COMPUTER ASSISTED INVENTORY CONTROL SYSTEM

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ABSTRACT

The basic purpose of holding inventories is to provide an essential decoupling between demand and unequal flow rate of materials in a supply chain. Therefore, a major issue in supply chain inventory management is to coordinate inventory policies adapted by the different supply chain actions. This includes integration of information coming from vendors, manufacturers and distributors, so as to smooth up the flow of materials in, through and out of a manufacturing firm, in a more responsive way to customer's demand. The main drawback for effective inventory management is the lack of accurate and timely information, especially at the operational level. The materials information system enables management to use the inventory classification scheme for tighter control, to determine material requirements, to handle schedule changes, to evaluate vendors, and to utilize material exchanges more effectively. The information system in business and manufacturing organizations is better organized with the help of computers. In a computer based system, the flow of information within the different departments of an organization and with the external environment can easily be maintained. A computer based decision support system may possess additional decision-aiding tools like selective inventory control techniques, EOQ determination, demand forecasting, statistical analysis etc. This paper briefly presents an integrated and systematic approach towards the management of independent demand inventories using computer database systems.

INTRODUCTION

Most production systems contain inventories. Production cannot operate effectively unless it is backed by a series of efficient service functions, one of which is materials management. Its main objective is to ensure that work-centers are supplied with the right type of materials and components at the desired time with the required amount. Inventory is the amount of raw materials, consumable items, components and spares, semi-processed materials, fuel and lubricants, finished goods, etc. that should be stocked for the smooth operation of a plant. Any enterprise, whether engaged in production, construction or scientific research could not run properly and make further developments without inventories. It costs money to maintain inventory; therefore, inventories are inherently undesirable in the sense that storing them does not contribute to the direct transformation of materials and represents a non value added cost of doing business. However, poor inventory control always results in low economic performance and even bankruptcy.

Many manufacturing or service organizations, in which the flow of thousands of different items are to be managed manually, the control of inventories is a cumbersome and monotonous job. If a computerized system is implemented to ensure that stocks are properly controlled and secured, the painstaking task of creating too many documents and data processing will be reduced; moreover, accurate stock records can be maintained. Computers can use data in receipts and withdrawals to manage the amount of stock-in-hand in a fraction of minutes for all items. In today's competitive and global market scenario, managers should use the computer technology in data processing and communication networking as they have gained the ability to access and manipulate a large data of information.

Literature Review

In the past, many researchers have worked in the area of inventory control. However, very less amount of work has been done in the area of computer applications to inventory management. During the last decades, computers have gained acceptance in many big and medium size firms. Computer information systems have been a source of much controversy until very recent years. Manthou[1] presents a case study on the use of computer information system in the area of inventory management for medium to large companies of northern Greece, and Hong[2] shares the experience shown in China at a certain boiler works plant. Both researchers have commented on the requirement of an integrated approach to inventory management, qualified and trained store personnel, and use of decision support systems with the help of computer software.

The performance of a manufacturing process is traditionally associated with the quality of its output and with its productive effectiveness and efficiency; and depends on the way the process has been designed, built and operated. The paperless office or factory is often spoken as the place of the future. Alan Keene[3] considers the role of shop floor data collection in automatic information flow throughout a manufacturing process. The development of new products entails knowledge generation and transfer between organizational units, plant maintenance requires historical data, so that information storing and retrieval are crucial, and both processes are affected by the knowledge involved as a result of technology and human skill. Garavalli[4] has considered a computer knowledge based model that can be used to measure, interpret and control essential information.

Mohan[5] briefly summarizes the features and technologies implemented in the IBM relational data base management system (DBMS) products. Record and index management, concurrency control and recovery methods, high availability and support for parallelism, query optimization and execution techniques and distributed data are being considered.

For manufacturing companies, to satisfy the customer's demand with a delivery time shorter than the total lead-time required at least a part of the manufacturing process must have been started before the customer order arrives. To achieve this, Segerstedt[6] has recommended a reorder point system (ROP) or material requirements planning (MRP) algorithm to be used in a practical inventory system. For each item stored in the database, the reorder level is decided such that the available inventory will satisfy the demand until replenishment arrives. The order size is settled by a calculated economic order quantity and/or decided by the user adjusted to a suitable packing, price discount, annual demand etc. [6].

MATERIALS FLOW IN SCM

Most prominent companies have a backing of an efficient Supply Chain Management (SCM): from finding reliable sources of supply to distributing their end products, through buying of right quality material-components and processing. A supply chain is a network of organizations that are involved in the different activities to increase the value of products and services. Such activities are mainly the procurement of materials, the transformation of these materials into intermediate and finished products, and the distribution of finished products to end-users.

An effective management and control of materials flow across the boundaries between companies and their customers is vital to success of both. Hence, Supply Chain Management (SCM) is concerned with the integrated management of the flow of goods and information through the supply chain so as to ensure that the right goods are delivered in the right place and quantity at the right time. Therefore, materials management can be defined as the aggregate of management functions that support the complete cycle of materials flow; from the purchase to internal control of production materials, from the planning and control of work-in-process to the warehousing, shipping, and distribution of finished products.

Integrated Materials Management

Various functions served by materials management include materials planning, purchasing, receiving, warehousing, scrap and surplus disposal. If some of the functions were to be separately handled, normally a conflict of interest occurs. Purchasing department, if allowed to operate independently, may make decisions, which result in sub-optimization. For example, under a separate set-up, the purchase department may treat discount as a very important factor and buy large quantities of materials to benefit from the discount without taking into account of its impact on the warehousing and carrying costs. Organizations, which have operated through the concept of Integrated Materials Management (IMM), usually get the following advantages:

- Better accountability,
- Better coordination,
- Better performance, and
- Adaptability to computer data-processing system development.

Integrated materials management can be described as the function responsible for the coordination of planning, sourcing, purchasing, moving, storing and controlling materials in an optimum manner so as to provide a pre-decided service to the customer at a minimum cost. The scope of materials management is vast and the following functions can be broadly identified:

- Materials Planning and Control,
- Purchasing, and
- Stores and Inventory Control

Materials Planning and Control

The basic nature of any manger's job is planning and control. Hence, the materials planning and control function is given a prominent place in the integrated materials management set-up. Planning for materials and working out a realistic budget not only help motivate workers but also serve as a control device. Based on the sales forecast and production plans, the material planning and control is done. This involves estimating the individual requirements of parts, preparing materials budget, forecasting the levels of inventories, scheduling the orders and monitoring the performance in relation to production and sales.

Purchasing

Purchasing includes selection of sources of supply, finalization of terms of purchase, placement of purchase orders, follow-up, maintenance of smooth relations with suppliers, approval of payments, evaluating and rating of vendors, etc. It ensures continuity of supply of raw materials, sub-contracted items and spare-parts and at the same time reduce the ultimate cost of finished goods. Such important terms like right price, right quality, right contractual terms, right time, right source, right material, right place, right mode of transportation, right quantity and right attitude are referred as purchasing parameters.

Stores and Inventory Control

Maintenance of store records, proper location and stocking. Stores is also responsible for the physical verification and reconciling them with book figures. The inventory control covers aspects such as setting inventory levels, ABC analysis, fixing economical ordering quantities, setting safety stock levels, lead time analysis and reporting.

INVENTORY CONTROL FUNDAMENNTALS

Inventory is stores of goods and stocks. Stock keeping items usually are raw materials, consumable items, work-in-process, finished products and other supplies. Inventory control is an activity that maintains the stock keeping items at desired levels. Operations management focuses on the conversion of inputs into outputs of goods and services. There may be stock points at the input (raw materials), conversion (work-in-process), and output (products) stages during the process (Fig. 1).

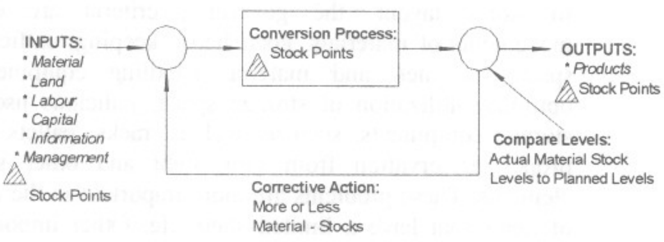

Fig. 1 Material Conversion Process

Inventories are neither completely bad nor entirely good. Too many inventories cause excessive holding costs, extra space-requirements, and product obsolescence. Companies accumulate finished-goods inventory to help level the production schedule when demand is not uniform. Inventories of finished goods or subassemblies may be held so that the company can respond to customer demand in less than the lead-time required. Inventories of in-process inventories between stages of production allow some processes to run at rates that differ from those of the processes that feed them or that use their output. The fundamental reason for carrying inventories is that it is physically impossible and economically impractical for each stock item to arrive exactly where it is needed at the exact time of requirement. Therefore, inventories may be classified into four major categories: Production inventories, In-Process inventories, Finished Goods, and Maintenance and operating supplies.

Warehouse Management

Stores play a vital role in the operations of a company. It is in a direct touch with other departments in their day-to-day activities. The most important purpose served by the stores is to provide uninterrupted service to the manufacturing, maintenance and production divisions. Furthermore, stores are often equated directly with money, as money is locked up in the stores. In order to serve the users with raw materials or spare parts immediately on request, the items have to be stored in the warehouse. Many decisions in stores management such as: selection of racks, bins, handling equipment, safety practices, codification, training personnel and accounting requires considerable skill and ability to coordinate with other departments as well as with outside agencies.

In stores layout, the governing criteria are easy movements of materials, good house keeping, sufficient space for men and material handling equipments, optimum utilization of storage space, judicious use of storage equipments, such as shelves, racks, pallets and proper preservation from rain, light and other such elements. These problems are more important in the case of items that have a limited shelf life. Other important factors governing the location are the number of end users and their location, the volume and the variety of goods to be handled, the location of the central receiving section and accessibility to modes of transportation such as rail or road.

The activities of receiving the goods, stocking in appropriate locations, material handling and issues must be done swiftly and economically. The stores building must have adequate facilities for preservation of stores. Sometimes facilities such as cold storage, heating equipments, air-conditioning and similar facilities may be required. These should be planned in advance. Comfortable working conditions must be provided to the stores personnel to get maximum efficiency and morale. Therefore, the important factors in the design of stores building are availability of sufficient lightening and safety measures.

Management of Spare-Parts

In this interdependent world the requirement of spares is indispensable and their management is influenced by a variety of different factors. Spare parts can be defined as parts identical to the part of a machine, which need replacement due to wear and tear during the operating life of the equipment. Spare parts may look small and appear cheaper than the machine or raw material, but they play a vital role in maintaining, ensuring and reinforcing the reliability of any equipment.

Peculiar features of spare parts that distinguish them from other types of stock keeping materials are [7]:

- their requirement is very small and uncertain, hence uneconomical to manufacture,
- they are large in variety and difficult to standardize
- there are problems in identification,
- decision making is delegated to lower management levels,
- a small range of item is able to meet a large percentage requirement,
- there is lack of sufficient information system,

It is necessary to have an integrated and innovative approach covering all aspects of the spare parts field in order to meet the complexities and challenges. In this context, government organizations, public sector undertakings, private sector firms, industry associations, professional associations, and academic institutions can play a crucial role in improving spares management and increasing the capacity utilization in Ethiopia.

Obsolescence, non-moving and scrap are words which are not liked by any prudent manager, even though they occur commonly in the spare parts field of every organization in all the sectors of the economy. Obsolescence is observed in several areas such as management, technology, spare parts, store items, and even human life. The challenge before the spare part managers in the context of obsolete and non-moving spares is how to reduce if not able to eliminate the incidence.

A distinction can be made between surplus and obsolete items in that the former can be consumed at some future time, while the obsolete item is unlikely to be used in future. *Surplus* materials arise because they are in excess of a reasonable rate of consumption due to wrong judgement at the procurement stage. *Scrap* can be defined as the residue from a manufacturing process, which can not be economically used within the organization. *Obsolete spares* are those spare parts, which are not damaged and have some common economic worth but are no longer useful for the company's operation due to several reasons.

In order to minimize the accumulation of obsolete items, the possible causes have to be first analyzed. The common reasons for obsolete spares can be summarized as follows [8]:

- The transfer of the project surplus items to the main stores which may not fit regular consumption in future,
- Introduction of non-planned and sudden technological changes or design modifications, with out adequate preparation, renders spares of old machinery to be obsolete,
- Maintenance staff tends to categorize many non-moving items as insurance spares, which are not likely to be used for a very long time. It is desirable to keep only one such standby to avoid incidence of obsolescence,
- Adoption of standardization and elimination of non-standard varieties have led to obsolescence of the non-standard spares,
- When a machine breakdown occurs, it is rectified by using parts of an identical machine. When continued unchecked, the remnants of the cannibalized machinery become obsolete,
- Sub-optimizing decisions like bulk buying to take care of discounts or freight advantages to take care of economic batch quantities of manufacture, without adequately considering factors such as shelf life, storage space requirements, and technological changes, leads to obsolete spare parts.
- In some organizations spare parts continue to be ordered on the basis of previous year's operation even though the equipment has been phased out of commission, due to communication gaps,
- The stores continue to keep spares even though the equipments using the spares have been sold,
- Changes in product mix, fashion, style, modernization, rationalization, etc. to meet market demands may render the existing stock of spares obsolete.
- Inability to carryout the failure analysis and forecast the future requirement or spares sales, leading to non-moving and obsolete stock.

In each of the above reasons for obsolescence, one can infer the solution as better planning, forecasting, use of scientific methods, information systems, records and communication. For instance, design changes, technological upgrading, equipment discard policies, and product mix changes, etc must be communicated in advance to the parts executive. This will enable the purchaser to freeze pending orders and modify forecasted plans accordingly.

- There are different cost reduction techniques, which can be applied for spare parts management. These may include:

- Lead time analysis,

$$\begin{pmatrix} Total\ \ annual \\ relevant\ \ costs \end{pmatrix} = \begin{pmatrix} Cost\ \ of \\ the\ item \end{pmatrix} + \begin{pmatrix} Procuremen\ \ t\ or \\ Setup\ \ cost \end{pmatrix} + \begin{pmatrix} Inventory \\ Holding\ \ cost \end{pmatrix} + \begin{pmatrix} Stockout \\ Cost \end{pmatrix}$$

- Identification by codification,
- Value analysis,
- Timely disposal of obsolete items,
- Selective inventory control,
- Preventive maintenance policies,
- Maintenance documentation,
- Computer applications for spare parts management,
- Variety reduction by standardization, and
- Spares bank,

Relevant Inventory Costs

Having inventory in stock costs money. As a company increases its inventory, some costs increase, other costs decrease, and still some other costs are unaffected. Those costs not affected by the decision at hand can be ignored in the analysis of inventory. The costs affected by the decision are called relevant costs and obviously should be considered in reaching a decision if the amounts are not trivial. In operating an inventory system, managers should consider only those costs that vary directly with the operating doctrine in deciding when and how much to reorder; costs independent of the operating doctrine are irrelevant. Basically, there are five types of relevant costs:

- Cost of the item,
- Cost of procuring the item,
- Cost of carrying the item in inventory,

- Cost associated with being out of stock when units are demanded but are unavailable, and
- Cost associated with data gathering and control procedures for the inventory system.

The main objective in inventory control is to find the minimum cost operating doctrine over some planning horizon. We need to consider all relevant costs: - the cost of the item, procurement cost, carrying cost, and Stockout cost. Using a one-year planning horizon, these costs can be expressed in a general cost equation:

Each cost in the equation can be expressed in terms of order quantity and reorder point for a given inventory situation. The solution method is then to minimize the total cost. For a simple model in which cost of item and cost of stockouts are irrelevant, the tradeoff is between only two costs: procurement and carrying cost.

The annual carrying costs increase with larger values of order quantity Q. This is logical; large values of Q result in large average inventory levels and therefore a large carrying cost. Likewise, when Q is large, fewer orders must be placed during the years so that the annual procurement cost decreases (Fig. 2). The optimal order quantity Q^* is the point at which annual total cost is at a minimum.

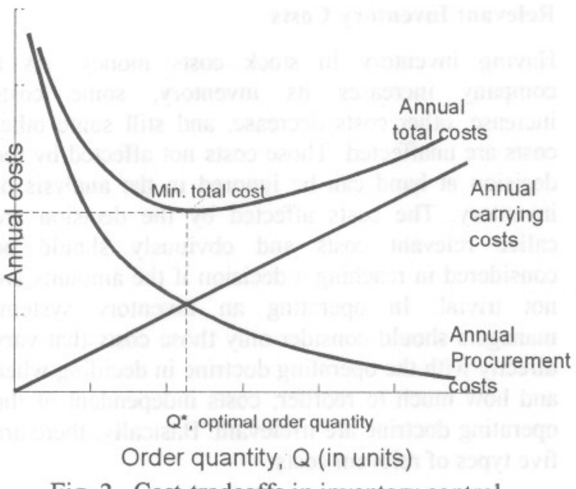

Fig. 2 Cost-tradeoffs in inventory control

Combining ordering cost, purchasing cost, and holding cost the total annual relevant cost is given as:

$$Tc(Q) = S\frac{D}{Q} + CD + IC\frac{Q}{2}$$

Where S is the setup cost per order, D is the demand per replenishment period, C unit cost of item, I holding cost per item per cost and Q the quantity to be ordered. To find the value of Q^* that minimizes the total cost, Tc, we set $Tc' = d\frac{Tc}{dQ}$ to be equal to zero.

$$Tc'(Q) = d\frac{T_c}{dQ} = -S\frac{D}{Q^2} + \frac{IC}{2} = 0$$

$$\Rightarrow Q^* = \sqrt{2S\frac{D}{IC}}$$

INVENTORY CONTROL SYSTEMS

An inventory system is a collection of people, equipment and procedures that function to keep account of the quantity of each item in inventory and to determine which items to purchase or make in what quantities and at what times. The goal of an inventory control system is to see that a company has items on hand when they are needed with out ever having too many inventories in stock. An inventory system should indicate when the level of a stock item is low enough that it is time to reorder. This level of inventory is called the *reorder point*. In a good inventory control system, only the right quantities of each item are ordered when required.

Control over inventories means good long range and intermediate planning of production operations, good production scheduling and good methods of control. A comprehensive inventory-control system, including production planning, scheduling and control must be closely coordinated with other planning and control activities such as cash planning, capital budgeting and sales forecasting, since it impinges on a wide range of production, sales and the financial policy and operating decisions.

Demand Forecasting Methods

Depending on the shape of the demand curve, some of the important individual item short-term forecasting and aggregate medium-range forecasting techniques which can be employed in inventory control are:

- Linear and quadratic regression,

- Moving average, and
- Exponential smoothing.

Managing of Dependent-Demand Inventories

Dependent demand as the name implies is directly related to the demand for another item or other items that are required to make some other item. Therefore, instead of requiring forecasts, dependent demand of an item can be derived or calculated from the demand for the item of which it becomes a part. Dependent-demand items often are managed by material-requirements-planning (MRP). Some companies have also successfully implemented the just-in-time (JIT) approach to keep inventories as low as possible.

Managing Independent-Demand Inventories

Independent-demand is demand for an item in its current form from some user outside the organization that has the inventory. The item may be a finished good sold for use as it is, a repair or service part or a subassembly that some other organization will further transform into a final product. Independent-demand items serve customers directly. Sufficient, but not excessive, inventories of these items provide customers with a dependable source of rapid supply. Since the demand rate is determined by some entity outside the producing organization, demand is not known for certain and must be forecasted. Managing these inventories wisely helps prevent excess stocks and keeps costs low, so a high level of customer service can be maintained at reasonable costs.

Different mathematical models have been used to help determine the most economical amounts to add to inventory and when they should be added. Since the beginning of the 20th century, many complex and sophisticated models have been developed and proposed to help manage independent-demand inventory items. Complex models, however, often apply to a rather specialized, restrictive set of conditions. Only the more general characteristics of basic models and the types of systems that employ them will be dealt here for practical purpose of independent-demand inventory management. Operation managers must make two basic inventory policy decisions: when to order stock and how much to reorder. These decisions are referred to as the inventory control *operating doctrine*. As part of the operating doctrine, the inventory level at which stock should be reordered is called the *reorder point* (***R***). The amount of stock that should be reordered is called the *order quantity* (***Q***). Both the inventory level that signals the reorder and the order quantity are economic decisions at the heart of the operations manager's inventory control function. Although the manager may not actually operate the system, he/she is responsible for setting this operating doctrine. Since companies may stock thousands of different independent-items, they need some fairly simple and reliable way to indicate when each item should be purchased and in what quantity. Independent-demand items that come from outside the organization can be managed by fixed quantity, fixed interval or minimum-maximum (2-bins) inventory control systems.

Selective Inventory Management

Many existing inventory management systems can be significantly improved by simply adopting decision rules that do not treat all stock items equally. Inventories with higher annual dollar volume deserve more attention, because they can potentially yield higher profits or else big losses. On the contrary, inventories with lesser annual dollar value does not deserve this frequent follow up and attention as controlling of inventories cost money. Therefore, assigning a priority rating to each stock item is recommended in maintaining inventories. The number of item categories appropriate for a particular company depends on its circumstances and the degree to which it wishes to differentiate the amount of effort allocated to various groups of inventories. Usually, it is common to use three priority ratings. For example, items can be grouped as 'A' (most important), B (moderately important) and C (less important) items. Sometimes, other bases of classification can also be used depending on the pertinent inventory situation in a particular company.

Inventories that are to be held might not all be managed in the same way. Selection of an inventory control method depends on a number of factors: the length of time the company intends to maintain the inventory, the type of demand it is to serve, the cost of item, the number and type of items in stock, the degree of control desired, and so on. Depending on various operating factors, stock items may be classified on different bases for ease of inventory control. The important bases of inventory-classification are discussed below.

- *ABC-Analysis:* This is one of the basic principles of selective inventory control as applied to materials management by grouping items as *A*, *B* and *C*-items. In ABC analysis items are grouped on the bases of their relative value or money usage.
- *VED- Analysis:* This analysis pertains to the classification of materi·ls and maintenance spares denoting the criticality of the items as a main factor:
- *FSN-Analysis:* In this case, the quantity and rate of consumption of items by company is analyzed in order to group items for selective inventory management.

Inventory Modeling

Inventory modeling is a quantitative method for deriving a minimum cost operating doctrine. Thus, the purpose of modeling inventory situations is merely to derive an optimum operating doctrine, and four basic steps may be involved in the process:

- Examine the inventory situation carefully, listing characteristics and assumptions concerning the situation,
- Develop the total annual relevant cost equation in narrative,
- Transform the total annual cost equation from narrative into the shorthand logic of mathematical descriptions, and finally
- Optimize the cost equation, finding the optimum for how much to order (*EOQ*-economic order quantity) and when to re order (R-reorder point).

Inventory models can be classified as either *deterministic* (variables are known with certainty), or *stochastic* (where variables are probabilistic).

The Basic EOQ /or the Simple Lot-size/ Model

The previous derivation of optimum order size is often called the basic *EOQ* model or the simple lot size formula. Ford Harris and R.H. Wilson apparently derived the formula in 1915.

The ideal deterministic inventory situation for this model is characterized by the following assumptions (Fig. 3):

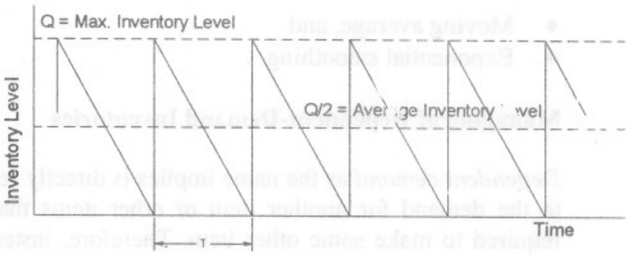

Fig. 3 Inventory level for an ideal procurement situation

- Demand is deterministic and occurs at a constant rate,
- If an order of any size is placed then an ordering and setup cost S is incurred,
- The lead time for each order is zero,
- No shortages are allowed, and
- The cost per unit year of holding inventory is $H = IC$.

Further, D is defined as the number of units demanded per annum and Q units are ordered each time when inventory level is zero. Given the five assumptions, the *EOQ* model determines an ordering policy that minimizes the yearly sum of ordering cost, purchasing cost, and holding cost. As already derived, the economic order quantity or *EOQ* is given by:

$$EOQ = Q^* = \sqrt{2S\frac{D}{IC}} \text{ units}$$

Stochastic Inventory Models

One reason for stocking of inventories is to allow production or procurement in economic lot sizes. Another reason for inventory is to protect against uncertainty of demand. In reality, one does not know precisely the number of units that will be demanded each day during the lead-time. Thus, demand can be thought of as a probabilistic variable with some expected amount of demand during a period of time and an explained variation about the expected value. Also the duration of lead-times may have unexplained or unexpected variation (Fig. 4).

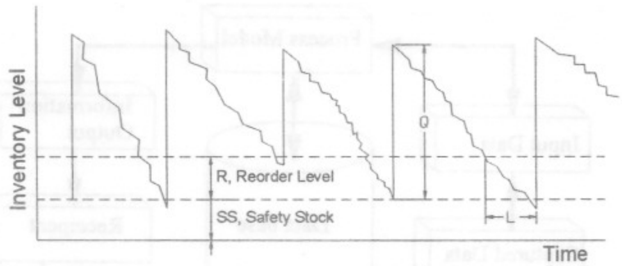

Fig. 4 Inventory Level for Variable Demand Situation

Variable Demand: for simple inventory models, we assumed that future demand is known with certainty. Generally, however, this is not the case; demand must be estimated. The most common way to estimate demand is to collect past data and forecast future demand based on the data.

Variable Lead-Time: like demand, is often uncertain rather than constant. If it is uncertain, the length of lead-time takes on some distribution.

Demand During Lead-Time: the two sources of demand variation during lead-time: the length of lead-time itself, and demand per time period of lead-time interact to determine demand during lead-time.

$$\begin{pmatrix} Expected\ demand \\ during\ lead\text{-}time \end{pmatrix} = \begin{pmatrix} Exp.\ demand \\ per\ unit\ time \end{pmatrix} \begin{pmatrix} Average \\ Lead-time \end{pmatrix}$$

$$\Rightarrow \qquad \hat{D}_L = \hat{d}.\hat{L}$$

The order quantity is simply the simple lot size formula with expected annual demand substituted for annual demand:

$$EOQ = D^* = \sqrt{2S\frac{\overline{D}}{IC}}$$

Because of demand's variable nature, the demand distribution may take on different shapes. It may be a very unconventional empirical distribution, or it may be a normal distribution, Poisson distribution, or exponential distribution. Using the expected average demand in the *EOQ* formula is appropriate for this model regardless of the shape of the demand distribution.

Safety Stock

The safety stock *SS*, required to safeguard stockouts is determined by a probabilistic analysis of the demand-forecast error. The distribution of demand-forecast error for independent items is assumed to be a normal distribution, and henceforth a normal probability density function is used to decide upon the value of assurance or safety factor. The safety stock is then computed by multiplying the standard deviation of the forecast error, σ_d, by safety factor of standard deviation, k_{SD}.

$$SS = k_{SD}.\sigma_d$$

$$and, \quad REL = SS + \hat{D}_L$$

An alternative and perhaps easy approach of measuring the variability of forecast errors is by employing the concept of mean absolute deviation, *MAD*. Mean-absolute-deviation of forecast errors can be approximated as the mean value of the latest three error magnitudes.

$$MAD \cong \frac{|D_1 - \hat{D}_1| + |D_2 - \hat{D}_2| + |D_3 - \hat{D}_3|}{3} \qquad (7.6e)$$

By definition, *MAD* can also be related with standard deviation as:

$$\text{MAD} = \sigma_d\sqrt{\frac{2}{\pi}} \cong 1.25\sigma_d$$

$$\text{Thus,} \quad \text{SS} = k_{SD}.\sigma_d = k_{MAD} MAD$$

$$\text{where,} \quad k_{MAD} = 1.25(k_{MAD})$$

The safety factor, k_{SD} or k_{MAD}, depends on the level of assurance required to safeguard stockouts and is found from a normal probability density function of forecast errors. Therefore, prior to selecting a safety factor, a decision table of expected assurance-levels for each individual item is formulated by the inventory controller on the basis of item groupings on account of their criticality and value analysis. Presumed values of expected assurance levels, which can be used in practical applications, are shown in Fig. 5 as an example.

		ABC-Analysis		
		A	B	C
Criticality Analysis	V	75 %	90 %	99 %
	E	50 %	75 %	90 %
	D	50 %	50 %	75 %

Fig. 5 Expected Assurance Levels (Sample values)

COMPUTER APPLICATION TO IC

Properly designed software systems on a personal computer offer great potential for aiding decision-makers, in all sizes of organizations, for inventory controlling and production planning. In inventory management, a computer assisted order quantity determination and reorder point control can be exercised. Receipt and issue documents can be stored in a database program to carryout various inventory analysis. In addition a computer system provides specially designed reports to different levels of users; for example, information on aggregated basis for senior management, on an exception basis for middle management and on detailed basis for clerical staff.

Many firms have benefited from applications of computers without being aware that computers are working for them. One aspect of computer automation that affects both manufacturing and service sectors is *office automation*. Paperwork is a major part of the processing in most service industries, and often it is the end product. Office automation in manufacturing companies usually has the greatest effect on workers in the support functions. In either case, however, classical office automation procedures are designed to assist personnel with repetitive physical tasks, even though the work the automation supports may be highly cognitive.

Management Information System

Much of the progress in automatic manufacturing and services is related to progress in the ability to transmit, store and execute digital data and commands. Information is data that have been put into a meaningful and useful context and communicated to a recipient who uses it to make decisions. The purpose of Management Information System (MIS) is thus to collect data related to the external world and the internal operations within the company and convert the data to valuable information.

Advances in technology are rapidly transforming the workforce from one that endures long hours of physical effort into one that is dependent on information both as producers and users. The quality of information rests on four pillars: *accuracy, timeliness, reducing uncertainty,* and *relevance*. A simple schematic diagram that represents cycle of information flow is shown in Fig. 6.

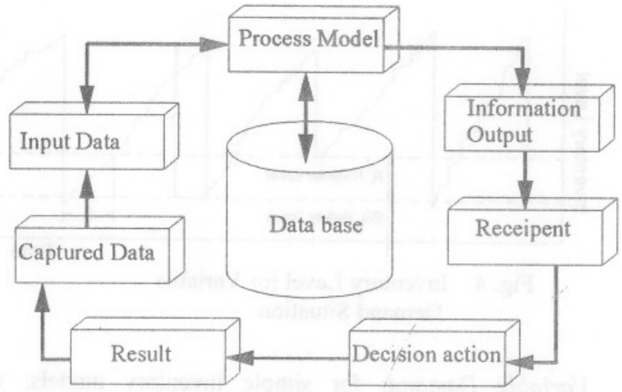

Fig. 6 Information Cycle

Information technology (IT) is all pervasive and used in many parts of companies in a wide variety of businesses. A business benefits from IT depend on data communication and the capability to network computers. Computers gained the ability to exchange data, sometimes even at great distances so that many employees at different places could work with a common database. Employees can now generate, test and exchange ideas that help a business perform better and quicker. IT is having a great impact on how companies provide goods and services and how they operate and are properly managed.

Electronic Data Interchange (EDI)

Electronic Data Interchange (EDI) involves the use of standard formats and compatible hardware so that those computers in two different companies can exchange messages or "talk each other". Some companies have found certain advantages in electronic data interchange to exchange reliable data with their business partners. A computer at a large retailer, for example, can send inventory records to determine which items are below their reorder levels. A buyer can indicate which items are to be purchased. The computer can prepare purchase orders, sort them, and store them electronically in designated "mailboxes" in its memory or in its database at a time share data service. Through a data link, a computer at a vendor company will periodically check the mail in its box. The vendor's computer then enters the purchase order into its order entry system prepares a pick list to withdraw the proper items from its inventory and prepares the packing slip to ship it. This processing eliminates the handling and keying of data and is much faster. Later the vendor's computer can transmit data back to the retailer's computer regarding the items that have been shipped. The retailer knows what goods are in transit, so the price tickets can be prepared and ready when the goods arrive, naturally, such applications of EDI require standardized formats and communication protocols, just as communication within a company does. In fact, EDI is helping many companies, which are targeting to achieve "zero-inventories' by implementing the Just-In-Time (JIT) supply chain management.

Database Management System Development (DBMS)

Database management activities involve the design, maintenance, and use of collections of data describing an organization's activities. These comprehensive collections of data, usually called database, can also be computerized. The requirement for database management activities becomes greater as computer systems are used to support the needs of analysts and decision-makers at higher managerial levels. Successful database management begins with effective database design.

Data Base Management Systems (DBMS) have become so well accepted as basic tool for management of business information systems. Organization's information systems must have a sound foundation in development of a database system. The decision to develop business information systems in a DBMS environment can represent a major commitment of organizational manpower and monetary resources. Therefore, the decision should involve the participation of top management outside the information systems organization. Database management involves both philosophy as well as technology, so that an awareness of the advantages of this implementation approach for reasons of managerial control as well as technical efficiency should be developed. The heart of database management system is the explicit consideration of data as a corporate resource, which like any other resource, must be managed and maintained. Further, the centralized data administration activities required to operate a successful corporate database system may have a major impact on organizational power and responsibility relationships.

To facilitate the process, a structure such as a pre-printed form or columns labeled on a spreadsheet or in a ledger book is often developed. In computer systems, this structuring of data is of critical importance to enable its later retrieval. This data hierarchy has the following components:

- Character,
- Field, Data Item and Data Element
- Record
- Recordset /File
- Database

Activities usually performed with data processing in either manual or computer-based database systems include:

- Recording
- Storing
- Retrieving
- Selecting or Classifying
- Sorting
- Computing
- Displaying

Performing any combination of the seven activities just described is called *data processing*, and when performed with the assistance of computer hardware and software it becomes *electronic data processing* or simply *EDP*. The processed data made useful for decision-making purposes is what we defined as *information* and the system that does the processing is a *database information system*. For instance, an inventory controller may want to use data processed by an inventory system to help him/her make accurate purchasing decisions.

Inventory Controlling with Computer

Computers can use data on receipts and withdrawals of materials to maintain the amount of stock on hand for all the inventory items controlled by the computer system. A software application can be used to keep track of the on-hand balance and perform other functions, such as reporting items that are below their reorder levels and recommending the economic quantity to buy or produce.

Computer programs are used to control the level of inventories and to provide materials at the right time and quantity. Computer can handle and process various historical data on price levels, lead-time analysis, replenishment period demand analysis, vendors delivery performance, and so on very easily. Various controlling tools such as ABC analysis, and EOQ determination can be programmed into the computer so that tedious and time-consuming calculations are avoided for ease of inventory controlling. Factors such as safety stock, maximum stock level and reorder points require statistical analysis; and when thousands of items have to be carried, it will be quite impossible to control them manually. The computer may also print or display a list of items, each day, showing that replenishment is needed as the on-hand balance is under the reorder level. Sometimes preferred vendor identification for each item is stored in the database, so that the computer can automatically prepare the purchase orders to be sent; or alternatively an Electronic Data Interface, as it was explained, can be used to automatically transmit orders.

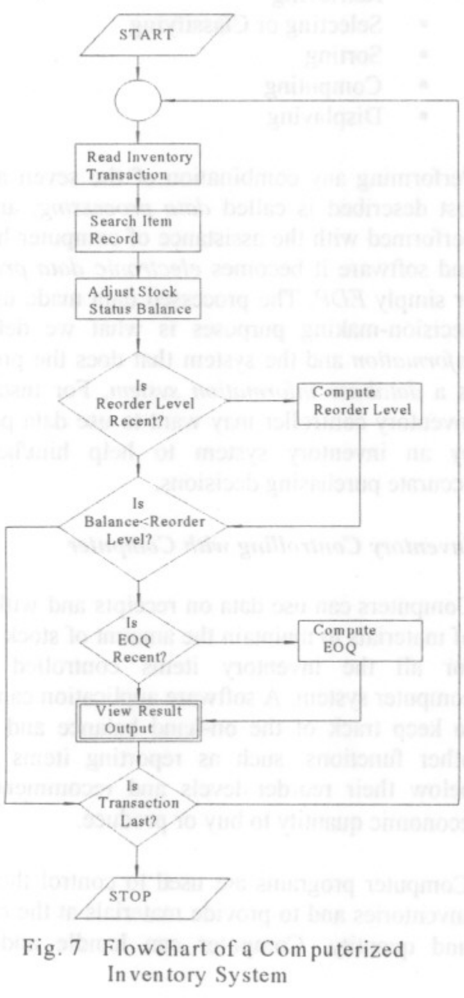

Fig. 7 Flowchart of a Computerized Inventory System

Figure 7 represents a simplified flowchart for an independent-demand inventory control system to provide an overview of the decisions and calculations that might be made in such a system. Just like many other computer programs, the development an inventory controlling application software should pass through a sequence of four phases.

Phase I: System Analysis

- Information gathering through
  - interviews, and
  - document collection
- Defining current system,
- Problem recognition,
- Determine new system requirements, and
- Determine visibility of automating.

Phase II: System Design

- System level flowcharting,
- Design of the user's interface:
  - The working environment,
  - Input/output forms, and
  - Event driven control modules,
- Design of the database system, and
- Design of reports.

Phase III: Program Implementation

- Determine processing steps,
- Develop modular implementation,
- Program coding of global modules, and
- Debugging of the program.

Phase I: Operation & Maintenance:

- Error detection and correction,
- Testing and further maintenance,
- Improvements of system's application, and
- Response to changing environment.

CONCLUSION

An integrated approach to inventory decisions with the help of appropriate materials information system is considered in this paper. An attempt is made to promote awareness for the requirement of MIS in the area of inventory management. The distinct advantage of an integrated computer system is that it involves the line personnel and provides timely and quick information on inventory status of stocked items. It is also used for operational convenience by giving flexibility in decision-making actions. It avoids the monotonous manual work that has been invested in creating too many documents and preparing summarized reports. It is therefore essential to computerize a company's working system, if a sound materials management is to be implemented. In Ethiopia, such a computerized system is almost non-existent in most of the industries at the required level. The capabilities of available computer software and hard ware facilities are not being exploited to the desired purpose. The main problem is believed to be inadequacy of qualified personnel in the area of information technology and lack of senior management's commitment. Technical and communication skills are so vital in developing an integrated information system to the operation of a company. Hence, training of new recruits and existing employees is essential. Management should be aware that it is high time, for most of medium to large industries, to introduce an integrated information system if they want to remain competitive in today's global market scenario.

REFERENCES

[1] **Manthou, V.,** *"Concepts and Applications of Inventory Management in Northern Greece"*, International Journal of Production Economics, Vol. 35, 1994, 149-152.

[2] **Hong, Yang; Cheng Zhong, Xiao,** *"Computer-aided inventory control system in china"*, International Journal of Production Economics, Vol-35, No 1-3, June 1994, 153-159.

[3] **Keene, Alan,** *"Automatic Data"*, Manufacturing Engineer, Vol-74, No-3, Jun 1995, 131-133.

[4] **Garavalli, A. C.; Michele, G.; Schiuma, G.,** *"Inventory management in supply chains: a reinforcement learning approach"*, Eleventh International Working Seminar on Production Economics, Congress IGLS, February 2000, Austria, 209-218.

[5] **Mohan, C.,** *"IBM's Relational DBMS Products: Features and Technologies"*, SIGMOD Record, Vol-2, No.-2, Washington DC, USA, June 1993, 445-448.

[6] **Segerstedt, Anders,** *"Comparison MRP, Cover-Time Planning and Reorder Point Systems"*, Eleventh International Working Seminar on Production Economics, Congress IGLS, February 2000, Austria, 379-385.

[7] **Gopalakrishnan, P.; Banerji A. K.;** *"Maintenance and Spare Parts Management"*, Prentice-Hall of India Pvt. Ltd., New Delhi, 1997.

[8] **Gopalakrishnan, P.; Sundaresan, M.;** *"Materials Management – an Integrated Approach"*, Prentice-Hall of India Pvt. Ltd., New Delhi, 1998.