, two persons can usually operate more satisfactorily than one.

Where two persons are concerned, they will to some extent check each other's work, thus minimizing errors.

In team work two stock takers working independently of each other but counting the same stock. This method is most accurate, as it provides an instant double check for the stock takers who can compare each section counted to verify each other's count.

Stock taking by storekeepers

- **In your organization who is responsible for stock checking?**

Under normal circumstance the storekeeper should not be involved in the actual stock taking. However, it is advisable to enlist the help of sore keepers in the process of

stock taking. Because of their knowledge of stocks and where they are kept, they are able to find and identify items quickly. The ideal team (discussed above) is a storekeeper and another person who is not storehouse staff, thus combining speed of operation with independence of check.

Occasionally, store keepers are required to take stock of their own stores for balance sheet purposes without outside assistance or supervision, but this practice is not recommended. To make a storekeeper responsible for his own stock taking not only express him to the temptation to conceal genuine discrepancies to avoid criticism of his work, but also provides opportunities for deliberate fraud. It is much more satisfactory to have the stock taking done by full-time stock takers, internal audit, or finance department staff, or some other independent persons.

To avoid the need for counting individually large numbers of small items, such as nuts and bolts store keeper should count using scales/cases; it is easy to see that large quantities can be checked quickly in his way.

For some bulky item such as solid fuel, sand, cement, gravel, etc.. Weighing is out of the question because of the time and expense involved, and exact measurement may also be impracticable, estimation can be resorted to with a suitably qualified technical person.

It should be noted that it is advisable to conduct stock taking by the time to reorder level of the item is reached because by this

time there will be less items to be checked and hence we can save time and money.

• ***Is there any method which better fits to your organization after your read this material?***

Finally, the actual stock taking procedure employed will depend upon several important factors, including the size of the operation involved, the extent of stock variation the size of the store, the staff and resources available, and the quality and reputation of the stock takers involved.

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3.6 Stock Discrepancies

• ***Some times the amount of stock at the store might be greater than the records; what are the probable reasons for this?***

When the amount of stock found by physical examination fails to agree with the balance on the stock records, a discrepancy exists. If the stock found exceeds the recorded figure there is a surplus and, conversely, if the physical stock is less than the book figure, there is a deficiency. There are three main classifications for stock discrepancies. Each classification denotes the amount of time and management energy spent in isolating the cause of the discrepancies and the steps needed to be taken to prevent a second incident. The classification are:

a) ***Minor discrepancies***: this is where the variation between calculated and physical stock is very small compared with the over all quantities involved. In this case management would not waste time and resources on any attempt to investigate such a minor discrepancy.

b) ***Major discrepancies***: this occurs when very large and valuable variation between calculated and physical stock is detected. In such cases, because of the stores accountability and responsibility for all stock held, a complete investigation into the causes of the discrepancies must be carried out.

c) ***Operation discrepancies***: this is where, although the amount of variation involved is very small, the importance of the items involved in terms of the continued operation of the organization is so vital that a major investigation may have to be carried out to determine the fault and ensure that stocks of the vital material are secured and accurate.

Stock takers should not declare a discrepancy on any item with out first giving the store keeper concerned the opportunity of investigation because:

- There may be duplicated locations of which the checkers are not aware, but the store keeper should know of the item.

- It can be expected that the store keeper has a better practical knowledge of his stock than any one else, and he may be able to correct errors on the part of the stock taker, particularly errors on the part of the stock takers, particularly errors of identification.
- It gives the store keeper an opportunity to explain or correct the difference if he/she can, and ensures that he/she is aware of discrepancies which may reflect upon the performance of his/her duties.
- When the storekeeper has been called in and fails to explain a difference, he should sign the stock sheet to indicate his/her agreement that the discrepancy is genuine.

Causes of stock discrepancies

- ***What are the expected causes of stock variation in your organization?***

Stock discrepancies are accounted for by one or of the causes listed below:

a) Original incorrect stocktaking

b) Mathematical errors within the stock record card may produce an incorrect calculated stock for comparison.

c) Units of issue in a large stocktaking can become confused or changed without notification to the stock takers, and therefore a miscount will occur.

d) Misplacement of stock into the wrong shelf, cupboard, bin, etc, can result in stock being counted by recorded against the wrong stock count sheet.

e) The basic stores documents (issue notes, delivery notes, and transfer notes) that carry the data needed to adjust stock records and stock control systems may become lost or incorrectly entered.

f) Stocktaking adjustments from previous tock takes can influence the accuracy of the current stock, if the stock

discrepancies were incorrectly written off as lost, only to become a surplus in the current stock taking.
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g) Stock taken form stores without proper documentation for notification to the stores will result in stock deficiencies.
h) Unreported damage or deterioration of stock.
i) Theft or fraud.

- ***What are the measures taken to minimize future stock discrepancies?***

Investigation of stock discrepancies

Once the stock taker and the storekeeper have agreed that a discrepancy exists, the procedure of investigation depends upon the nature and value of the discrepancy. Large amount are more worthwhile investigating than small sums; more concern is felt about deficiencies than about surpluses and, where discrepancies may have arisen through bulk (making a large number of small issues over a period from a bulk stock, especially by weight). They are not perhaps thought worthy of any detailed inquiry. The degree of investigation is, therefore, a matter of judgment in the circumstances of each case. Generally, the following list of steps should be considered in the investigation process bearing the above-discussed points in mind.

1. Examine the record card since the date of the last check to make sure that there are no arithmetical errors or obvious omissions or duplications in posting.
2. See that there has been no confusion over units of issue.
3. Examine stores kept in neighboring locations to see if a balancing discrepancy exists on another item.
4. Check the basic documents (receipt, issue, transfer, return to store notes, etc) for any exceptionally large or apparently unusual transactions.
5. Have the physical stock taking verified by an independent senior official.
6. Interrogate the storekeeper to find out if he/she has any explanation or suspicions as to how the discrepancy has arisen.
7. Examine the results of the last stocktaking to see whether there was a discrepancy on that occasion or not. In odd causes it may be found that a deficiency at one stock

taking is followed by a surplus on the next, and this may be because the first check was inaccurate.
8. Make inquires of user departments in case there may have been issues from or returns to store without documentation outside normal working hours.
9. In serious cases, where theft or fraud is suspected, call in the police.
10. Where necessary, review and tighten up physical security measures and documentary procedures. After investigation, both stock records and accounts require adjustments in respect of declared discrepancies. This may be done direct from stock sheets or by a special discrepancy report form, listing all the items concerned, showing vocabulary number, description, unit of issue, quantity as per stock record, quantity found on physical check, discrepancy showing surpluses and deficiencies separately, unit price and value.
The adjustment of stock cannot be made without the authorization of the stores manager or a senior member of the management team. Obviously, only the most high-ranking members of staff should be able to write off valuable stock, in order to avoid possible fraud.

Stock Obsolescence and redundancy

• ***What is the fate of obsolete or useless material in your organization?***

Stock, which is described as obsolete, is that which no longer has any use or value to the organization that holds the stock.
There are mainly four stages in this respect:
a) Obsolescent
b) Obsolete
c) Redundant
d) Scrap

Obsolescent: The term obsolescent is used to describe the stock that will soon be of no use or value to the organization that has it in stock. This usually happens because of change in the method of production or technological change that means, for a period of

time, the organization will have to use two lines of stock, the new line being gradually phased in as the old is phased out.

Obsolete: this is the next stage of the process, when the stock completely becomes worthless to the organization. This is not to say that another organization which has not adopted the changes which made the stock obsolete may not be interested in purchasing the stock for its own use. However, in most cases, such changes reflect a major alternation in methods or materials by an industry, and companies engaged in that industry change very quickly over the new material and therefore the market for the old stock is greatly reduced.

Redundant: this is when the stock in question is completely useless to both its owner and other organizations.

Scrap: at this stage, the stock is sold off for the value of the materials it is produced form rather than any value in its own right.

Causes of obsolete stock

Several factors can cause stock to become obsolete and most of these are out side the control of the organization itself. It is inevitable that, in a highly advanced technological society, obsolescence will occur; this is added to the problems of changing consumer demands and tastes that can lead to stocks becoming obsolete in a relatively short period of time. More specifically the factors are:

- ***Technological changes***
- ***Changes in customer demand***: there are several factors that can cause a change in customer demand such as actions of major competitors (price, quality, and advertisement), changes in fashions and trends, and changes in the customers' own production system and methods.
- ***Alternations on the part of suppliers***; in some case a supplier may decide to halt the production of an item, which the organization has incorporated into its original design. If this halt of production is very sudden, then any part-finished work or work

in progress held in stock could be in danger, unless a suitable alternative supply can be located.

It is vital that stores management takes steps to minimize the effect of stock becoming obsolete and redundant. Stock represents the organization's money and therefore must not be wasted as result of excess redundant stock.

- ***Do you think that the measures your organization is right or not?***

The store manager can reduce the amount of stock wasted in various ways such as:

a. Ensuring that working stocks are kept at a level low enough to reduce the risk of obsolescence, if some changes come about.

b. Constantly reviewing stock movement frequencies (via the stock record system). A falling rate of usage in certain items could indicate that they have been superseded by another item held in stock.

c. Being aware of changes in techniques and demands within the industry. This helps the stores manger to forecast the useful life cycle of stock held, and will forewarn him/her or major changes and other implications.

d. Maintaining communications between stores and the other major departments involved. The relevant departments must know all changes in sales, designs, method and operations and, stores must ensure that they are kept informed of all developments that could affect the life cycle of the stocks held.

A break down in these channels of communications will lead to large and expensive amounts of stock becoming scrap. Maintaining special contact between stores and purchasing to ensure that changes communicated to purchasing, in terms of new orders, are passed on to the stores.

e) Making arrangements to dispose of obsolete stock immediately the decision is made to declare the stock obsolete. This will enable the stock to be sold off at a

reduced price, but with some return. Delay will reduce the salability of the stock dramatically and therefore the price and return will automatically falls.

Wastage of stock occurs not only because of obsolescence but also due to deterioration. Deterioration means that, items are physically damaged or spoiled because of the following reasons:

i. The inherent nature of the material is such that it deteriorates in the course of time i.e. the shelf life of the item may be limited.

ii. Inadequate storage conditions.

iii. Faulty or careless handling of materials.

iv. Failure to follow suppliers' storage instructions as provided on the packaging
or delivery documents.
v. Failure to follow stock rotation code and therefore allowing old stock to be left unused while newer stock is used.

- ***In your organization which one is the major cause for stock wastage; obsolescence or deterioration? What actions are taken to minimize the financial loss from the wastage of inventory?***

In special circumstance, for example, if there has been a fire or a serious flood in the storehouse, special effort should be made to review stocks for possible deterioration.

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Summary

Successful inventory management requires a system to keep track of inventory transaction and inventory classification. As the value and importance of inventory in a warehouse varies, we have to classify according to their importance and value for the controlling purpose.

Store keeping is the function of receiving, storing and issuing of materials. In almost all industries, the inventory (raw materials, finished components, tools, generate stores, etc…) represents a very large investment. It is therefore, important that strict orderliness and method are employed to ensure accuracy, preservation and safety at all stages of material movement and custody.

Stocktaking means taking or checking the stores record with the actual item in the store. The store record at any time should show the exact physical quantity of inventory, which are available for use. Stocktaking is a means to as certain any discrepancy of actual store when compared with record.

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Chapter four
Material Requirements Planning (MRP)

4.1 Introduction:

Dear learners this chapter deals with materials Requirement Planning (MRP). Material requirements are inventories required for some purpose. This purpose may be sale or something else, but in this chapter, the purpose is primarily production. Given

that we are dealing with materials requirements for production, many would classify MRP as inventory analysis, making certain assumptions made in the previous chapters. MRP sets inventory procedures and keeps truck of inventory levels, but it also serves as a link between inventory, production and purchasing. The term requirement planning implies that the inventory needs occur in response to production needs created by demand. Purchasing satisfies these inventory needs on a just –in –time basis when ordering additional stocks. MRP coordinates these activities (i.e. inventory control, production scheduling and purchasing) and this coordination is its primary benfit. This is the reason that many consider MRP a production planning tool.

For years, many companies tried to manage production and delivery of dependant demand inventories with independent demand systems, but the outcome seldom was satisfactory. As a result, MRP–a computerized information system—was developed specifically to aid in managing dependent demand inventory and scheduling replenishment orders. The MRP system enables businesses to reduce inventory levels, utilize labor and facilities better, and improve customer service.

Objectives

Dear learner, when you complete this chapter you should be able to:

- Identify and understand MRP inputs and outputs
- Describe components that are helpful to process MRP
- Process Material requirement planning computations
- Describe and understand safety stock
- Describe and determine lot sizing

4.2 An Overview of MRP

Dear learner, Assumes you want to construct your own building; would you buy and store all the materials ranging from gravel to paint at the beginning of construction? This chapter describes MRP (material requirement planning). MRP is a planning and scheduling techniques used for both production and assembly.

Inventories that support the production process are called manufacturing inventories. Since manufacturing inventories serve a different purpose than finished goods inventories, different purpose than finished goods inventories, different

management techniques are required for them. Material requirement planning, or MRP, is a technique used to plan for and control manufacturing inventories.

Material requirement planning is not new in concept. Logic dictates that the Romans and the Axumites used it in their construction projects, the Venetians in their shipbuilding, and the Chinese in building the Great wall. Building contractors have always been forced into planning for material to be delivered when needed and not before, because of space limitations. What is new is the large scale and the more rapid changes that can be made by the use of computers. Now firms that produce many products involving thousands of parts and materials can take advantage of MRP.

Material requirement planning combines traditional inventory methods that stress quantity with the important elements of time. Through time phasing, inventory requirements are expressed in terms of time in addition to quantity. Through MRP, the user is supplied with valuable information that was unavailable with older methods, such as

- When customers demand for component parts must be satisfied and whether such demand will be spaced in time or all at once
- When existing stocks will run out;
- When replenishment orders should be sent out (order release); and
- When the quantity ordered will arrive (order receipt).

The objective of MRP in its standard form is to generate information that will initiate the correct order action; be it a release or a revision. It applies equally to purchase (external) orders and shop (internal) orders.

Given the demand for inventories derived from forecasting methods at the discretion of the user, MRP converts gross inventory requirements into net requirements for each component by comparing gross requirements with supplies on hand. These net requirements are then time phased to ensure the timely release of an order that will fulfill future demand for that item or component with exactly the right quantity.

Material Requirements Planning (MRP) is a computer-based information system designed to handle ordering and scheduling of dependent-demand inventories (e.g. raw materials, component parts, and subassemblies). A production plan for a specified number of finished product is translated into requirements for component parts (raw materials, etc) working backward form the due date using lead-times information to determine when and how much to order.

In a manufacturing environment, the items carried in inventory generally consists of raw materials, parts, subassemblies, and assemblies that will be used in the manufacture or assembly of end items such as automobiles, appliances, and a host of other products.

What sets inventories of these items apart from inventories of retail items or finished goods is that demand for finished goods can be characterized as independent demand, whereas demand for items that become part of another product can be characterized as derives, or dependent demand. MRP has been developed to handle the ordering and scheduling of dependent - type inventories.

The next subsection will discuss the dependent and independent demand.

When a producer of automobiles, for example, makes a decision on how many automobiles to produce during a given month, this automatically fixes the quantities of the materials and parts that go into making the autos. Thus, if 700 cars will be produced, and each is to have a compact spare, tire, then exactly 700 compact spare tires will be required. Similarly, each car will need 4 wheels; hence, the 700 cars will require exactly 2,800 (700x4) wheels. The same can be said for all the nuts and bolts screws, bumpers, shocks absorbers, car windows, and so on. Because each car will require the same quantity of each materials or part, the total quantity needed is simply a function of the number of cars that will be produced. Thus, the demand (requirements) for each different part or material is derived from knowledge of the components of each car and the

numbers of cars to be produced. Thus, it is possible to determine almost exactly how much of each component will be required.

From the above illustrations one can understand that the major distinction in the way inventories are managed results from the nature of demand for those items. When demand for items is derived from plans to make certain products, those items said to have dependent demand. In the above illustration, the parts, wheels, nuts and bolts, screws, etc., that go into the production of an automobile are examples of dependent demand because the total amount of parts and sub-assemblies needed during any time period is a function of the number of cars that will be produced. Conversely, demand for the finished cars is independent.

The main purpose of a basic MRP system are to control inventory levels, assign operating priorities for items, and plan capacity to load the production system. These may be expanded as follows;

Inventory

Order the right part

Order in the right quantity

Order at the right time

Priorities

Order with the right due date

Keep the due date valid

Capacity

Plan for a complete load

Plan an accurate load

Plan for an adequate time to view future load.

The theme of MRP is ''getting the right materials to the right place at the right time.''

The objective of inventory management under an MRP system is to improve customer service, minimizing inventory investment, and maximize production operating efficiency.

Hence, requirements for end items generate requirements for lower-level components, which are broken down by planning periods (e.g., weeks) so that ordering, fabrication, and assembly can be scheduled for timely completion of end items while inventory levels are kept reasonably low.

Historically, ordering and scheduling of assembled products suffered from two things. One was the enormous task of setting up schedules, keeping track of large numbers of parts and components, and coping with schedule and order changes. The

other was that little effort was made to differentiate between independent demand and dependent demand; all too often, techniques that were designed for independent-demand items were being used to handle assembled items, which result in excessive inventories. Consequently, inventory planning and scheduling presented major problems for manufacturers.

Later manufacturers began to recognize the importance of the distinction between independent and dependent demand items and to approach these two categories of items in different ways. Much of the burden of record keeping and determining material requirements in many firms has not been transferred to computers, using techniques such as MRP.

In doing so MRP begins with a schedule for finished goods that is converted into a schedule of requirements for the subassemblies, component parts, and raw materials needed to produce the finished items in the specified time frame. Thus, MRP is designed to answer three questions:

- *What* is needed?
- *How much* is needed? and
- *When* is it needed for dependent demand items?

Material requirements planning has three advantages

1.Statistical forecasting for components with lumpy demand results in large forecasting errors. Compensating for such errors by increasing safety stock is costly, with no guarantee that stock outs can be avoided. MRP calculates the dependant demand of components from the production schedules of their parents, thereby providing a better forecast of component requirements.

2. MRP systems provide managers with information useful for planning capacities and estimates financial requirements. Production schedules and material purchases can be translated into capacity requirements and birr amounts and can be projected in the time periods when they will appear. Planners can use the information on a parent item

schedules to identify times when needed components may be unavailable because of capacity shortages, supplier delivery delays, and the like.

3.MRP systems automatically update the dependant demand and inventory replenishment schedules of components when the

production schedules of parent items change. The MRP system alerts the planners whenever is needed on any component.

4.3 MRP INPUTS AND OUT PUTS

As we have seen, the MRP system is a commonsense computer-based approach to coordinating the purchasing and the use of materials with the needs of complex production schedules. Because it is computer based, some discussions of the inputs and out puts is necessary for a complete understanding of how MRP works. The three major inputs are

- *The master production schedule*: tells what a finished product is composed of
- *The bill of materials*: tells how much finished product is desired and when
- *The inventory record file*: tells how much inventory is on hand or on order

Most of this section will deal with the inputs and their use. The outputs are the decisions resulting from the use of the MRP system. Specifically, these decisions are

- Which parts to orders
- How many to order; and
- When to order

Master production schedule: The master schedule states which end items are to be produced, when these items are needed, and what quantities are needed. The master production schedule is the controlling mechanism of the MRP system. In it, the needs for each end item are spelled out by scheduling period (daily, weekly, and so forth). The manager using an MRP system specifies the needs, and the system generates all of the production and purchasing schedules for each component and subcomponent of each end item.

Example

Figure: A MPS for end item P *table 4:1*

Item: **p**

1
2
3
4
5

6
7
8
9
Quantity
200
100
The figure illustrates how a master schedule for end item ***P*** might appear. It shows that 200 units of ***P*** will be needed at the start of week 6 and that another 100 units of **p** will be needed at the start of week 8.
The quantities in a master schedule can come from a number of different sources, including customer orders, forecasts, order from wholesalers and external demand.
Generally speaking, a master schedule is generated initially in terms of what is *needed* and not what is *possible*, so the initial schedule may or may not be feasible given the limits of the production system. Moreover, what appears on the surface to be a feasible master schedule may not be so when end items are translated into requirements for procurement, fabrication, and assembly. Unfortunately, the MRP system cannot distinguish between a feasible master schedule and a nonfeasible one. Consequently, it is often necessary to run a proposed master schedule through MRP processing in order to obtain a clearer picture of actual requirements, which can then be compared to available capacity. If it turns out that the current master schedule is not feasible, a decision may be made to increase capacity (e.g., through over time or subcontracting) or to revise the master schedule. In the latter case, this may entails several revisions, each of which is run through the system until a feasible plan is obtained. At that point, the master schedule frozen, at least for the near term time period, thus establishing a firm schedule from which to plan requirements.

The Bill of Materials (BOM):

A bill of materials (BOM) contains a listing of all of the assemblies, sub assemblies, parts, and raw materials that are needed to produce one unit of a finished product. Thus, each finished product has its own bill of materials. As such, it also is the means by which the master schedule acts as the controller

for each system. For each end item, the bill of materials lists all of the materials required to produce the end item. This list includes all components, of course, but it also includes items required for productions that do not

become part of the end item, such as solder for welding, grease for lubricants, and dying for forming processes. The bill of materials used in the MRP system also provides additional information to link the items, including the specific place in the process where each item is needed and lead times for obtaining each item. This type of bill of materials is referred to as a ''structured'' bill of materials.

Inventory Record File or Inventory Master File

The inventory master file contains an extensive amount of information on every item that is produced, ordered, or inventoried in the system. It includes such data as on hand quantities, on order quantities, lot sizes safety stock, lead time and past usage figures.

The inventory master file is updated whenever items are withdrawn from or added to inventory or whenever an order is released revised or completed. Accuracy of inventory transactions is essential to MRP's ability to keep inventory levels at a minimum. It is estimated that 95% inventory accuracy is a prerequisite for an effective MRP system.

An accurate inventory count is essential to a successful MRP system. Access to stockroom is limited so that the withdrawal of inventory can be carefully monitored. Cycle counting in which inventory is counted continuously during the year. On a specified cycle, can improve operations by reconciling difference as they occur instead of waiting for end-of-the previous inventories. As inventory needs grow in size and complexity, the inventory record system evolves from one that is stored in the head of the responsible individual, to one that is stored in some form of card or paper file, and finally, to one that is stored in a computer data base. This computer database is, essentially, the inventory record file required for MRP. Thus, the use of an MRP system is a logical next step in this progression of the inventory system. Clearly, the MRP system cannot determine how many of a particular part to order until it knows how many of that part is

currently has on hand. The inventory record file provides this information for the MRP system.
The inputs are linked to the outputs by the MRP scheduling calculations. Briefly, the master production schedule specifies both the number and the time requirements for end items. The bill of materials (there is one for each end item) is used to calculate the needs (again, in terms of number and time) for all components. The inventory record file is
100
used to determine if the needs can be met from current stocks or if an order needs to be placed.
The primary inputs of MRP are bills of materials, which tells the composition of a finished product; a master schedule, which tells us how much finished product, is desired, and when; and inventory record file, which tells how much inventory is on hand or on order. The planner processes this information to determine the net requirements for each period of the planning horizon.

Product Structure File

Once the MPS is set, the MRP system accesses the product structure file to determine which component items need to be scheduled. The product structure file contains a bill of materials (BOM) for every item produced. The bill of material lists the item when and in what quantity each item is needed in the assembly process.
When each item is needed can best be described in the form of a product structure diagram, as shown in figure below. An assembled item is sometimes referred to as a parent, and a component as a child. The number in parentheses beside each item is the quantity of a given component needed to make one parent.

Figure 4:1

Each finished product has its own bill of materials. The listing in the bill of materials life is hierarchical; its shows the quantity of each item (in parentheses) needed to complete
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one unit of the following level of assembly. The nature of this aspect of a bill of material is perhaps most readily grasped by considering a ***product structure tree***, such as the one illustrated in the above figure. We see that end item X is

composed of two ***B***s and one ***C***. Moreover, each ***B*** requires three ***D***s and one ***E***, and each ***D*** requires four ***E***s. Similarly, each ***C*** is made up of two ***E***s and two ***F***s. These requirements are listed by level, beginning with level 0 for end item, then level 1 for the next level, and so on. The items at each level are components of the next level up and are parents of their respective components. Note that quantities of each item in the product structure tree refer only to the amounts needed to complete the assembly in the next up.

A product structure tree is useful in illustrating how the bill of material is used to determine the quantities of each of the ingredients (requirements) needed to obtain a desired number of end items.

Example: Using the information in the product structure tree; do the following

a. Determine the quantities of B, C, D, E, and F needed to assemble one X

b. Determine the quantities of these components that will be required to assemble 100 Xs.

Solution

a) ***Table 4:2***

Component
Quantity

B -------- 2 Bs per X
=2
D---------3 Ds per B x 2 Bs per X
= 6
E--------4 Es per D x 3 Ds per 2 Bs per X
= 24
E------ 1 Es per B x 2 Bs per X
= 2
C----- 1 Cs per X
= 1
E----- 2 Es per C x 1C per X
= 2
F---- 2 Fs per C x 1Cs per X
= 2

Note that E appears in three separate places; its total requirements can be determined by summing the separate amounts, which gives 28.

b) In order to assemble 100 units of X, the quantities of each component must be multiplied by 100.

The essence of material requirements planning is determined the quantity and timing necessary for each component in order to achieve the quantity and timing of end items in master schedule. The process then begins with the master schedule. Then, each end item is "exploded" into its component parts using the bill of materials file, indicating the assemblies, subassemblies, parts, and raw materials that will be needed. Conceptually, this is the same as identifying an end items product tree.

The quantities that are generated by exploding the bill of materials are ***gross requirements***: they don't take into account any inventory that is currently on hand or due to be received. The materials that must actually be required to meet the demand generated by the master schedule are the ***net requirements***.

The determination of the net requirements (netting) is the core of MRP processing. It is accomplished by subtracting from gross requirements the sum of inventory on hand and any scheduled receipts and then adding in safety stock requirements, if applicable:

Net requirements in period t= Gross requirements in period t- project inventory in period t

Net requirements are sometimes adjusted to include safety stock and an allowance for waste, although, for simplicity reason, this is not included in examples or problems.

The timing and sizes of orders (i.e., materials ordered from suppliers or work started with in the firm) are determined by ***planned-order releases.*** The timing of the receipts of these quantities is indicated by ***planned-order receipts.*** Depending on ordering policy, the planned-order releases may be a specified quantity (e.g., multiples of 50 units), or they may be equal to the quantity needed at that time. The following example illustrates the difference between these two ordering policies as well as the general concepts of time-phasing material requirements in MRP. As you work through the example, you may find it useful to refer to the following list of terms

- ***Gross requirements***: the gross requirements are the total expected demand for an item or raw material during each time period/production plan. They also include demand not otherwise accounted for, such as demand for replacement parts for units already sold. For end items, these quantities equal the planned-order releases of their immediate "parents."

- ***Schedule receipts***: The schedule receipts (some times called ***open orders***) are orders that have been placed but not yet completed or scheduled to arrive from vendors or elsewhere in the pipeline. For a purchased item, the schedule receipt could be in one of several stages: being ordered by a buyer, being processed by a supplier, being transported to the purchaser, or being inspected by the purchaser's receiving department. If a production is making the item in-house, the order could be on the shop floor being processed, waiting for components, waiting to be moved to its next operations.
- ***Project on hand***: the expected amount of inventory that will be on hand at the beginning of each time period: scheduled receipt + available from last period.
- ***Net requirements:*** the actual amount needed in each time period.
- ***Planned order receipt:*** A planned receipt is a new order not yet released to the shop or the supplier. It the quantity expected to be received by the beginning of the period in which it is shown. Planning for receipt of these new orders will keep the projected on-hand balance from dropping below the desired safety stock level. If no safety stock is called for, the purpose of these new orders is to avoid a negative projected on hand balance. Under lot-for-lot ordering, this quantity will equal net requirements. Under lot-size ordering, this quantity may exceed net requirements. Any excess is added to available inventory in the next time period.
- ***Planned*-order-releases**: A planned order release indicates when an order for a specified quantity of an item is to be issued. It shows a planned amount to order in each time period; equals planned-order receipts offset by lead time. This amount generates gross requirements at the next level in the assembly or production chain. When an order is executed, it is removed from the "planned-order receipts" and "planned-order release" rows and entered in the "scheduled receipts" row.

• ***What is the difference between gross requirement and net requirement?***

The MRP process is best explained through an example. We will use a worksheet called the MRP matrix to record the calculations

that are made. The table below shows the matrix and provides a brief description of the entries that are required.

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Table 4.3

Week numbers

1

2

3

4

5

6

7

8

Item:

Gross Requirement

Scheduled Receipt

Projected on hand

Net requirements

Planned order receipts

Planned order releases

Example-1: ABC Company produces end item E_{17} of 100 units by the beginning of 5^{th} week. E_{17} is made from components P_1 and P_2. Again P_1 is made from three units of RM_2 and P_2 is made from RM_5. Given the following product structures, and master scheduling, determine when orders should be released for the end item and components and the size of those orders. Assume lead-time for both the end item and components is one week.

Solution:

Figure 4. 2- Product tree for end item E_7

E_7

P_1

(4)

P_2

(2)

RM_2

(3)

RM_5

(15)

Develop a master schedule: End item 7
Table 4.4
Week
1
2
3
4
5
6
Quantity
100
The plan begins with the master schedule. We can see that 100 units are needed at the start of Week 5. This means that gross requirements for end Item 7 also are 100 units at the start of Week 5. Then, because there are no scheduled receipts or available inventory of End Item, the net requirements are 100 units in Week 5. Hence, there is a planned receipt of 100 units in Week 5. Then, because lead-time (for assembly) of the end item is 1 week, there is a planned order release of 100 units one week ahead of this (i.e., in Week 4).
Master schedule: End item 7
Table 4.4a
Week
1
2
3
4
5
6
Quantity
100
End item 7 LT=1 ***table 4.4b***
1
2
3
4
5
6
Gross requirements

100
Scheduled receipts
-
Available
-
Net requirements
100
Planned order receipt
100
Planned order release
100
106
Part P1 (4) LT=1 ***table 4.4c***
1
2
3
4
5
6
Gross requirements
400
Scheduled receipts
150
Available
150
150
Net requirements
250
Planned order receipt
250
Planned order release
250
Raw material RM2 (3) LT=1 ***table 4.4d***
1
2
3
4
5
6

Gross requirements
750
Scheduled receipts
-
Available
100
100
Net requirements
650
Planned order receipt
650
Planned order release
650
Part P2 (2) LT=1 ***table 4.4e***
1
2
3
4
5
6
Gross requirements
200
Scheduled receipts
40
-
Available
40
40
Net requirements
160
Planned order receipt
160
Planned order release
160
107
Raw Material RM5 (1.5**) Lt=1** ***table 4.4f***
1
2
3

4
5
6
Gross requirements
240
Scheduled receipts
40
Available
200
200
240
Net requirements
0
Planned order receipt
Planned order release

Each end item will use 4 of Part P1. Therefore, the planned order release of 100 units of end Item 7 in Week 4 will create a requirement of 4 x 100=400 of Part $\mathbf{P_1}$, also in Week 4. But Part $\mathbf{P_1}$ has a scheduled receipt of 150 units in Week 2, making 150 units available in Weeks 2 and 3. So, net requirements become 400-150=250 units in week 4. Thus, there is a planned order receipt of 250 units of part P1 in Week 4. Because lead time is one week, there is a planned order release of 250 units (i.e. fabricate 250 of part P1) one week earlier (i.e. week3.)

Because each part P_1 will require 3 units (pounds) of Raw Material Rm_2, the 250 units will require 3x250=750 units of Raw Material RM_2 will be available (i.e. are now on hand). Hence, net requirements will be 650 units, in week 3. Because lead time is one week, the planned order release is 650 units in week 1.

Gross requirements for Part P_2 are derived from the quantity of the end item needed (i.e., 100 in this case). Because two of parts P_2 are needed for each unit of the end item a total of 2x100=200 units will be needed. There are no scheduled receipts, but 40 units will be available, so net requirements become 160 units. Thus, a planned order receipt of 160 units in week 4 is needed and a planned order release of the same amount in week 3 is needed because lead-time is, again, one week.

The 160 units of part P_2 will require 1.5 x 160 =240 pounds of Raw Material Rm_5 in week 3. There is a scheduled receipt of 40

pounds in week3, added to the previously available quantity of 200 pounds. 240 pounds will be available in week 3. Because that just equals gross requirements of Raw Material Rm5, no additional ordering will be needed.

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MRP output

MRP systems have the ability to provide management with a fairly broad range of outputs. These are often classified as primary reports, which are the main reports, and secondary reports, which are optional outputs.

Primary reports concern production and inventory planning and control. These reports normally include the following:

1. A schedule of ***planned order***, which indicates the amount and timing of future orders.
2. ***order release***, which authorizes the execution of planned orders
3. ***changes* to planned orders**, which can include revisions of due dates or order quantities as well as cancellations of orders

Secondary reports concern such things as performance control, planning, and exceptions:

1. ***Performance-control reports*** are used to evaluate system operation. They aid managers by measuring deviations from plans, including missed deliveries and stock outs, and by providing information that can be used to assess cost performance.
2. ***Planning reports*** are useful in forecasting future inventory requirements. They include purchase commitments and other data that can be used to assess future material requirements
3. ***Exceptional reports*** call attention to major discrepancies such as late and overdue orders, excessive scrap rates, reporting errors, and requirements for non existing parts.

The wide range of outputs generally permits users to adapt MRP to their particular needs.

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4.4 OTHER CONSIDERATIONS

• What should be considered other than MRP in inventory control?

Aside from the main details of inputs, out puts and processing, managers must be knowledgeable about a number of other

aspects of MRP. These include the holding of safety stock, lot-sizing choices, and the possible use of MRP for items that are not finished products.

4.4.1 Safety Stock

Theoretically, inventory systems with dependent demand should not require stock below the end item level. This is one of the main advantages of an MRP approach. Supposedly, safety stock is not needed because the manager can project usage quantities once the master schedule has been established. Practically, however, there may be exceptions. For example, a bottleneck process or one with varying scrap rates can cause shortages in downstream operations. Furthermore, shortages may occur if orders are late or fabrication or assembly times are longer than expected.. On the surface, these conditions lend themselves to the use of safety stock to maintain smooth operation; but the problem becomes more complicated when dealing with multiechelon items (i.e., multiple-level items such as assembled products) by the fact that a shortage of *any* component will prevent manufacture of the final assembly. However, holding safety stock for all lower-level items loses the major advantage of MRP.

- **What is the use of safety stock in your organization if it is available?**

MRP system deals with these problems in several ways. The manager's first step is to identify activities or operations that are subject to variability and to determine the extent of that variability. When lead times are variable, the concept of *safety time* instead of *safety stock* is often used. This results in scheduling orders for arrival or completion sufficiently ahead of the time they are needed in order to eliminate or substantially reduce the element of chance in waiting for those items. When quantities tend to vary, some safety stock may be called for. How ever, the manager must carefully weigh the need and cost of carrying extra stock. Frequently, managers elect to carry safety stock for end items, which are subject to random demand and for selected lower- level operations when safety time is not feasible, say, because of capacity limitations.

It is important in general to make sure that lead times are accurate, particularly when the objective is to have incoming shipments of parts and materials arrive shortly before they are needed. Early arrivals increase on hand inventory and carrying costs, but late arrivals can raise problems, possibly delaying all following operations. Knowing this, managers may inflate lead times (i.e., use safety time) and cause early arrivals, defeating the objectives of matching the arrival of orders with production schedules.

If safety stock is needed, planned order release amounts can be increased by the safety stock quantities for the designated components.

4.4.2 Lot Sizing

An important issue in inventory management, whether for independent- or dependant-demand items, is choosing a lot size to order or for production. In conjunction with scheduling orders to be released (i.e., the “when to order” decision), the second inventory management question “how many to order” must also be answered. This is called ***lot sizing.*** A simple approach, called lot-for-lot is to order each period only what is needed in the next period. How ever, this lot size may not be the most appropriate. Determining the appropriate lot size for the production of intermittently demanded product is complex, but the general objective is to balance ordering or set up cost with inventory holding costs.

- **What are the difference between safety stock and lot sizing?**

For independent demand items, managers often use economic order sizes and economic run sizes. For dependent demand systems, however, a much wider variety of plans is used to determine lot sizes, mainly because no single plan has a clear advantage over the others. Some of the most popular plans for lot sizing are described in this section.

Table 4.5

Period
1
2
3
4

5
Demand
70
50
1
80
4
Cumulative demand
70
120
121
201
205
Demand for part B
• What is t he cumulative demand of period 1, 2, and 3 from the above table?
111
For either independent- or dependent-demand systems, a primary goal of inventory management minimize the sum of ordering cost (or setup cost) and holding cost. It is often the case with independent demand that demand is uniformly distributed throughout the planning horizon (e.g., six months, year). Demand tends to be much lumpier for dependent demand, and the planning horizon shorter (e.g., three months), so that economic lot sizes are usually much more difficult to identify. Consider the situation depicted in the above table. Period demand varies from 1 to 80 units, and no demand size repeats, at least over the horizon shown.
Managers can realize economies by grouping order or run sizes. This would be the case if the additional cost incurred by holding the extra units they were used led to a savings in setup or ordering cost. This determination can be very complex at times, for several reasons. First, combining period demands into a single order, particularly for middle-level or end items, has a cascading effect down through the product tree. That is, in order to achieve this grouping, items at lower levels in the tree must also be grouped. Hence, their set up and holding costs must also be incorporated in the decision. Another reason is the uneven period demands and the relatively short planning horizon. These

factors require a continual recalculation and updating of lot sizes. Not surprisingly, the methods used to handle lot sizing range from the complex, which attempt to include all relevant costs, to the very simple, which are easy to use and understand. And in certain cases, the simple models seem to approach cost minimization, although generalizations are difficult. Let's consider some of these models.

Lot-for-Lot Ordering: Perhaps the simplest of all of the methods is lot-for-lot ordering. The order or run size for each period is set equal to demand for that period. Not only is the order size obvious, it also virtually eliminates holding costs for parts carried over to other periods. Hence, lot-for-lot ordering minimizes investment in inventory. Its two chief drawbacks are that it usually involves many different order sizes and thus cannot take advantage of the economies of fixed order size (e.g., standard containers and other standardized procedures), and it requires a new setup for each run. If setup costs can be significantly reduced, this method may approximate a minimum cost lot size.

Economic Order Quantity Model: Sometimes economic order quantity models (EOQ) are used. They can lead to minimum costs if usage is fairly uniform. This is sometimes

the case for lower-level items that are common to different parents and for raw materials. However, the more lumpy demand is, the less appropriate such an approach is. Since demand tends to be most lumpy at the end item level, EOQ models tend to be less useful for end items than for items and materials at the lowest levels.

Fixed-Period Ordering: This type of ordering provides coverage for some predetermined number of periods (e.g., two or three). In some instances, the span is simply arbitrary; in other cases, a review of historical demand patterns may lead to a more rational designation of a fixed period length. A simple rule is: Order to cover a two period interval. The rule can be modified when common sense suggests a better way.

- **What is the difference between lot-for-lot ordering and fixed-period ordering?**

Summary

MRP is a planning technique that creates a schedule for all the dependant demand items in an end item's bills of materials based on fixed manufacturing lead times. The end item is exploded using the bill of materials, and material requirement plans are developed that show quantity and timing for ordering or producing components.

MRP is the preferred way to schedule production and inventory when demand is dependent. MRP looks at inventory management for situations where demand is not continuous or constant overtime where many items are maintained in the same inventory system, and where many of the inventory items are linked directly to other items ion the inventory. MRP also goes beyond the scope of inventory management to include production scheduling and purchasing considerations.

The primary idea to coordinate all activities so as to order exactly the amount required at exactly the time that it is needed. Although MRP required only the simplest of calculations, the complex business systems to which it is applied require that a computer be used to implement MRP and manage the necessary information.

The MRP system consists of three basic components: the master production schedule, the bill of materials, and the inventory record file. The master production schedule specifies the needs for the end items; the bill of materials translates this scheduled in to needs for all component items; and the inventory record file keeps track of on-hand inventory for all items.

MRP uses requirements philosophy- parts are ordered only as required by the master schedule. Past demand for parts is irrelevant, and component inventories are not replenished when they reach a low lever.

A successful MRP system required (1) implementation planning, (2) adequate computer support, (3) accurate data, (4) management support, and (5) user knowledge. Both system and people problems must be solved to use MRP successfully. When this is done, benefits include reduced inventory, increased customer service, and improved efficiency.

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Chapter five
Inventory cost control Models
5.1 Introduction
Dear learners in the previous chapters we saw inventories as stock of goods held for expected use or for future potential use. Even though different organizations can have different inventories based on their activities the reason for carrying inventories, and the way they are managed are similar regardless of the specific items. Consequently, the discussion presented in this chapter pertains to inventory management in all types of business organizations.
The key questions to be answered in this chapter are the following:
- How much to order
- When to order
- How much control is appropriate

The chapter begins with brief discussion of holding and ordering costs related to inventory. The remainder of the chapter is devoted to a description of the various models that are available to managers for effective inventory management and control. The models described in this chapter are suited for inventory items that have independent demand. Independent demand means that demand for the items is not derived from demand for other items. These independent demand models are:
- Basic economic order quantity (EOQ) model
- Production order quantity model
- Quantity discount model

Objective
Dear learners, when you complete this chapter you should be able to
- Describe the costs associated with inventory
- Understand the basic EOQ model and its assumptions and solve typical problems.
- Describe the quantity discount and solve the typical problems.
- Describe the reorder point models and solve typical problems.

5.2 Carrying / Holding costs
• If you buy and hold a stock of inventory;
a) What are the expected advantages?

b) What are the expected disadvantages?

Carrying material in inventory is expensive. Prior to the relatively recent periods of higher interest rates, a number of studies determined that the annual cost of carrying a production inventory averaged approximately 24 percent of the value of the inventory. The escalating volatile costs of money in recent years, however, has increased the typical firm's annual inventory carrying costs to a figure between 25 and 35 percent of the value of the inventory. Five major elements make-up these costs in the following manner:

1. Opportunity cost of invested funds 12-20%
2. Insurance costs 2-4%
3. Property taxes 1-3%
4. Storage costs 1-3%
5. Obsolescence and deterioration 4-10%

Total carrying costs 20-40%

Let's briefly examine these carrying costs

1. **Opportunity cost of invested funds:** when a firm purchases $50,000 worth of a production material and keeps it in inventory, it simply has this much less cash spend for other purpose money invested in production equipment or in external securities earns a return for the company. Conceptually, then, it is logical for the firm to charge all money invested in inventory an amount equal to that it could earn if invested elsewhere in the company. This is the "opportunity cost" associated with inventory investment.
2. **Insurance costs**: Most firms insure their assets against possible loss from fire & other forms of damage. An extra $50,000 worth of inventory represents an additional asset on which insurance premium must be paid.
3. **Property taxes:** As with insurance, property taxes are levied on the assessed value of a firm's tax bill.

4. **Storage costs:** The warehouse in which a firm stores its inventory is depreciated a certain number of dollars per year over the length of its life. One may say, then, that the cost of warehouse space is a given number of dollars/birr per cubic foot per year. And this cost conceptually can be charged against inventory occupying the space.

5. **Obsolescence and deterioration:** In most inventory operations, a certain percentage of the stock spoils, is damaged, is pilfered. Even though warehouse managers guard against these occurrences, a certain number always take place. With new products being introduced at an increasing rate, the probability of obsolescence is increased accordingly. Consequently, the larger the inventory, typically the greater the absolute loss from this source.

Generally speaking, this group of carrying costs rises and falls nearly proportionately with the rise and fall of inventory level. Further, the inventory level is directly related to the quantity in which the ordered material is delivered. When the complete order is shipped at one time, the larger the order, the higher the average inventory level during the period covered by the order. Hence, costs of carrying inventory vary nearly directly with the size of the delivery quantity.

Holding/carrying costs often are expressed in terms of cost per unit on an annual basis. Some organizations prefer to specify a fixed dollar/birr amount where as others prefer to specify carrying costs relative to unit price (e.g. 30% of unit cost/unit price)

If a firm has estimated its approximate inventory carrying costs, as a percentage of inventory value, the annual inventory carrying costs that would be generated by delivery quantities of various sizes can be calculated as follows:

(Carrying cost per year)= (average inventory value) X (inv. carrying costs are 2% of inv.

Values)

(Carrying cost per year)= (Average inventory level)X(material unit cost)X (inv. Carrying

Cost as a % of inv. Values)

or

Annual carrying cost= (Average inventory level) (Holding cost per unit per year)

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AH= (Q)H or Q x S x I

2

Where AH = Annual holding cost

Q= order or delivery quantity for the material in units

S= delivery unit cost of the material
I= Inventory carrying cost for the material, expressed as a percentage of inventory
value
H= Holding cost per unit per year

Example 1: A shoe, salesman has just decided to open his own shoe store. However, he has very little money to invest and wants to start his business as soon as possible, His solution is to maintain some advertisements; he operates out of his home. Whenever any one wants a pair of shoes, the sales man orders them and delivers them to the customer in a few weeks.

The salesman's idea has the advantage of eliminating inventories. However, people do not like to buy shoes in this way; they almost always want to try them on first. Although some "low overhead" businesses can do extremely well, the shoe business is not one of them.

For this example, we can identify both the major costs associated with maintaining inventory and the major costs of not having inventory. For the shoe sales man to open his own shoe store, he must stock a wide variety of shoe. To do this, he must borrow (form a bank or from his own sources) a large sum of money. In order for the new shoe store to make a profit, the revenue from sales must cover the interest payments on the money borrowed to purchase the shoes. The salesman also must buy or lease space (the store) to display some of the inventory and to stock the remainder. So the major costs of inventory, the inventory holding costs, results mostly from the capital invested and from the cost of renting or leasing the space required for the inventory.

The contribution of each costs just mentioned to the holding cost of an item depends on the item in inventory. Gold/Diamond, for example, are very capital intensive and take-up little space. However, due to the required security precautions, the space they use may be

expensive. Companies often use a percentage of the value of an item, based on past financial records. From the accounting viewpoint; only variable costs are included in the holding cost? Fixed costs (those that are incurred regardless of the inventory

level) are not considered. Let us consider the computation of holding costs in example 2.

Example 2: Five items are stored in inventory at a warehouse that use a holding cost percentage of 25 percent per year for each of the items. The costs of the items are as follows:

Item Cost
1 $ 40
2 90
3 70
4 120
5 60

What holding costs should be used for each item?

Based on the fact that the policy of the company is to use a 25% annual holding cost, the annual holding cost is obtained by multiplying the cost of the items by 0.25.

Table 5:1

Item	**Purchase cost X Holding cost %**	**Annual Holding cost**
1	$40X.25	$ 10.00
2	$ 90 X .25	22.50
3	$ 70 X .25	17.50
4	$ 120X .25	30.00
5	$ 60 X .25	15.00

As this point, it would still seem that the way to minimize inventory costs (and thus, operating expensed) is to maintain no inventory. But as example 1 showed, there is another inventory cost; the shortage cost. The shortage cost is more difficult to measure

than the carrying cost. The shortage cost is the cost of lost sales, the cost of customers that never return for future sales, and the cost relating to loss of good will. Because shortage costs are so difficult to estimate, many companies specify a service level, or percentage of shortage allowed, and then calculates the shortage cost implied by the tolerated service level. A higher service level (fewer shortages allowed) implies a higher shortage cost. Larger inventions are needed to minimize shortage costs. In example 1 above, the service level was 0, be cause no shoes were available for sale.

5.3 Order/Acquisition costs

- ***If a bakery orders all its requirements of flour;***

a)At one time in a year

b)12-times a year

What are the benefits and disadvantages related with each decision?

Looking at inventory costs is another light; a different set indirect materials cost factors emerges. This is the fixed cost associated with placing an order in the inventory system. These factors all contribute to the cost of generating, processing, transporting, receiving an order, along with the related paper work. Examples of these costs are listed below and can be thought of as inventory acquisition /ordering costs.

1. A certain portion of wages and operating expenses of such departments as purchasing and supply, production control, receiving, inspection, and accounts payable-those departments whose personnel devote time to the generation and handling of the order.
2. The cost of supplies such as engineering drawings, envelopes, stationery, and forms for purchasing, production control, receiving, accounting, and so forth.
3. The cost of services such as computer time, telephone, fax machines, telegraph, and postage expended in procuring material.

When considering this group of ordering/acquisition costs, observe that they behave quite differently form carrying costs. Acquisition costs are not related to inventory size per se; rather,

they are a function of the number of orders placed or deliveries received during a

given period of time. In other words order cost is independent of the number of items ordered. One simplified example will illustrate this point; suppose a buyer in the purchasing and supply department receives a requisition for a special fabricated part used in the manufacturing of one of the firm's product. Assume further that the part has been purchased before and that price quotations from three or four shops are on file. The buyer first reviews the present inventory situation and probably checks with production control to see if any significant changes are anticipated in future production. Drawings and specifications of the part are then reviewed refresh his/her memory regarding required doing and other technical details for the purchased. Next, the buyer reviews the quotations to determine why the order was placed with the stated supplier last time. Before deciding if the previously selected supplier should again receive the order, the buyer must also review supplier performance data. Finally, the buyer decides which supplier should receive the order and subsequently inquires about the firm's current shop loads and any other matters that are available during the investigation. It is entirely possible that a negotiation session may also be required.

In total, the buyer's investigation may require anywhere from an hour to several days. The total cost of the buyer's time to the company will be the same whether the purchase order is written for 20 parts or 200 parts. This process may result in the development of a term contract with the suppliers, in which case the buyer's effort is spread over all deliveries of the items during the life of the contract. If this is not the case, however, the next time the buyer received another requisition for this part, he or she will go thorough somewhat the same process, generating almost the same indirect cost for the company.

The largest segment of the acquisition cost element is made up of these types of indirect labor and overhead costs, generated in purchasing and in the other departments that subsequently become involved in handling some activity associated with the purchase. The cost of supplies & services consumed in the

placement & handling of an order typically varies directly with the number or orders placed. While the costs are significant, they are considerably less so that the human & related overhead cost figures just discussed. The variable acquisition cost per order varies widely among firms depending on the specific cost inclusions. If a firm experiences a certain annual usage of an item, the

number of orders placed during the year will decline as the individual order quantity increases, thus generating lower annual acquisition costs.

When orders are being manufacture, ordering costs also exist, but they are a part of what is called setup costs. Setup cost is the cost to prepare a machine or process for manufacturing an order. This includes time & labor to clean and change tools or holders. Operational managers can lower ordering costs by reducing setup costs and by using such efficient procedures as electronic ordering & payment.

In many environments, setup cost is highly correlated with set up time. Set ups usually require a substantial amount of work prior to setup actually being performed at the work center with proper planning much of the preparation.

Required by a setup can be done prior to shutting down the machine or process. Setup times can thus be reduced substantially. Machine and processes that traditionally have taken hours to setup are now being setup in less than a minute by the more imaginative world-class manufactures. Reducing setup times is an excellent way to reduce inventory investments to improve productivity.

5.4 The basic economic Order quantity (EOQ) model

• If a person runs his/her own restaurant how much times does she/he buys per 6 months?

Inventory analysis is based on the calculation of the total inventory costs as a function of some unknown variable. In the basic EOQ model, that variable is the size of the order quantity. Based on the total cost function, an optimal level for the decision variable can be found.

The economic order quantity (EOQ) model is one of the oldest and most commonly known inventory control techniques. This

technique is relatively easy to and is based on several assumptions:

1. ***Constant demand***: in the EOQ model, a constant demand was assumed (e.g. five units per day). In reality, demand may fluctuate. In such a case, it is necessary to modify the EOQ formulation (e.g., by using safety stock)

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2. ***Constant unit price***: the EOQ analysis assumes that constant unit price can be expected. It did not extend to include variable prices due to discounts as larger quantities are ordered. This procedure is discussed later.
3. ***Constant holding cost***: it is assumed that the holding cost is constant. However, as the level of inventory increases, the holding cost may decrease (e.g., due to storage efficiency) or increase (e.g., due to higher capital costs).
4. ***Constant ordering cost***: This assumption is usually valid for limited ranges of order quantity. For exceptional cases, the EOQ model can be modified by computing different ordering costs.
5. ***No shortages:*** The assumption is made that all demand is immediately supplied and therefore there will never be a shortage. As long as the demand is constant and delivery time is either constant or zero, the assumption will hold. Other wise, a safety stock should be added or a modified model with a shortage can be used.
6. ***Instantaneous (or fixed) delivery:*** it is assumed that deliveries are received on a desired date. This can be assured by instantaneous delivery; for example, if the supplier happens to be in the same area and can deliver quickly on short notice. Alternatively, if the lead time and the demand are both constant, an order can be placed so that the delivery will arrive exactly on a desired date. But in the case of variations in the lead time or the demand, the EOQ must be modified.
7. Independent demand: Quite often, several items are purchased from the same supplier. And the ordering cost can be reduced by ordering several items in one order. This saves paper work, transportation costs, and may also result discounts. Special models have been developed to deal with situations where several items are ordered together, a practice known as ***joint ordering.***

8. ***Lead-time***: that is, the time between placement and receipt of the order- is known and **constant.**

9. Quantity discounts are not possible

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10. The only variable costs are the cost of setting up or placing an order (setup costs) and the cost of holding or storing inventory overtime (holding or carrying cost).

11. Stock outs (shortages) can be completely avoided if orders are placed at the right time.

12. Only a single item under continuous review is considered

13. The entire quantity ordered arrives in the store at one time.

- ***Write any of the five assumption of EOQ model?***

With these assumptions, the graph of inventory usage over time has a saw tooth shape; no shortages are allowed; each new order arrives just as the inventory level reach 0.

Figure 5:1

The cycle begins with receipt of an order of Q units. These are withdrawn at a constant rate over time. When the quantity on hand is just sufficient to satisfy demand during lead time (the time between submitting an order and receiving that order), an order for Q units is submitted to the supplier. Because it is assumed that both the usage rate and the lead time do not vary, the order will be received at the precise instant that the inventory on

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hand falls zero. Thus, orders are timed to avoid having excess stock on hand and to avoid stock-outs.

Because demand is constant overtime, inventory drops at uniform rate overtime (refer to the above figure). When the inventory level reaches 0 each item, the new order is placed and received, and the inventory level again jumps to Q units (represented by the vertical lines). This process continues indigently over time. Thus, orders are timed to avoid having excess stock on hand and to avoid stock outs.

Minimizing costs

The objective of most inventory modes is to minimize total cost. With the assumptions just given significant cost are set up (or

ordering) costs and holding (or carrying) cost. All other costs, such as the cost of the inventory itself, are constant. Thus if we minimize the sum of ordering and holding costs, we will also minimize total costs

figure 5:2

• Dear learners what do you conclude from the above two figures?

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The optimal order quantity reflects a trade-off between carrying costs and ordering costs; as order size is varied; one type of cost will increase while the other one decreases. For example, if the order is relatively small, the average inventory will be low, which will result in low carrying cost. However, a small ordering size will necessitate frequent orders, and that will drive up annual ordering costs. Conversely, annual ordering costs can be held down by ordering large quantities at infrequent intervals, but that would result in higher average inventory levels and therefore increased carrying costs. Thus the ideal solution will typically be an order size that causes neither a few very large orders nor many small orders, but one that lies somewhere between those two extremes. The exact amount to order will depend on the relative magnitude of carrying and ordering cost.

To help government or business firms visualize this, in the following figure, we graph total cost as a function of the order quantity, Q.

Figure 5:3

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As we can see form the figure, a reduction in either holding or setup cost will reduce the total cost curve. A reduction in the total cost curve also reduces the optimal order quantity (lot size). In addition, smaller lot sizes have a positive impact on quantity and production flexibility.

You should note that in the figure, the optimal order quantity occurs at the point where the ordering cost curve and the carrying cost curve intersect. This was not by chance, with the EOQ model, the optimal order quantity will occur at a point where the total setup cost is equal to the total holding cost. We use this fact to develop equations that solve directly for Q*. The necessary steps are:

1. Develop an expression for ordering/set up cost
2. Develop an expression for holding cost
3. Set carrying cost equal to holding cost
4. Solve the equation for the optimal order quantity.

Using the following variables, we can determine ordering and holding cost and solve for Q

Q= Order quantity in units
P= Purchase price
D= Annual demand in units for the inventory item
S= Setup or ordering, cost for each order
H= Holding or carrying cost per unit per year
TC= Total annual cost.

Let us now consider each of this cost.

1. Annual ordering /set up cost= (number of orders placed per year) X (setup or order cost per period)

(**Set up or order cost per order**)

= (D/Q) S = D/Q S

Annual demand

Number of units in each order

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2. Annual holding cost = (Average inventory level) X (Holding cost per unit per

year)

= (*holding t per unit per year*)

order quantity

cos

2

⎛⎞
⎜⎟
⎝⎠

= (Q/s) H

= Q/S H

3. Optimal order quantity is found when annual setup cost equals annual holding

cost, namely;

= (D/Q) S = Q/2 H

4. To solve for Q simply cross-multiply terms and isolate Q on the left of the equal

sign.

period)

$D/Q\ S = Q/2\ H$

$2D\ S = Q_2H$

$Q_2 =$

$$\frac{2DS}{H}$$

$$\mathbf{Q=}\frac{2DS}{H}$$

Now we have derived equations for the optimal order quantity Q, it is possible to solve inventory problems directly.

Example 3: A small clinic that uses disposable needles, would like to reduce its inventory cost by determining the optimal number of needles to obtain per order. The annual demand is 1,000 units; ordering cost is birr 10 per order; and the holding cost per unit per year is birr 0.50. Using these figures, we can calculate the optimal number of units per order.

$$Q=\frac{2DS}{H}$$

$$Q=\frac{2(1000)(10)}{0.50}$$

$= 4000 = 200$ UNITS

Therefore at one time 200 units of disposable needles is ordered and received.

We can also determine the expected number of orders placed during the year (N) and the expected time between orders (T) as follow.

Expected number of orders (N) =

$$\frac{\text{demand}}{\text{ordered } Q} = \frac{D}{Q}$$

D

Expected time between orders = T = Number of working days per year

N

The following example illustrates this concept. Using the data from the clinic and
assuming a 250-day working year, we find the number of orders (N) and the expected
time between orders (T) as:

N =

Q

$demand$

=

200

1000

=5

Hence, orders have to be placed 5 times to get the annual demand of 1000 units of
disposable needles. At each order the clinic pays an ordering cost of birr 10. Then the
total annual ordering cost is 5 x 10 = birr 50

The expected time between the orders is calculated as;

T = Number of working days per year

Expected number of orders

= 250 working days per year = 50 days between order

5 orders

As mentioned earlier in this section, the total annual variable inventory cost is the
sum of ordering and holding costs:

Total annual cost = ordering cost +Holding cost,

TC =

Q

DS

$+ H$

Q

2

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Again, using the clinic data from the above examples, we determine that the total

annual inventory costs as :

$$TC = \frac{Q}{DS} + H\frac{Q}{2}$$

$$TC = \frac{(\ )(\ )}{200} + 0.50\frac{1000}{2}$$

= (5) ($10) + (100) ($.50)

= $50 + $50 = $100

Note that at EOQ, the holding cost and the ordering costs are equal. The total inventory cost expression may also be written to include the actual cost of the material purchased. If we assume that the annual demand and the price per disposable needle are known values (for example, 1,000 deposable needles per year at P=birr 10) and total annual cost should include purchase cost, then the above equation becomes;

$$TC = \frac{Q}{DS} + H\frac{Q}{2} + PD$$

Because material cost does not depend on the particular order policy, we still incur and annual material cost of DXP= (1000) (10) = Birr10, 000. (Later, we will discuss the case in which this may not be true-namely, when a quantity discount is available.)

Example 4: A tire distributor company sells 4,800 tires per year. Tires are purchased
at a price of $27 per tire in batches of 240 tires each. The holding cost is $2 per tire
per year, and the ordering cost is $30 per order. What is the total inventory cost?
The average inventory is =
2
Q
=
2
240
= 120 tires.
The number of orders per year is
Q
D
=
240
4800
=20 orders per year.
So the total inventory cost =
Q
DS
+ H
Q
2
=
240
$30(4800)
+
2
$2(240)
= $840
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the total cost including the purchase price is
TC = PD +
Q
DS
+ H

Q
2
=($27 x 4800) +
( )( )
240
$30 4800
+ 240
2
$2
= $129,600 + $600+ $ 240 = $ 130,440
Notice that the cost for the unit is $129,600. This figure is independent of the order
size. Whether we place one order of size 4800 or 4800 orders of one tire each, the
total cost for tires will be $129,600. Second notice that the annual ordering cost
($600) is greater than the annual holding costs ($240). Typically, this is the sign that
too many orders are being placed and that fewer but larger orders would be more cost
efficient.
We have developed a table for various values of the order quantity (see the table
below). The table shows as the order quantity increases, the holding costs increases
and the ordering/setup cost decreases. In addition, as we discussed in the previous
example the total cost is minimized at the point where the holding cost and ordering
cost are equal.
Or at Q=
H
2DS
=
2
2(480)(30)
= 379.47
Inventory costs as a function of order quantity (based on example 4)

Table 5:2

1 order Q	2 Annual ordering cost (SD/Q)	3 Annual Holding cost (HQ/2)	4 Inventory cost [(2) + (3)]	5 annual unit cost (PD)	6 annual Total cost [(4) + (5)]
50	2,880	50	2,930	129,00	132,530
100	1,440	100	1,540	129,600	131,140
150	960	150	1,110	129,600	137,710
200	720	200	920	129,600	130,520
250	576	250	826	129,600	130,426
300	480	300	780	129,600	130,380
350	411	350	761	129,600	130,361
400	360	400	760	129,600	130,360
450	320	450	770	129,600	130,370
500	288	500	788	129,600	130,388
550	262	550	812	129,600	130,412
600	240	600	840	129,600	130,440
650	222	650	872	129,600	130,472
700	206	700	906	129,600	130,506
750	192	750	942	129,600	130,542
800	180	800	980	129,600	130,580

Note = All costs are in dollars

Example 5: Aman paining company consumes 58 gallons of paint per day, at a price of $ 5 per gallon. Assuming that the company works 251 days per year, the annual

consumption is 14,558 gallons. The holding cost is $ 4 per gallon per year, and the
order cost is $22 preorder. Compute the optional order quantity and the total cost.
The first step is to find the EOQ. From the formula, we have
Q=
$\frac{2DS}{H}$
=
$\frac{2(14,558)(\$22)}{\$4}$
= 400 gallons per orders(round off)
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When an order is placed, it is for 400 gallons of paint.
The number of orders per year is D/Q, i.e. =
$\frac{14558}{400}$
= 36.395 or about 36.40 orders
are placed about 3 times per month (i.e, 36/12). The actual time between orders is
Q/D, or 0.027 years. This means that an order is placed every 6.9 (working) days,
based on the working year of 251 days (i.e., 0.027 x 251).
The total inventory cost is =
$\frac{DS}{Q} + \frac{H}{2}Q$
=
$\frac{(\$22)(14556)}{400} + \frac{(\$4)(400)}{2}$
= $800.69 + $800 = $1600.69
The total cost including the purchase price is
TC = PD +

Q
DS
$+ H$
Q
2
= ($5X14,558) +
( )( )
400
$22 14556
+ (400)
2
$4
= $72,790 + $800.69 + $800
= $74,390.69
As you see the holding cost and the ordering cost are essentially equal, as should be
expected for the optimal order quantity.

• ***What is the holding cost if all the 14558 gallons is ordered at one time? What is the ordering cost if all the 14558 gallons is ordered at one time?***

5.5 EOQ with Non instantaneous replenishment/Economic production quantity (EPQ)

• ***Assume that a certain machine produces a part at the rate of 10 per hour to be used in the assembly of an item at the rate of 7 per hour. If there is 10 hours of working days what is the amount of inventory at the end of that day?***

In the basic EOQ model, it is assumed that orders are delivered as whole units at a single
point in time (instantaneous replenishment). This is more suitable for purchased quantity
in which the whole lot is usually delivered at one time. However, in some instances such
as when a firm is both a producer and user, or when deliveries are spread over time,
inventories tend to build up gradually instead of instantaneously.

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The assumptions of EPQ model are similar to those of the EOQ model, except that in stead of orders received in a single delivery, units are received incrementally during production. The assumptions are:
- Only one item is involved
- Annual demand is known
- The usage rate is constant
- Usage occurs continually, but production occurs periodically
- The production rate is constant
- Lead times does not vary
- There are no quantity discounts

If usage and production (or delivery) rates are equal, there will not be an inventory build up since all output will be used immediately, and the question of lot size doesn't come up. This model is designed for production situations in which once an order is placed, production begins and a constant number of units are added to inventory each day until the production run has been completed. To satisfy demand and avoid back orders, the production rate must be greater than the demand rate. This ensures a gradual buildup of inventory during the production period. When the production run is completed, the inventory shows a gradual decline until a new production run is started. The inventory pattern for this system is shown in the following figure. Figure 5:4 illustrates how inventory is affected by periodically producing a batch of particular item.

During the production phase of the cycle, inventory builds up at a rate equal to the difference between production and usage rate. For example, if the daily production rate is 20 units and the daily usage rate is 5 units, inventory will build up at the rate of 20 – 5 = 15 units per day. As long as production occurs, the inventory level will continue to build; when production ceases, the inventory level will begin to decrease. Hence, the inventory level will be maximum at the point where production ceases. When the amount of inventory on hand exhausted, production is resumed, and the cycle repeats itself.

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Figure 5:4

Because the finite replenishment rate usually implies a production rate, this model usually is referred to as an economic production quantity model (EPQ) or economic lot size model (ELS). Within the context of this discussion, however, the EPQ model is merely an extension of the EOQ model. This model is applicable under two situations.

1. When inventory continuously flows or builds up over a period of time after an order has been placed or
2. When units are produced and sold simultaneously

Under these circumstances, we take into account daily production (or inventory-flow) rate and daily demand rate.

As it is stated above, this model is especially suitable for the production environment; it is commonly called the production order quantity model. It is useful when inventory continuously builds up over time and traditional economic order quantity assumptions are valid.

If we have a production system that produces 50 units per day, and we decide to schedule 10 days of production each time we want additional units, we have a 50(10)= 500- unit production run size. Alternative terminology may refer to the 500 units as the production

lot size or the lot quantity. We denote the production lot size by Q and build a model that

minimizes total annual cost.

As in the EOQ model, we are now dealing with two costs, the inventory holding cost and

the ordering cost. The total cost analysis for the EPQ model is exactly the same as for the

EOQ model, the inventory-holding and the ordering cost. While the inventory holding

cost is identical to our definition in the EOQ model, the ordering cost may be more

correctly referred as ***production-set up costs.*** This cost, which includes labor hours,

materials, and lost production costs incurred while preparing the production system for

operation, is fixed cost that occurs for every production run, regardless of the production

quantity. Let us begin building our model attempting to write the inventory holding cost
in terms of our production quantity model, Q. Again, our approach is to develop an
expression for average inventory and then establish the holding cost associated with the
average inventory level.
We saw in the EOQ model that the average inventory was simply one-half the maximum
inventory, or
2
Q
. The previous page shows a constant inventory buildup rate during the
production run and a constant inventory depletion rate during the non production period,
the average inventory for the production lot size model will be half of the maximum
inventory level. However, in this inventory system the production quantity, Q, does not
go into inventory at one time, and thus the inventory level reaches a level of Q units.
Let us see if we can compute the maximum inventory level. First we define the following
symbols:
Q = number of production quantity
H = holding cost per unit
d = daily demand rate for the product
p = daily production rate for the product
t = number of days for a production run.
Since we are assuming p is larger than d, the excess production each day is p – d, which
is the daily rate of inventory buildup. If we run production for t days and place p – d units
in inventory each day, the inventory level at the end of the production run will be (p – d)
140
t. from the figure of the previous page, we can see that the inventory level at the end of

the production run is also the maximum inventory level. Thus we can write

Maximum inventory = (p – d)t

If we know we are producing a production quantity of Q units at a daily production rate

of p units, then Q = pt, and we can compute the length of the production run t to be

t = $\frac{Q}{p}$ *days*

Thus

Maximum inventory = $\left(1 - \frac{d}{p}\right)Qt$

$$= \left(1 - \frac{d}{p}\right)Q$$

$$= \left(1 - \frac{d}{p}\right)\frac{Q}{2}$$

The average inventory, which is half of the maximum inventory, is given by

Average inventory = $\frac{1}{2}\left(1 - \frac{d}{p}\right)Q$

2
1
With an annual inventory holding cost of H per unit, the general equation for annual
inventory-holding cost is
Annual inventory holding cost = ⎜ ⎜
⎞
⎟
⎠
⎜ ⎜ ⎛
⎝
⎜ ⎜
⎞
⎟
⎠
⎜ ⎜
⎛
⎝
t per uunit
annual holding
inventroy
average
cos
= *QH*
p
d
⎜ ⎜
⎞
⎟
⎠
⎜ ⎜ ⎛
⎝
1-
2
1
If D is the annual demand for the product and S is the set up cost for a production run,
then the total annual setup cost, which takes place of the total annual ordering costs of the
EOQ model.
Annual setup cost = **(***number of production runs per year* **)(***setup* cos *t per run***)**
= *S*
Q
D
⎜ ⎜

⎞
⎟
⎠
⎛
⎜
⎝
Thus total annual cost (TC) model is
QH
p
d
⎞
⎟
⎠
⎛
⎜
⎝
⎞
⎟
⎠
⎛
⎜
⎝
1-
2
1
+ S
Q
D
⎞
⎟
⎠
⎛
⎜
⎝
⎞
⎟
⎠
⎛
⎜
⎝
141
In this total cost model, we use the ratio of daily demand to daily production,
p
d
.
Actually this ratio of demand relative to production is the same, regardless of the
period of time considered. In terms of an annual demand, D, and an annual
production capacity, P, the ratio
p
d
P
D
= . Substituting

P
D
for
p
d
provides this total
cost formula.
TC = S
Q
D
QH
P
D
⎛ |
⎝
⎞
⎠
⎛ |
⎝
⎞
⎠
+ |⎠
⎞
⎛|
⎝
1-
2
1
Using the expression for holding cost above and the expression for setup cost developed
in the basic EOQ model, we solve for the optimal number of pieced per order by equating
set up cost and holding cost.
Set up cost =
( )
( )
S
Q
D
Holding cost = QH
p
d
⎛ |
⎝

⎞
⎜ ⎟
⎝
⎠
1-
2
1
Set ordering cost equal to holding cost to obtain Q:
( )
( )
S
Q
D
=
( )
( )
⎟⎠
⎞
⎜⎝
⎛
-
P
D
Q
H
1
2
Q =
H
2*DS*
x
p d
p
-

Example 6: Nathan Manufacturing, Inc; makes and sells specially hubcaps for the retail automobile after market. Nathan's forecast for its wire-wheel hubcap is 1,000 units next year, with an average daily demand of 4 units. However, the production process is most efficient at 8 units per day. So the company produced 8 per day but used only 4 per day.

Given the following values, solve for the optimum number of units per order. (Note; This
plant schedules production of this hubcap only as needed, during the 250 days per year the
shop operates).
Annual demand = D = 1000 units
Setup costs = $10
Holding cost = H = $ 0.50 per units per year
142
Daily production rate = P = 8 units daily
Daily demand rate = d = 4 units daily
Q =
H
$2DS$
x
$p\ d$
p
-
Q=
0.50
2(1000)(10
x
(8 4)
8
-
Q= 40000 x 2
Q= 282.8 hub caps or 283 hub caps
d = 4 = D = 1000
Number of days the plant is in operation 250
When annual data are used, we can express Q as:
Q =
⎛ |
⎞
⎠
⎝
⎛ |
⎞
⎠
⎝
-
annual produciton rate
annual demand rate
H

DS
1
2
The total cost equation with the price of the item is represented by
TC= PD + (
2
HQ
)
P
$P - D$
+
Q
SD
Example 7: Bala Aerospace Corporation can produce Subcomponents at a rate pf
300 per day, and it uses these subcomponents at a rate of 12,500 per year (of 250
working days). Holding costs are $2 per item per year, and setup costs are $30 per
order.
a) What is the economic production quantity?
b) How many production runs per year will be made?
C) What will be the maximum inventory level?
Q =
H
$2DS$
x
$p\ d$
p
-
143
Q=
2
2(12,500)(30)
x
(300 50)
300
-
= 671

All entries in this equation are given explicitly, except for d, which is 12,500 = 50
250
The number of production runs per year is
n = D/Q = 12,500 = 18.63
671
(The length or time between production runs is 250/18.63 = 13.42 working days)
Maximum inventory level = Q ⎞⎟
⎟⎠
⎛ -
p
1 *d*
= 671 (1-50/300) = 559
Example 8: A toy Manufacturer uses 48,000 rubber wheels per year for its popular truck
series. The firm makes its own wheels, which it can produce at a rate of 800 per day. The
toy trucks are assembled uniformly over the entire year. Carrying cost is $1 per wheel per
year. Set up cost for a production run of wheels is $45. The firm operates 240 days per
year. Determine the following :
a) The optimal run size
b) The minimum total annual cost for carrying and set up.
c) The cycle time for the optimal run size
d) The run time
Solution:
D= 48,000 wheels per year
S = $45
H = $1 per wheel per year
p = 800 wheels per day
d =
240
48,000
= 200 wheels per day
a) Q =
H
2*DS*

x
p d
p
-
144
Q =
800 200
800
1
2(48000)45
-
= 2400 wheels
b) TC = carrying cost + set up cost
= *S*
Q
D
H
Maximum inventory
+
2
( )
Thus, we must first compute maximum inventory;
Maximum inventory = Q ⎪ ⎪
⎭
⎬
⎫
⎪ ⎪
⎩
⎨
⎧
⎛ -
p
p d
= 2400 ⎭
⎬
⎫
⎝⎜
⎩
⎨
⎧
⎛ -
800
800 200
= 1800 wheels
TC = $45
2,400
48,000
$1
2

1,800
$x + x$
= 900 + 900 = $1800
Note again that set up cost is equal to carrying cost at EOQ.
c) Cycle time = *days*
wheels per day
wheels
d
Q
12
200
2400
= =
Thus, a run of wheels will be made every 12 days.
d) Run time: *days*
wheels per day
wheels
p
Q
3
800
2400
= =
Thus, each run will require three days to complete.

5.6 EOQ with quantity discounts

• ***When you buy more quantity, there is a practice of getting at a lower price.***

Then would you buy more for a lesser price and stock for long period of time?

A major assumption of the EOQ models is that the purchase price per unit is constant,
regardless of the number of units that are purchased. As a result, the purchase price does
not enter into the calculation for the optimal order quantity.
There are many instances, however, when this assumption is not valid. Quantity
discounts are price reductions for large orders offered to customers to induce them to buy

in large quantities. To avoid any appearance of favoritism toward one customer over another, the discounts are formally incorporated in the vendor's published price structure and are available to all computers.

To increase sales, many companies offer quantity discounts to their customers. A quantity discount is simply a reduced price (P) for an item when it is purchased in large quantities. It is common to have a discount schedule with several discounts for large orders. In addition, to keeping good customers happy there are other benefits to the producer who offers quantity discounts. Customers will place larger order, which means the company can have larger production runs with fewer costly setups. In the quantity discount case, purchase cost is included in the total cost model.

The formula price break scheme might appear as follows:

Quantity purchased price per unit

1- 39 units $ 20.00

40 or more units $ 17.50

In this case, if fewer than 40 units are purchased at one time, the cost is $20 per unit. But if 40 or more units are purchased the cost is only $17.50 per unit. The price break, Q_d (for quantity discount) is 40. The price break is defined as the amount that must be purchased in order to take advantage of a lower price.

For some items, the price structure may include more than one price break. Consider the following extension of the previous example.

Quantity purchased price per unit

1- 39 units $ 20.00

40 - 59 units $17.50

60 or more units $ 16.00

This time, there are two price breaks at 40 and at 60. It seems logical that, if price breaks are available, the change in price should be considered when deter mining the optimal order quantity.

Q1 Q_d Q2

To determine the optimal order quantity for this quantity discount case, the key is still to

the EOQ, despite the fact that it fails to consider the price. The total inventory function
must now include the purchase price of the item being ordered.
As with other inventory models discussed so far, the overall objective.
Example 9: Prince Electronics purchase Video cassette (VCR) at $350 per VCR. The
holding cost is $35 per unit per year, the ordering cost is $120 per order, and sales are
steady at 400 per month. The company's supplier decides to offer price breaks for larger
orders, resulting in the following structure.
Quantity purchased price per unit
1- 99 units $ 350.00
100 - 199 units $325.00
200 or more units $ 300.00
Prince Electronics whishes to find the optimal order quantity and the minimum cost.
Step 1 : Q =
H
$2DS$
=
( )
$35
2 400 x12 ($120)
= 181.42
Regular price
Discount
price
147
Which we round to 181(Notice that, because the holding cost is annual, the demand used in
the formula must be annualized-that is, multiplied by 12.]
Step 2: There is a price break at 100, which is greater 181. There is also a price break at
200, which is greater than 181. Therefore, we have to consider, the total cost of ordering
181 units versus the total cost of ordering 200 units. We don’t need to consider ordering

100 units, because this is below the EOQ. Because the unit cost for the third discount (in
the above example [300] is the lowest, you might be tempted to order 200 or more units
merely to take advantage of the lower product cost. placing an order for that quantity,
however, even with the greatest discount price, might not minimize total inventory cost.
Granted, as discount quantity goes-up, the product cost goes down. However, holding cost
increases because orders are large. Thus the major trade-off when considering quantity
discounts is between reduced product cost and increased holding cost. When we include the
cost of the product, the equation for the total annual inventory cost can be calculated as
follows.

Total = Setup cost + Holding cost + product cost

or

TC=

( )

( )

H

Q

2

+

( )

( )

S

Q

D

+ PD

Where

Q = Quantity ordered

D = Annual demand in units

S = Ordering/ Setup costs per order or per setup

P= Price per unit

H= Holding cost per unit per year.

In the quantity discount situation, the analyst may calculate an EOQ for each price,
but the true economic order quantity is the amount that minimizes total annual cost,
including item cost. A method for finding the true EOQ is:
1. Calculate EOQs for each price breaks; reject any EOQ that is not within the
allowable quantity range for the price used.
2. For feasible EOQs calculate total annual cost
148
3. Calculate total annual cost at each higher price break
4. Pick the quantity having the lowest total annual cost. This is the true economic
order quantity.
TC181= (4,800 X $ 325) +
( ) ( )
181
$120 4,800
2
$351*x*181 *x*
+
= $ 1,56,000 + $ 3,168 + $3,182 = $ 1,566,350
We note that the difference between the holding cost ($3,168) and the setup cost ($3,182)
is due to our rounding the EOQ form 181.41 to 181.
TC 200 = (4800X$300) + ($35 X 200) + ($120 X 4,800)
2 200
= $ 1,440,000 + $3,500 + $ 2,880 = $1,446,380
Step 3 order 200 units, because the total cost of ordering that quantity is less than the
total cost that results form the use of Q.
In the above VCR example, the holding cost was fixed at $35. The holding cost often is
given as a percentage of the unit cost. If this is the case, then the economic order quantity
changes when the price changes and these changes must be taken into consideration when
using quantity discounts. Then the formula becomes Q =
IP
2*DS*

IP, i.e. it is common to express the holding cost (I) as a percentage of unit price (P)
instead of as a constant cost per unit H.

Example10: prince electronics has been using a $35 holding cost for an item priced at
$350. In light of discount the supplier is offering, prince electronics wishes to use a 10
percent holding cost rather than the fixed $35 holding cost. What is the optimal order
quantity, and what is the optimal cost?

We begin by examining three different economic order quantities one for each price. In
the following formulas, notice that the holding cost is the only figure that change.

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$$Qa = \frac{2(4{,}800\ \$120}{.10\ \$350}$$

$$x$$

$$x$$

$$=$$

$$35$$

$$2(4800\ x\$120)$$

$$= 181$$

$$Q_b = \frac{2(4{,}800\ \$120)}{.10\ \$325}$$

$$x$$

$$x$$

$$=$$

$$32.5$$

$$2(4800\ x\$120$$

$$= 188$$

$$Q_c = \frac{2(4{,}800\ \$120)}{.10\ \$300}$$

$$x$$

$$x$$

$$=$$

30
2(4800 *x*$120
= 196
Q_a is the optimal order quantity based on a price of $350 per unit, because the holding
cost is .10X$350 = 35 However, Q_a = 181 and, at 181 units, the price is $325, not $350.
This means that Q_a does not make sense and can be discarded.
Q_b is based on a price of $325 and, because this is the price if we order 188 units, Q_b is a
possible solution. Q_c is based on $ 300 price, because Q_c = 196, which generates a
different price, Q_c is not feasible. Thus, of the three EOQs the only feasible one is 188.
Therefore we need to compare the total cost of ordering 188 units with the total cost of
ordering 200 units.
TC_{188} = ( )
( )
188
4,800 $120
2
.10($325 188)
4,800 $325
x x
x + +
= $1,560,000 + $3,055 + 3,064 = $1,566,119
TC_{200} = ( )
200
(4,800 $120)
2
.10($300 200)
4,800 $300
x x
x + +
= $1,440,000 + 3,000 + $2,880 = $ 1,445,880
As you see it is better to order 200 units as it generates the least cost.
Reorder point

• ***Assume that you are a manager of a bakery. The bakery uses 10 quintals of flour per day. The time between an order placement and arrival is 3 days. What should be the level of inventory in the stock when you initiate an order?***

Now that we have decided how much to order, we will look at the second inventory question, when to order. Simple inventory models assume the receipt of an order is instantaneous. Inventory timing with reorder point (ROP) is probably as sold as humanity

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Inventory level unit

Slop = units/day = d

(may be older: some animal, such as squirrels, also replenished low stocks), The ROP provides for replenishing stocks when they reach some low level. The classic use of the reorder point occurs in a perpetual inventory system and it assumes.

1. That a firm will place an order when the inventory level for that particular items reaches Zero, and
2. That it will receive the ordered items immediately. However, the time between placement and receipt, of an order, called lead time, or delivery time, can be as short as few hours or as long as months. Thus, when to order decision is usually expressed in terms of a reorder point (ROP) - the inventory level at which an order should be placed.

Lead time = L Time (days)

Figure 5:5

The amount generally includes expected demand during lead-time and perhaps an extra cushion of stock, which serves to reduce the probability of experiencing a stock out during lead-time.

There are four determents of based and forecast quantity.

1. The rate of demand (usually based on a forecast)
2. The length of lead time
3. The extent of demand and lead time variability
4. The degree of stock-out risk acceptable to management.

Q*

The reorder point curve (ROP) curved

ROP units

The models generally assume that any variability in either demand rate or lead-time can
be adequately described by a normal distribution. However, this is not a strike
requirement the models provide approximate reorder points even in cases where actual
distribution depart substantially form normal.
The discussion begins with the simplest case (demand and lead time both constant) and
proceed to models that can be used when either demand or head time or both, is variable
The order point (ROP) is given as
ROP = (Demand per day) (Lead time for a new order in days)
= d X L
The equation for ROP assumes that demand during head time and lead time it self are
constant. When this is not the case, extra stock, often called safety stock should be added.
Lead time: Denote by L the lead time in days between the time an order is placed and the
time the units arrive. The order for units needs to be place, not at T, but at L days before
T if the order is to arrive when the inventory runs out at a time. Rather than express the
reorder point in days, we express it in units. During the lead time, the daily demand rate
is d.
The demand per day, d, is found by dividing the annual demand, D, by the number of
working days in a year:
d = D
Number of working days in dyed.
Example 11: The MIS department of XX store uses Flash disk at a rate of 4,000 per year
(250 working days). The annual holding cost is $2 per Flash disk and the cost of placing
an order is $10. It takes the vendor 5 days from the time the order is placed to deliver the

Flash disk. What is the complete inventory policy (amount to order and time to order?)
To compute policy is given by Q and ROP. The order quantity is
Q =
2
2 2(2400)(10)
=
H
DS
= 200
152
The reorder point is given by Ld, where d is the daily demand rate. In this example, the
daily demand rate is given by d= 16
250
4000
= flash disks per day. There fore
ROP= Ld = 5 x 16 = 80
Example 12: Electronic assembler, inc. has a demand for 8,000 VCR, per year. The firm
operates a 250 day working year. On average, delivery of an order takes 3 working days.
We calculate the reorder point as
D = d = 8000 = 32 units
Number of working days in dyed. 250
ROP = Reorder Point = d X L = 32 units per day X 3 days
= 96 units
Thus, when inventory stock drops to 96, an order should be placed. The order will
arrive 3 days later, just as the firm's stock is depleted.
Example 13: A patient takes a two - a day vitamin, which are delivered to his home
by a route and seven days after an order is called in. At what point should the patient
telephone his order in?
Solution:
Usage = 2 vitamin per day
Lead time = 7 days
ROP = usage X lead time

= 2 vitamin per day X 7 days = 14 vitamin
Thus, the patient should reorder when 14 vitamin tablets are left.

Safety stock/ Buffer stock

- ***What does it mean when we say safety stock?***

Regardless of the system used for inventory timing, keeping customers well served is
difficult. Consumptions and output rates vary, and stoppages, accidents, and natural

disasters sometimes disrupt operations,. These difficulties lead managers to rely on protection in the form of buffer stocks, also called safety stock, even well-run just-in-time operations and quick-responses programs must rely some what on safety stocks.
In the case of safety stock, the assumption for known, constant demand rate is dropped. We still assume that the demand rate does not change overtime; that is, the expected demand, or the average, does not change. But we allow for the possibility of a variable rate of demand. Buffer stock, a special class of inventory, is like having extra tire in a car: you hope you don't need it, but you don't dare operate without it.
An individual drives form Addis Ababa to Bahir Dar 570 k/m. If this car consumes 1 liter per 5 K/m, how much gasoline is needed in the tank at the start of the trip.
Clearly, 114 liters gasoline should be in the tank, but the person couldn’t feel comfortable. The prudent action, therefore, is to make sure that, although an initial inventory 114 liters are required; there will be more than 114 liters in the tank at the start of the trip.
Maintaining safety stock is similar to buying more gasoline than necessary; it is merely the formalization of common, every day practice. Essentially, it amounts to proper exercise of caution. People who have a nine o'clock appointment plan to arrive a little early in case of delays. In inventory, similar cautions practice is used every where, even where the kind of formal inventory analysis presented in this chapter is not employed. The inventory manager decides how much is needed and orders that amount plus '' a little extra" just in case. This “little extra" is the safety stock. In any situations where a risk is present, steps should be taken to reduce that risk.

In general when variations exist in usage or lead time the ROP is
ROP = Expected demand during lead time + Safety stock
Example 14: a flour factory uses an average of 200 plastic bags per day, and lead time averages four days. Because both usage rate and lead times are variable, the inventory manager carries a safety stock of 100 bags to lessen the chance of a stock out. Determine the ROP.
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Solution
ROP= Expected demand during lead time + Safety stock
= 200 bags per day X 4 days +100 bags = 900 bags.
Thus the flour factory should reorder when existing stock equal 900 bags.
Service level:
• ***When a customer comes to a shop and he/she couldn't get the product she/he needs, what is the effect of it on your business performance?***
Because it costs money to held safety stock, a manager must be careful with the service it provides, since the service level increases as the risk of stock-out decreases. Order cycle service level can be defined as the probability that demand will not exceed supply during lead time. (i.e. that the amount of stock on hand will be sufficient to meet demand) Hence, a service level of 95 percent implies a probability of 95 percent that demand will not exceed supply during lead time. An equivalent statement is that demand will be satisfied in 95 percent of such instances. It does not mean that 95 percent of demand will be satisfied. The risk of a stock out is the complement of service level, a customer service of 95 percent implies a stock out risk of 5 percent. That is
Service level = 100 percent - stock out risk
The amount of safety stock that is appropriate for a given situation depends on the following factors.
1. The average demand rate and average lead time
2. Demand and lead time variability
3. The desired service level
For a given order cycle service level, the greater the variability in either demand rate or lead time, the greater the amount of safety stock that will be needed to achieve that service level. Similarly, for a given amount of variation in demand rate or lead

time achieving an increase in the service level will require increasing the amount of safety stock, selection of a service level may reflect stock out costs (e.g. the manager wants to achieve a specified service level for a certain item.
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Summary

Inventory management decisions require accurate information on the amount of on-hand inventory, scheduled receipt, and backorders in order to determine the inventory position for every independent demand item.

Good inventory management is often the mark of a well-run organization. Inventory levels must be planned carefully in order to balance the cost of holding inventory and the cost of providing reasonable levels of customer service. Successful inventory management requires a system to keep track of inventory transactions, accurate information about demand and lead times, realistic estimates of certain inventory-related costs, and a priority system for classifying the item in inventory and allocating control efforts.

A basic inventory management question is whether to order large quantities infrequently or to order small quantities infrequently or to order small quantities frequently. The EOQ provides guidance for this choice by indicating the lot size that minimizes (subject to several assumptions) the sum holding and ordering costs over some time period such as a year.

In the continuous review system, the buyer places orders of a fixed lot size Q when the inventory position drops to the reorder point. In the periodic review, the quantity varies from order to order. Every fixed time intervals, the buyer places an order to replenish the quantity consumed since the last orders.

When inventory items are made instead of bought, inventory is replenished gradually over some production period. This condition is called non instantaneous replenishment/economic production quantity (EPQ). The amount of inventory accumulated during the production period is reduced by concurrent sales. Hence the maximum amount in inventory will be less than the production lot sizes. The economic lot size is a balance between annual holding and annual ordering cost. Sales during the

production period have the effect of lowering the average inventory and annual holding
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costs, so balance is restored by increasing the size of each order. Large orders reduce the number of orders placed during a year.
When quantity discounts are available, the total relevant costs include annual holding cost, ordering, and material costs. Purchasing larger quantities to achieve price discounts reduce annual ordering and material costs but usually increase annual holding costs. The order quantity is based on minimizing the total of relevant costs per year, instead of obtaining the minimum purchase price.
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Chapter six
JUST IN TIME SYSTEM

6.1 Introduction

Dear learners, in the previous chapters we discusses various issues or concepts related to inventory. We state the importance of inventory to function properly internally and to meet customers demand externally. In this chapter we consider inventory as evil because it tied up money and require more storage space. Hence we try to learn the benefits of minimum inventory and how can we apply to realize minimum inventory in the manufacturing setups.

Just in time (JIT) systems, which are designed to produce or deliver goods or services as needed and minimize inventories, require major changes in traditional operating practices. Often a crisis (such as being faced with going out of business or closing a plant) galvanizes management and labor to work together and effect the needed changes. Converting from traditional manufacturing to a just in time system bring up not only inventory control issues, but also process management and scheduling issues. In this chapters we identify the characteristics of just-in-time systems, discuss how manufacturing and service operations utilize JIT systems. I also address the strategic implications of such systems and some of the implementation issues that companies face. Finally I also raise issues necessary to change the traditional operating systems and the challenges faced in using just-in-time system.

The Japanese have captured a sizable share of world markets for many products because of the significant progress they have made in manufacturing. Among the reasons for this success are the Japanese style of management, the development and adaptation of many new technologies, and the use of new methods for material management and control. This chapter discusses the Japanese approach to material management and control known as Just-in-time (JIT). JIT is more than a new way of managing materials; it is a philosophy whose objective is to eliminate all sources of waste, including unnecessary inventory and scrap in production.

Objectives

Dear learners, when you finalize this chapter you should be able to:

- Define Just- In- Time
- Explain the elements of JIT
- Describe kanban
- Explain the benefits of JIT
- Describe the difference between push and pull
- Explain the difference between JIT and traditional production system

6.2 THE JUST- IN – TIME CONCEPT

Just -in-time (JIT) is a philosophy of continuous and forced problem solving that drives out waste. The term JIT is used to refer to a repetitive production system in which both the movement of goods during production , and deliveries form suppliers, are carefully timed so that at each step of the process the next (usually small) batch arrives for processing just as the preceding batch is completed. The result is a system in which there are neither idle item waiting to be processed, nor idle workers and equipment waiting for items to process.

The just-in-time phenomenon is characteristic of lean production system, which, you may recall, operate with very little "fat" (e.g. excess inventory, extra workers, wasted space). It refers to a production system in which operations such as processing, movement of material and goods, etc. occur as they are needed or demanded. The result is very little inventory (i.e. idle

resources); production is very much a hand-to-mouth type of operations.

JIT pertains to the timing, to the flow of parts and material through the system, and the timing of services. Companies that employ the JIT/Lean production approach typically enjoy a competitive advantage over companies that used more traditional approach to repetitive processing. They have lower processing costs, fewer defectives, greater flexibility, and are able to bring new or improved products to the market more quickly.

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The JIT approach was developed at the Toyota Motor company of Japan by MR.Tailchi Qhno (who eventually became vice president of manufacturing) and several of his colleagues. The development of JIT in Japan was probably influenced by the fact that Japan is a crowded country with few natural resources. Not surprisingly, the Japanese have become very sensitive to waste and inefficiency. They regard scrap and rework as waste, and they regard inventory as an evil because it takes up space and ties up resources.

A widely held view of JIT is that it is simply a system for scheduling production that results in low levels of work-in-process and inventory. But in its truest sense, JIT represents a philosophy that encompasses every aspect of the process, from design to after the sale of a product. Moreover, the key element of a JIT system is quality.

In JIT systems, quality is ingrained in both the product and the process. Companies that use JIT have achieved a level of quality that enables them to function with small batch sizes and tight schedules. JIT systems have very high reliability; major sources of inefficiency and disruption have been eliminated, and workers have been trained not only to function in the system, but also to continuous improve it.

In the following section, the key elements of JIT system are described. They provide a basis for understanding how this system functions.

- ***Can we apply JIT with the context of Ethiopia? Why?***

6.3 Key elements of JIT systems

JIT systems are designed to achieve a smooth flow of production using minimal inventories. The system is fairly flexibly, with a high degree of worker participation in problem solving, continuous improvement, and attention to detail. However, the most important aspect of a JIT system is that quality is built into the system. High quality is a prerequisite for this system; no other element is as critical.
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The key elements of the system are the following:
1. High quality levels
2. Production smoothing
3. Low inventories
4. Small lot sizes
5. Quick, low-cost setups
6. Layout
7. Preventive maintenance and repair
8. Multifunctional workers
9. A cooperative spirit
10. Few, reliable suppliers
11. A pull system of moving goods
12. Problem solving
13. Continual improvement
Let's examine each of these elements

High quality levels

As mentioned, JIT systems require high quality levels, the system are geared to a smooth flow of work; the appearance of problems due to poor quality creates disruption in this flow. In fact, because small lot sizes and the absence of buffer stock result in low in-process inventories, if problems occur, production must cease until they have been resolved. Obviously, shutting down an entire process is costly and cost into planned outputs levels, so it becomes imperative to try to avoid shutdowns, and to quickly resolve problems when they do appear.

JIT systems use a three-part approach to quality. One part is to design quality into the production process. The fact that JIT systems produce standardized product leads to standardized job methods, workers who are very familiar with their jobs, and the use of standardized equipment, all of which contribute to high quality levels. Moreover, the cost

of product design quality (i.e. building quality in at the design stage) can be spread over many units, yields a low cost per unit.
The second part to the approach is to insist that vendors provide high-quality material and parts to minimize disruptions due to problems with incoming goods. Once a high degree of confidence in vendor quality has been achieved, the time and cost of inspecting incoming goods can be practically eliminated.
The third part to the approach is to make workers responsible for producing goods of high quality. This requires providing adequate equipment and tools to the work, providing proper training in work methods and in measuring quality and detecting errors, supporting and encouraging worker errors to improve quality, and giving workers the authority to make changes when problems are found.
A central technique of JIT systems is to minimize defects through the use of automation (note the extra syllable on in the middle of the word). This refers to the automatic detection of defects during production. It can be used with machines or manual operations. It consists of a mechanism for detecting defects when they occur and a mechanism for stopping production for purposes of correcting the cause of the defects. Thus, the halting or production forces immediate attention to the problem, after which an investigation of the problem is conducted and corrective action, is taken to resolve the problem.

- ***What are the approaches to JIT utilized to maintain quality?***

Production smoothing

JIT production requires a smooth flow of goods through the system to achieve a meshing of the different operations and the movement of goods and materials form the supplier to the final output. Every activity must be carefully coordinated because there is very little stack. Therefore, aggregate production schedules are set over a time horizon (often a month) in order for production and purchasing schedules to be established. The monthly plan provides the basis for determining an average daily production plan. The plan may

be revised slightly, perhaps weekly, as updated information such as sales orders become available. Surprisingly, these systems can handle variety by keeping final assembly schedules flexible, For example, in the final assembly of automobiles, customer orders can be filled on a daily basis by changing the mix for final assembly. If a customer wants air conditioning or a specific color, the system can tolerate that variety. Note, however, that companies using JIT production typically restrict the number of options available to a relatively small number, not as extreme as Hennery Ford in the 1920s ("you can have any color you want, as long as it's black"), but the selection are fairly limited so as to minimize disruptions to smooth production schedules.

Low inventories

People readily associate the term jus-in time with low inventories. And, In fact, one of the hallmarks of JIT systems is low inventories-or purchased parts and raw materials, work in process, and finished goods.

There are three important aspects of low inventories. Two reflect benefits, and one reflects a basic requirement of JIT systems. The first obvious benefit of low inventories is the savings of space- and space in work areas. Saving is also realized by not tie up money in idle inventory. The second benefit, more subtle, is a key aspect of the JIT philosophy. Inventories are buffers that tend to cover up recurring problems that are never resolved, partly because they aren't obvious and partly because the presence of inventory makes them seem less serious. When a machine breaks down, it won't disrupt the system if there is a sufficient inventory of the machine's output to feed into the next workstation. This use of inventory as the "solution" can lead to increasing amounts of inventory if breakdowns and focus on eliminating them. Similar problems with quality, unrealizable vendors, and scheduling can also be "solved'' by having ample inventories to fall back on. However, carrying that entire extra inventory creates a tremendous burden in cost and space and allows problems to go unresolved.

The JIT approach is to pare down inventories gradually in order to uncover the problems. Once they are uncovered and solved, more inventories is removed, additional problems

are found and solved, and so on. A useful analogy is a boat on a pond that has large hidden rocks. The rocks represent problems that can hinder production (the boat). The water in the pond that covers the rocks is the inventory in the system. As the water level is slowly lowered, the largest rocks are the first to appear (i.e. those problems are the first to be identify). At that point, efforts are undertaken to remove these rocks form the water (i.e. resolve these problems). Once that has been accomplished, additional water is removed form the pond, revealing the next layer of rocks, which are then worked on. As more and more of the rocks are removed, the need for water to cover them diminishes. Likewise, as more and more of the major production problems are solved, there is less and less need to rely on inventory.

The third important aspect of low inventories reflects a basic requirement of JIT systems: to be able to operate with low inventories, the major problems must have already been resolved. Thus, low inventories are the result of a process of successful problem solving, one that has occurred over time. Furthermore, because it is unlikely that all problems will be found and resolved, it is necessary to be able to deal quickly with problems when they do occur. Hence, there is a continuing need to identify and solve problems in a short time span to prevent new problems from disrupting the smooth flow of work through the system.

- ***List down the benefits of low inventories?***

Small lot sizes

Small lot sizes, both in the production process and in deliveries from suppliers, yield a number of benefits that enable JIT systems to operate effectively. One is that with small lots moving through the system, in-process inventory is considerably less that with large lots. This reduces crying costs, space requirements, and clutter in the workplace. Another advantage is that when problems with quality occur, inspection and rework costs are less because there are fewer items in a lot to inspect and rework.

Small lots also permit greater flexibility in scheduling. Repetitive systems typically produce a variety of products. In traditional systems, this generally means long

production runs of each product, one after the other. Although this spreads the setup cost for a run over many items, it also results in long cycles over the entire range of products. For instance, suppose a firm has three products, A, B, and C. In a traditional system, there would be a long run of product A (say, covering two or three days or more), then a long run of product B, and then a long run or product C before the sequence would repeat. In contrast, a JIT system, using small lots, would frequently shift form producing A to producing B and C. This flexibility enables JIT systems to respond more quickly to changing customer demands for output: JIT system can produce just what is needed, when it is needed. The contrast between small and large lot sizes.

It is worth nothing that in the JIT philosophy, the ideal lot size is one unit. Although that quantity may not always be a realistic goal because of practical considerations that require minimum lot sizes (e.g. machines that process multiple items simultaneously, heat-treating equipment that processes multiple items simultaneously, and machines which very high setup times), the goal is still to reduce the lot size as much as possible because small lot sizes have numerous benefits.

• Compare the benefits of small lot sizes over large lot sizes?

Quick, Low-cost setups

Small lots and changing product mixes require frequent setups. Unless these are quick and relatively inexpensive, the time and cost to accomplish them is prohibitive. Often, workers are trained to do their own setups. Moreover, programs to reduce setup time and cost are used to achieve the desired results; a deliberate effort is required, and workers are usually a valuable part of the process.

Setup tools and equipment and setup procedures must be simple and standardized. Multipurpose equipment or attachments can help to reduce setup time. For instance, a machine with multiple spineless that can easily be rotated into place for different job requirements can drastically reduce job changeover time. Moreover, group technology may be used to reduce setup cost and time by capitalizing on similarities in recurring operations.

For instance, parts that are similar (in shape, materials, etc…) may require
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vary similar setups. Processing them in sequence on the same equipment can reduce the need to completely change a setup; minor adjustment may be all that is necessary.

Layout

Traditional factories often use layouts based on processing requirements (i.e. work centers designed to handle a certain type of processing, such as drilling, cutting, or packaging). Consequently, in traditional manufacturing systems, a group of parts moves from one processing center to the next. Each move adds to the time in which parts are in the system, as lots wait to be moved, wait at the next center to be processed, and so on. This also adds to the amount of inventory in the system. In such systems, the time devoted to actually working on a part may consists less than 5 percent of the time a part is in the system. For the remaining 95 percent of the time, no useful purpose is served by having the part in the system; no value is added. In a real sense, there is a considerable amount of waste and inefficiently.

JIT systems commonly use layouts based on product requirements. Equipment is arranged to handle streams of similar products with similar processing or assembly requirements. This avoids having to move large lots of parts around the work area; parts pass in small lots form one work center to the next with little or no waiting and with substantially less need for in-process inventory. Moreover, material handling costs are greatly reduced, as is the space needed to support a given level of output. Factories tend to be smaller and more efficient, and machines can be moved closer together, which has the further benefit of enhancing communication among workers.

• ***Mention the benefits achieved from the layout systems of JIT over the traditional manufacturing systems?***

Preventive maintenance and repair

Because JIT systems have very little in-process inventory, equipment breakdowns can be very disruptive. To minimize breakdowns, companies use preventive maintenance programs,

which emphasize maintaining equipment in good operation condition and

replacing parts that have a tendency of fail before they actually fail. Workers are often responsible for maintaining their own equipment.

Even with preventive maintenance, there will be occasional equipment failures. Companies must be prepared for this, so as to quickly return equipment to working order. This may mean maintaining supplies of critical spare parts and making other provisions for emergency situation, perhaps maintaining a small force of repair people or training workers to do certain repairs themselves.

Note, too, that when breakdowns do occur, they indicate a potential area for improvement. Thus, breakdowns become opportunities to be exploited in a JIT environment.

Multifunctional workers

In traditional production system, it is not unusual to find that a worker is trained for a relatively narrow set of tasks. For instance, some workers are trained to operate machinery, other to handle setups, and still others to perform maintenance and repair. JIT systems feature multifunctional workers, trained to handle all of those tasks. That does not mean that workers are expected to be able to handle adjustment and minor repairs as well as do their own setups. Remember, though, that under JIT systems, efforts are made to simplify setups, making it more appropriate to assign them to operators.

Workers in JIT systems are often trained to handle more than one production operation. That way, if a workers fall behind, others will be able to assist him or her in maintaining the schedule.

Workers are responsible for checking the quality of their own work and monitoring the quality of work they receive as input to their stations. Workers are also expected to participate in problem solving. In spite of all this workers involvement, there is the expectation that workers will strictly adhere to schedules, and if a worker believes that he or she has discovered an improved way of doing a task, that idea is to be submitted to others and approved before it is implemented. Hence, workers

are not permitted to alter established methods or routines individually.
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The concept of flexible workers has much to offer, but it is not without a downside, one negative aspect is the training cost and time that may be required to cross-train highly skilled workers. Another is that workers may resist flexibility for reasons such as loss of job security and the burden of learning new skills. Older workers may be shunted off to early retirement rather than be retained because their benefit time would be mush shorter than that or younger workers. Thus, it is important for companies to carefully consider which jobs are best suited to multifunctional workers, and which are not. In all likelihood, the lowest skilled jobs are the ones that will lead to the benefits of flexible workers.

• ***What are the difference between the traditional specialized workers and the multifunctional workers of JIT?***

A cooperative spirit

JIT systems require a cooperative spirit among workers, management, and vendors. Unless that is present, it is doubtful that a truly effective JIT system can be achieved. The Japanese have been very successful in this regard, partly because in the Japanese culture, respect and cooperation are ingrained. In western cultures, workers, Managers, and vendors have historically been strongly at odds with each other. Consequently, a major consideration in operating under a JIT system is to achieve and maintain a spirit of mutual respect and cooperation. This requires an appreciation of the importance of cooperation and a tenacious effort by management to instill and maintain that spirit.

• ***Can Ethiopian manufacturing system develop the JIT system? Why?***

Few, Reliable suppliers

Most JIT systems extend to suppliers, who are required to deliver high-quality parts and/or materials, in small lots, at fairly precise intervals.

Traditionally, buyers have assumed the role of monitoring the quality of purchased good, inspecting shipments for quality and quantity, and returning poor quality goods to the vendor for

rework. In JIT systems, there is little slack, so poor-quality goods cause a
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disruption in the smooth flow of work. Moreover, having to inspect incoming goods is viewed as inefficient because it does not add value to the product. For these reasons, the burden of insuring quality is shifted to the vendor. Buyers work with vendors to help them achieve the desired quality levels and to impress upon them the importance of consistent, high-quality goods. The ultimate goal of the buyer is to be able to certify a vendor as a producer of high-quality goods. The implication of this certification is that a vendor can be relied on to deliver high-quality goods without the need for buyer inspection.

Suppliers must also be willing and able to ship in small lots on a regular basis. Ideally, suppliers themselves will be operating under JIT systems. Buyers can often help suppliers convert to JIT system that integrates the facilities of buyer and supplier. If a supplier is dedicated to only one or a few buyers, this will make integration easier. Practically speaking, a supplier is likely to have many different buyers, some using traditional systems and other using JIT. Consequently, compromises may have to be made to both buyers and suppliers.

Such a spirit of cooperation between buyer and seller has not traditionally been present. In fact, traditionally, buyers and vendors have had a somewhat adversarial relationship. Buyers have typically used multiple-source purchasing, which means having a list of potential vendors and buyer can play vendors off against each other to get better pricing arrangements or other concessions. The downside of this is that vendors cannot rely on a long-term relationship with a buyer; therefore, vendors have not felt loyalty to a particular buyer furthermore, vendors have often sought to protect them selves form losing a buyer by increasing the number of buyers they supply.

- ***Do you need more/less supplier for your company? Why?***

Under JIT purchasing, good vendor relationships are very important. Buyer takes measure to reduce their lists of suppliers, concentrating on maintaining close working relationships with a few good ones. Because of the need for frequent, small deliveries, many buyers attempt to find local vendors to shorten

the lead tome for deliveries as well as to reduce lead-time variability. An added advantage of having vendors nearby is quick response when problems do arise.
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JIT purchasing is enhanced by long-term relationships between buyers and vendors. Vendors are more willing to commit resources to the job of shipping according to a buyer's JIT system given a long-term relationship. Moreover, price often becomes secondary to the other aspects of the relationship (e.g., consistent high quality; flexibility; frequent, small deliveries; and quick response to problems).
A key feature of many lean production systems is the relatively small number of suppliers used. In traditional production, companies often deal with hundreds or even thousands of suppliers, in a highly centralized arrangement not unlike a giant wheel with many, many spokes. The company is at the hub of the wheel, and the spokes radiate out to suppliers, who each must deal directly with the company. Very often, one supplier does not know who the other suppliers are or what they are doing. Each supplier works to specifications provided by the buyer. Suppliers have very little basis (or motivation) for suggesting improvements. Moreover, as companies often play one supplier off against other, the sharing of information is more risky than rewarding. In contrast to this, lean production companies may imply a tiered approach for suppliers: they use relatively few first-tier suppliers who work suppliers are responsible for dealing with second-tier suppliers who provide components for the subassemblies, thereby relieving the final buyer form dealing with large numbers of suppliers.
We find a good example of this in the automotive industry. Suppose a certain model has an electric seat. The seat and motor together might entail about 250 separate parts. A traditional producer might use over 50 suppliers for the electric seat, but a lean producer might use a single (first-tier) supplier who has the responsibility for the entire seats unit. The company would provide specifications for the overall unit, but leave to the supplier the details of the motor, springs, and so on. The first-tier supplier, in turn, might subcontract the motor to a second-tier supplier, the track to another second-tier supplier, and the

cushions and fabric to still another second-tier supplier. These second-tier suppliers might similarly subcontract some of their work to their-tier suppliers, and so on. Each tier has only to deal with those just above it or just below it. Suppliers and so on. Each tier has only to deal with those just above it or just below it, suppliers on each level

are encouraged to work with each other, and motivated to do so because that increase the probability that the resulting item (e.g. the seat) will meet or exceed the final buyer's expectations. In this "team or suppliers'' approach, all suppliers benefit forms a successful product and each supplier’s bears full responsibility for the quality of its portion of the product.

• ***What are the difference between suppliers of traditional manufacturing systems and suppliers of JIT systems?***

Pull versus push

The term push and pull are used to describe two different systems for moving work through a production process. In a push system, when work is finished at a workstation, the output is pushed to the next station; or, in the case of the final operation, it is pushed on to final inventory. Conversely, in a pull system, control of moving the work rests with the following operation; each workstation pulls the output from the preceding station as it is needed; output of the final operation is pulled by customer demand or the master schedule. Thus, in a pull system, work is moved in response to demand from the next stage in the process, whereas in a push system, work is pushed on as it is completed, with no regard for whether the next station is ready for the work. Consequently, work may pile up at workstations that fall behind schedule, say, because of equipment failure or the detection of a problem with quality.

JIT systems use the pull approach to control the flow of work, with each workstation gearing its output to the demand presented by the next workstation. Traditional production systems use the push approach for moving work through the system. In JIT systems, there is communication backward through the system from station to station, so that work moves "just in time" for the next operation, the flow of work is thereby coordinate, and the accumulation of excessive inventories

between operations is avoided. Of course, some inventory is usually present because operations are not instantaneous. If a workstation waited until it received a request from the next workstation before starting its work, the next station would have to wait for the preceding station to perform its work. Therefore, by design, each workstation produces just enough output to meet the (anticipated) demand of the next station. This can be accomplished by having the

following workstation communicate its need for input sufficiently a head of time to allow the preceding station to do the work. Or there can be a small buffer or stock between stations; when the buffer decreases to a certain level, this signals the preceding station to produce enough output to replenish the buffer supply. The size of the buffer depends on the cycle time at the preceding work station: if the cycle time is short, little or no buffer will be needed; if the sequence time is long, a considerable amount of buffer will be needed. Note, however, that production occurs only in response to usage of the following station; work is pulled by the demand generated by the next operation.

Another way to describe the pull system is that workflow is dictated by "next step demand.” There are a variety of ways in which such demand can be communicated, including a shout or a wave, but by far the most commonly used device is the Kanban. Kanban is a Japanese word for “card.” Kanban is a Japanese term that preceding station, he or she uses a Kanban card to communicate this. In effect, the Kanban card is the authorization to move or work on parts. In Kanban systems, no part or lot can be moved or worked on without one of these cards.

- ***What are the difference between pull and push systems?***

The system works this way: A Kanban card is affixed to each container. When a workstation needs to replenish its supply of parts, a worker goes to the area where these parts are stored and withdraws on container of parts. Each container holds a predetermined quantity. The worker removes the Kanban card form the container and posts it in a designated spot where it will be clearly visible and the worker then moves the lot to the workstation. The posted Kanban is then picked up by a stock person who replenishes the stock with another container, and so

on down the line. Demand for parts triggers replenishment, and parts are supplied as usage dictates. Similar withdrawals and replenishments occur all the way up and down the line from vendors to finished-goods inventories, all controlled by kanbans. In fact, if supervisors decide the system is too loose because inventories are building up, they may decide to withdraw some kanbans, thereby tightening the system. Conversely, if the system seems too tight, additional kanbans may be introduced to bring the system into balance.

- ***What are the ways of demanding inventory in your organization? Compare it with Kanban?***

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It is apparent that the number of kanban cards in use is an important variable. The ideal
number or kanban cards can be computed using this formula.

$$N = \frac{DT(1+X)}{C}$$

Where

N = Total number of containers

D= planned usage rate of using work center

T= Average waiting time for replenishment of parts plus average production time for
a
Container of parts.

X= policy variable set by management that reflects possible inefficiency in the system
(the closer to 0, the more efficient the system)

C= Capacity of a standard container (should be no more than 10 percent of daily
usage
of the part)

Note that D and T must use the same time units (e.g. minutes, days)

The usage at a work center is 300 parts per day, and a standard container holds 25 parts.

It takes an average of 12 day for a container to complete a circuit form the time a Kanban
card is received until the container is returned empty. Compute the number of Kanban

cards needed if X = 20.
Solution
N=? C= 25 parts per container
D= 300 pars per day X = .20
T= .12 days
N=
25
300(.12)(1(+.20)
= 1.728(rounded to two containers)
Note that rounding up will cause the system to be looser, and rounding down will
cause it to be tighter. Generally, rounding up is used.
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Problem solving

Problem solving is a cornerstone of any JIT system. Of interest are problems that interrupt, or have the potential to interrupt, the smooth flow of wok through the system. When such problems surface, it becomes important to resolve them quickly. This may entail temporarily increasing inventory levels which the problem is investigated, but the intent of problem solving is to eliminate the problem, or a least greatly reduce the chances of it recurring.

Problems that occur during production must be dealt with quickly. Some companies use alight system to signal problems; in Japan, such a system is called and on. Each workstation is equipped with a set of three lights. A green light means no problems, amber light means a worker is falling a little bit behind and a red light indicates a serious problem. The point of the light system is to keep others in system informed and to enable workers and supervisors to immediately see when and where problems are occurring.

Japanese companies have been very successful in forming teams composed of workers and managers that routinely work on problems. Moreover, workers are encouraged to report problems and potential problems to the teams. Teams may use brainstorming to generate possible solutions, where members meet and share thoughts and ideas on how problems might be resolved. The essence of these sessions is to encourage freethinking, so criticism is discouraged. Furthermore, a group

may prefer to withhold analysis of ideas when they are presented in order to keep from stifling initiative or creating an atmosphere in which there is hesitance in presenting potential solutions.
Groups may also use various statistical tools and quality control techniques such as sampling, control charts, and cause-and effect diagrams. It is important that management at all levels actively support and become involved in problem solving. This also requires a willingness to provide financial support and to recognize achievements. It is desirable to formulate goals with the help of workers, publicize the goals, and carefully document accomplishments. Goals give workers something tangible to strive for, and recognition can help maintain worker interest and morale.

• ***Does JIT encourage group decision making or individual decision making?***

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Continual improvement

The central theme of a true just-in-time approach is to work toward continual improvement of the system-reducing inventors, reducing setup cost and time, improving quality, increasing the output rate, and generally cutting waste and inefficiency,. Toward that end, problem solving becomes a way of life-a "culture" that must be assimilated into the thinking of management and worker alike. It becomes a never-ending quest for improving operations as all members of the organization strive to improve the system.

6.4 JIT versus traditional manufacturing

The preceding pages have described JIT systems and compared them to traditional manufacturing systems. The following table provides a brief overview of those comparisons.

Comparison of JIT and typical U.S. manufacturing philosophies

table 5:1

Factors

JIT

American (traditional) philosophy

Inventory

A liability, every effort must be expended to do away with it.

An asset, it protects against forecast errors, machine problems, and late vendor deliveries. More inventories are "safer".

Lot size

Immediate needs only. A minimum replenishment quantity is desired for both manufactured and purchase parts

Formulas, we’re always revising the optimum lot size with some formula base on the trade-off between the cost of inventories and the cost of setup.

Setups

Make them in significant, this requires either extremely rapid changeover to minimize the impact on production or the availability of extra machineries already setup. Fast changeover makes small lot sizes practical and allows a wide variety of parts to be made frequently.

Low priority issue. Maximum output is the usual goal. Rarely does similar through and effort go into achieving quick changeover.

Queues

Eliminate them. When problems occur,

Necessary investment. Queues permit

identify the causes and correct them. The correction process is aided

succeeding operations to continue in the event of a problem with the feeding operation. Also, by providing a selection of jobs, factory management has a greater opportunity to match varying operator skills and machine capabilities, combine setups, and, thus, contribute to the efficiency of the operation.

Vendors

Coworkers; part of the team. Multiple deliveries for all active items are expected daily. The vendor takes care of the needs of the customer, and the customer treats the vendor as an extension of the factory

Adversaries, multiple sources are the rule, and it's typical to play them off against each other

Quality

Zero defects. If quality is not 100% production is in jeopardy

Tolerate some scrap. We usually track what the actual scrap has been and develop formulas for predicting it.

Equipment maintenance
Constant and effective. Machine breakdowns must be minimal.
As required. Not critical because we have queues available.
Lead times
Keep them short. This simplifies the job of marketing, purchasing, and manufacturing, as it reduces the need for expediting.
The longer the better. Most foremen and purchasing agents want more lead-time, not less.

- ***Summarize the difference between the JIT (Japan) and the traditional production (US) in your own way?***

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6.5 Benefits of JIT systems

JIT systems have a number of important benefits that are attracting the attention of companies that produce using more traditional methods. The main benefits are:

1. Reduce levels of in-process inventories, purchased goods, and finished goods
2. Reduce space requirements
3. Increased product quality and reduced scrap and rework
4. Reduced manufacturing lead times
5. Greater flexibility in changing the product mix
6. Smoother flow of production, with fewer disruptions caused by problems due to quality; shorter set up times; multi skilled workers who can help each other and substitute for others in case of absenteeism
7. Increased productivity levels and utilization of equipment
8. Worker participation in problem solving
9. Pressure to build good relationship with vendors
10. Reduction in the need for certain indirect labor, such as material handlers.

6.6 Converting to a JIT system

The success of JIT systems in Japan has attracted keen interest among manufacturers of the world. A number of well-known firms have converted a portion of their operations to JIT systems.
To increase the probability that conversion will be successful, companies should adopt a carefully planned approach that includes the following elements:

1. Make sure top management is committed to the conversion and they know what will be required. Furthermore make sure that management is willing to provide visible support. Make sure that management knows what will cost and how long it will take to complete the conversion, and what results can be expected.
2. Study the operations carefully; decide which parts will need the most effort to convert.

3. Obtain the support and cooperation of workers. Prepare training programs that include sessions on set ups, maintenance of equipment, cross training for multiple tasks, cooperation, and problem solving. Make sure workers are fully informed on what JIT is and why it is desirable. Reassure workers that their jobs are secure.
4. Begin by trying to reduce setup times while maintaining the current system. Enlist the aid of workers in identifying and eliminating existing problems (bottlenecks, poor quality, etc.).
5. Gradually convert operations, beginning at the end of the process and working backward. At each stage, make sure the conversion has been relatively successful before moving on. Do not begin to reduce inventory until the major problems have been resolved.
6. Convert suppliers to JIT as one of the last steps. Be prepared to work closely with them. Start by narrowing the list of vendors, identifying those who are willing to embrace the JIT philosophy. Give preference to vendors who have long term track records as being reliable. Try to use vendors located nearby if quick response time is important. Establish long-term commitments with vendors. Insist on high standards of quality and adherence to strict delivery schedules.
7. Be prepared to encounter obstacles to conversion.

Obstacles to conversion

There can be numerous obstacles to conversion. Among the most crucial are the following:
1. Management may not be totally committed or may be unwilling to devote the necessary resources to conversion. This is perhaps the most serious impediments; the conversion is likely to be doomed without it.

2. Workers and/ or management may not display a cooperative spirit. The system is predicted on cooperation. Managers may resist because JIT shifts some of the responsibility from management to workers and gives workers more control over the workers. Workers themselves may resist because shared responsibility and
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cooperation is alien to them and because people generally resist change, preferring the unknown to the unknown.
3. suppliers may resist, for several reasons:
Buyers may not be willing to commit the resources necessary to help the supplier adapt to the JIT systems
They may be uneasy about long-term commitments to a buyer.
Frequent, small deliveries may be difficult, especially if the supplier has other buyers that are not using JIT systems
The burden of quality control will shift to the supplier
Frequent engineering changes may be have to make as the result of continuing JIT improvements on the part of the buyer.
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Summary

Just in time systems are designed to produce or deliver just the right products or services in just the right quantities just in time to serve subsequent production process or customers. Some of the key elements of JIT are a pull method to manage materials flow, consistently high quality, small lot sizes, short setup times, uniform work stations loads, standardized components and work methods, close supplier ties, flexible work force, product focus, automated production, preventive maintenance, and continuous improvement.

The JIT system (lead production) is based on a philosophy of eliminating waste and utilizing the full capability of each order. This system was originally developed in Japan but is now being used around the world. The objective of JIT is to improve return on investment. This is done by increasing revenues (though quality, delivery, and flexibility improvements), reducing costs, and reducing the investment required.

A two-card kaban system uses withdrawal and production-order card sets to control production flow. The authorized inventory of a part is a function of the number of authorized cards for that

item. The number of cards depends on average demand during manufacturing lead time, the container size, and a policy variable to adjust for unexpected occurrences. Many other methods may be used to signal the need for material replenishment and production.

The JIT system provides an organizational structure for improved supplier coordination by integrating the logistics, production, and purchasing processes.

Just-in-time concepts have been applied to the production of service. Service organizations that have repetitive operations, maintain reasonably high volume, and deal with some tangible item are most likely to benefit from JIT practices.

For operations having a product focus and competing on the basis of low cost and consistent quality, JIT system advantages include reduction in inventory, space requirements, and paper work and increase productivity, work participation, and quality. JIT systems require fundamental changes in the way all of the business functions are performed. Increasing cooperation and trust between management and labor, basing

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rewards on team rather than individual performance, and replacing adversarial supplier relationships with partnerships are some of the basic cultural changes involved in JIT system implementation.

Reducing lot sizes, setup times, and lead times is the key to decreasing inventories in a JIT system. The objective is a lot size of one unit. This is done through a small group improvement activities and management and labor cooperative efforts.

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