Indian Institute of Technology Kanpur

Material Management and Quality Assurance

Course material for Power Financing Corporation

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CHAPTER 1: Systems Approach to Materials Management

Material management is viewed as a system of assuring the availability of products desired by customers at the best obtainable cost of manufacture[1]. It is related to planning, procuring, storing and providing the appropriate material of right quality, right quantity at right place in right time so as to co-ordinate and schedule the production activity in an integrative way for an industrial undertaking[2]. Most industries buy materials, transport them in to the plant, change the materials into parts, assemble parts in to finished products, sell and transport the product to the customer. All these activities of purchase of materials, flow of materials, manufacture them in to the product, supply and sell the product at the market requires various types of materials to manage and control their storage, flow and supply at various places. It is only possible by efficient materials management which can be achieved by better understanding of the dynamics of production process [2].

1.1 Dynamics of Material Management

Material management system is a part or subsystem or module of a bigger system called organization whose purpose is to provide product or service. A productive organization is made up of series of cause-consequence dependent sub systems, i.e. modules, which represents division based on functionality, and this is a complex process with large numbers of feedback loops, which are necessary to keep the operations on goal. This interdependence sometimes effects very strongly on the final result of behavior dynamics of organizational business system. The result of dynamics behavior of business-production process can be manifested with fluctuation of relevant business variables, such as: speed of supplying raw materials, speed of arriving the raw materials, speed of finishing the final products, state of unfinished production, state of finished goods - inventory, speed of shipment, state of productive capacities, state of credits, debt, cash-flow, gross income, net income, speed of

[1] A.K. Datta, "Materials Management, Procedures, Text and Cases", Prentice- Hall of India, 1983
[2] C.M. Sadiwala, "Materials & Financial Management", New Age International, 2007

investment new capacities policies, etc. Figure below shows the business production process dynamics, i.e. organizational production system to be made up of direct or indirect flows influence on some or even all listed indicators (production relevant variables).

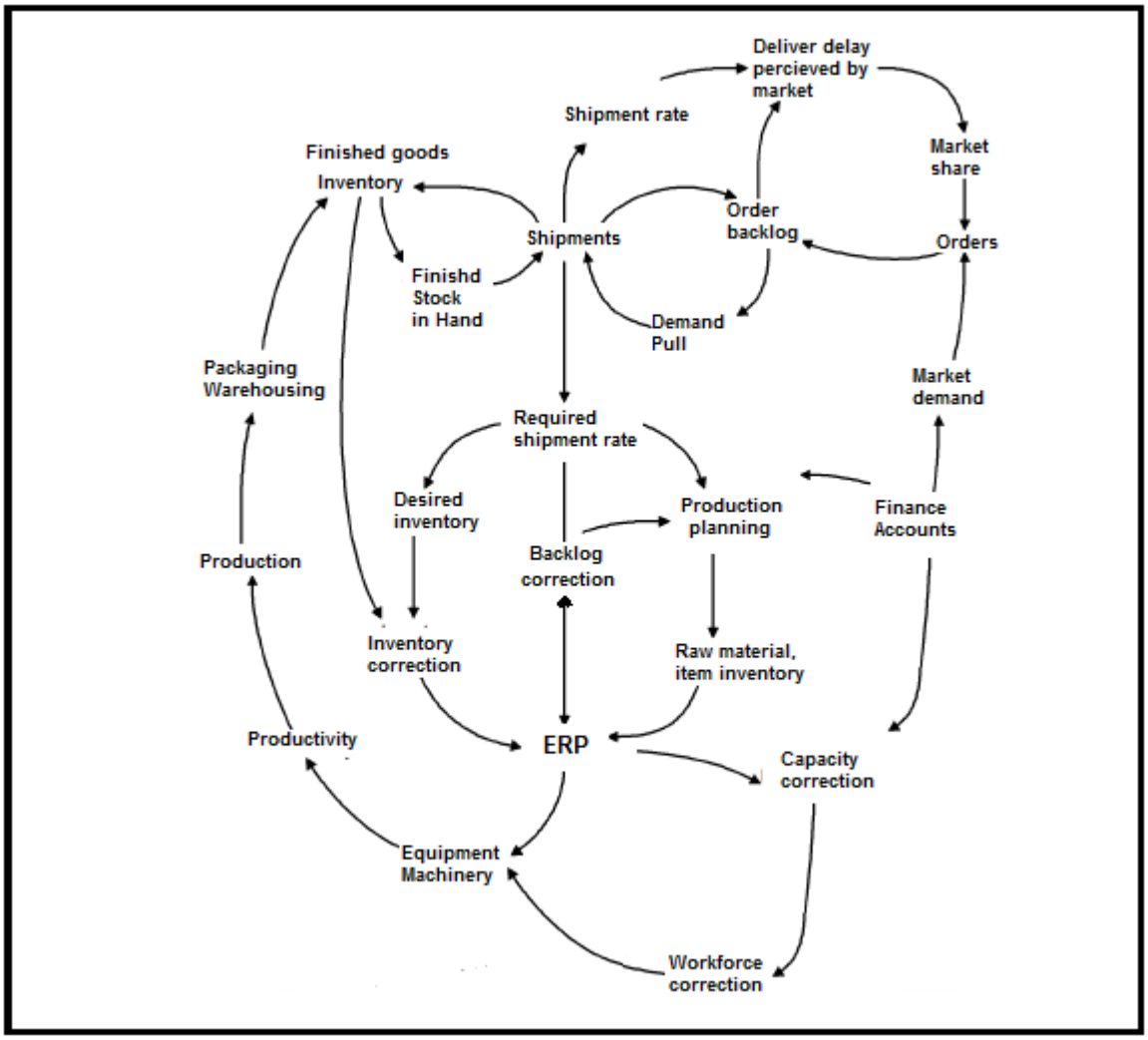

Figure 1.1.1: Dynamics of Material Management

Therefore, it is necessary to have a prior knowledge of this production process dynamics in order to define relationship between these indicator-variables and between every single module. Furthermore, it is possible to detect ineffective parts of such business organization system by necessary knowledge of this business-production processes and continuous modeling with System Dynamics. Further, with simulation of dynamics processes of production organization different behavior of this organization can be predicted, as response to different stimuli, i.e. test functions. For stimulus (known as test

functions), i.e. inputs in such processes in consequence consideration can be taken: changes in the markets, such as increase or decrease in credits for sale products or debit of this organization, introduction of new production equipment, change of supplier of components or materials, etc. Subjecting the production organization to different scenarios which are stipulated with changes in the market production organization can become more flexible, adaptive and robust dynamics of material management can be studied.

1.2 Objectives of material management

The principle objective of the Materials Management function is acquisition of materials

- of the right quality
- in the right quantity
- at the right time
- at the right price, and
- from the right source

Let us define these right things and other associated objectives[3]:

(i) *Right Material:* Identification and specification of materials required to be decided in consultation with engineering and production. Making efforts to locate suppliers who are capable to supply exactly what is required. Make available that which is required and specified. It also helps in standardization of products to allow inter-changeability.

(ii) *Right Quality:* For every item, supply to be made according to quality specification, neither of very high quality than specified (depends on pricing also) nor below, so that end product quality and process operations are not unduly affected. The quality of incoming materials should be consistently maintained.

(iii) *Right Quantity:* Based on annual or periodic estimates of consumption, the purchase be made in right quantity i.e. neither too high (storage and handling cost may increase) nor too low (sometimes material may not be available when needed in production department)

[3] IGNOU, "Production/Operations Management", Block5-Unit14

(iv) *Right Time:* Adherence to timing (as and when required) by the production can be achieved through storage. But making purchase too much advance so that the items will remain in the stores for the longer period (increasing the cost of storage and chance of obsolescence, damage, etc.) or just in the nick of the time-increasing the risk of stockout would not amount to be right time. Proper timing of purchase and requirement should be balanced.

(v) *Right Price:* Negotiation of purchase price should be competitive without sacrificing on quality and the reliability of supply. Bulk purchase or long term purchase contract can also be used effectively in negotiation of price. Major saving in overall cost of materials can be effected at this stage thus directly contributing to the organization.

(vi) *Low payroll Costs:* This not only refers to the total payroll of the materials management department but overall total expenditure of the materials department. If the department's overall annual expenditure is more than the savings it can achieve in the total material cost, then the department is not operating efficiently and rather helping the organization in saving in overall material costs it would actually be a burden on the organization. But the expenditure need not be unduly curtailed at the cost of undermining the functioning of department itself.

(vii) *Proper Records:* Maintenance of meticulous records is necessary for company point of view, because materials management function is responsible for approximately 50% of the company's budget. Proper record and administrative control supplemented by rigorous audit can contain temptations of corruption. Also proper records should constitute parts of company's overall database, which can be used in future for related planning and management decisions.

(viii) *Make or Buy Decisions:* Material management does not blindly go for purchase following the requisition of the usage department. It does the value analysis and in-house capacity analysis to arrive at decision of purchasing it or making in-house.

Summarizing: The objectives of material management can be categorized in two[4]:

(I) Primary objectives

(II) Secondary objectives

[4] C.M. Sadiwala, "Materials & Financial Management", New Age International, 2007

(I) Primary objectives

(i) Efficient material planning

(ii) Buying or Purchasing

(iii) Storing and inventory control

(iv) Supply and distribution of materials

(v) Quality assurance

(vi) Good supplier and customer relationship

(vii) Improved departmental efficiency

(II) Secondary objectives

(i) Efficient production scheduling

(ii) Standardization of material

(iii) Specification and codification of materials

(iv) Forecasting demand and requirement of materials

(v) Quality control of the material purchased

(vi) Proper material handling

(vii) Value analysis and value engineering

(viii) Developing worker's skills in material management

(ix) Smooth flow of materials in and out of the organization.

1.3 Systems approach to Material Management

The system approach involves studying the organization structure and process as inter-related various subsystems (their inputs and outputs) operating under the overall objective of bigger system i.e., organization. It involves identifying, understanding and managing interrelated processes within an organization and feedback and inputs from the outside. The advantage in studying organization as system is that it helps in integration and alignment of the processes to the desired results. It increases

the ability to focus effort on the key processes, providing consistency, effectiveness and efficiency of the organization.

A system may be defined as any group of interrelated parts or components which function together to achieve some goals. It can be described by its specific parts, the way in which they are related, and the goals to be achieved. A large manufacturing organization viewed in its entirety, is a social system (people work there), as well as technical system (machines, equipments and processes), having many divisions, which in turn may have departments, each of which is again a system or more precisely a sub-system. In the complex mechanism of organizations, it is very difficult to define the components of a system and its sub-systems, since any given system may have several layers of sub-systems.

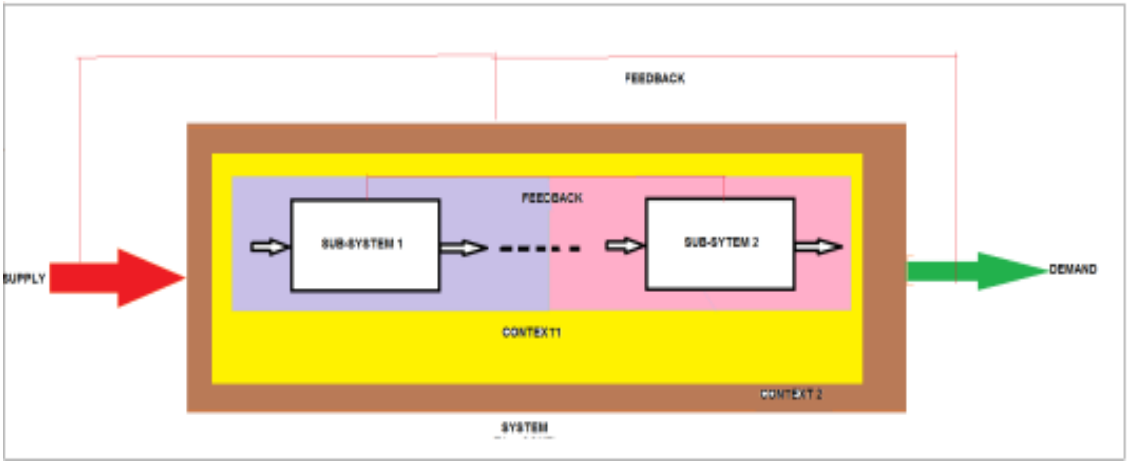

Figure 1.3.1: Systems approach

When we investigate the parts of a system, we find there are four distinct and essential ingredients of a system.[5] The first is ***input.*** In a manufacturing organization these constitute, people, machinery, raw and other materials. Then comes the ***process***, which means a series of operations performed by people and machinery, which transform raw and other materials into finished goods, which is its third ingredient, i.e. ***output***. Finally there is a fourth ingredient, ***control***, which gives rise to the need of management, which is always important in a complicated system, and leads to output. Further, since a system, especially a living social mechanism does not exist in vacuum but in a social environment

[5] A.K. Datta, "Materials Management, Procedures, Text and Cases", Prentice- Hall of India, 1983

over which it has little or no control, this control element is incorporated or works through feedback loop. This loop though trivial, is an important means through which management controls the operations of the enterprise, taking corrective measures when needed to achieve the desired goals. A business organization is an open, and not a closed loop system, because it does not operate independently of its environment, and external events can affect any of its components or parts. Similarly materials management system also interacts and gets influenced by the organizational environment and external environment as it is involved with diverse functions. Thus when we use system concept as framework for managing materials, we find that it not only interacts with its environment, that is to say, anything external to the system itself, but also interacts with the system's components. In particular, when outside constraints limit its operations, management must take corrective steps that will provide the change.

Materials management may be said to be an integrated system which emphasizes activities or functions and its relationship with others are pronounced. Therefore, it is not tied up to any specific structure, rather it is system oriented. It takes account of the functional dependence with an organization structure as a secondary consideration. However, an integrated systems approach considers the entire flow of materials as opposed to a partial flow. Any study which does not deal with this entire range of factors may tend to be simplistic. It is dynamic management function, which is again characterized by high level of sensitivity. Thus, a change in one sub-function is related to the changes in others, depending on the degree of sensitivity.

While the structure is static, the realities it attempts to fit into it are dynamic. Conversely, structural models should be settled on the basis of similarities of a given situation. Thus, it will be seen that some Materials Management functions require some modifications due to the changes in the industrial management dynamics, which characterize the industrial society of today.[6]

[6] A.K. Datta, "Materials Management, Procedures, Text and Cases", Prentice- Hall of India, 1983

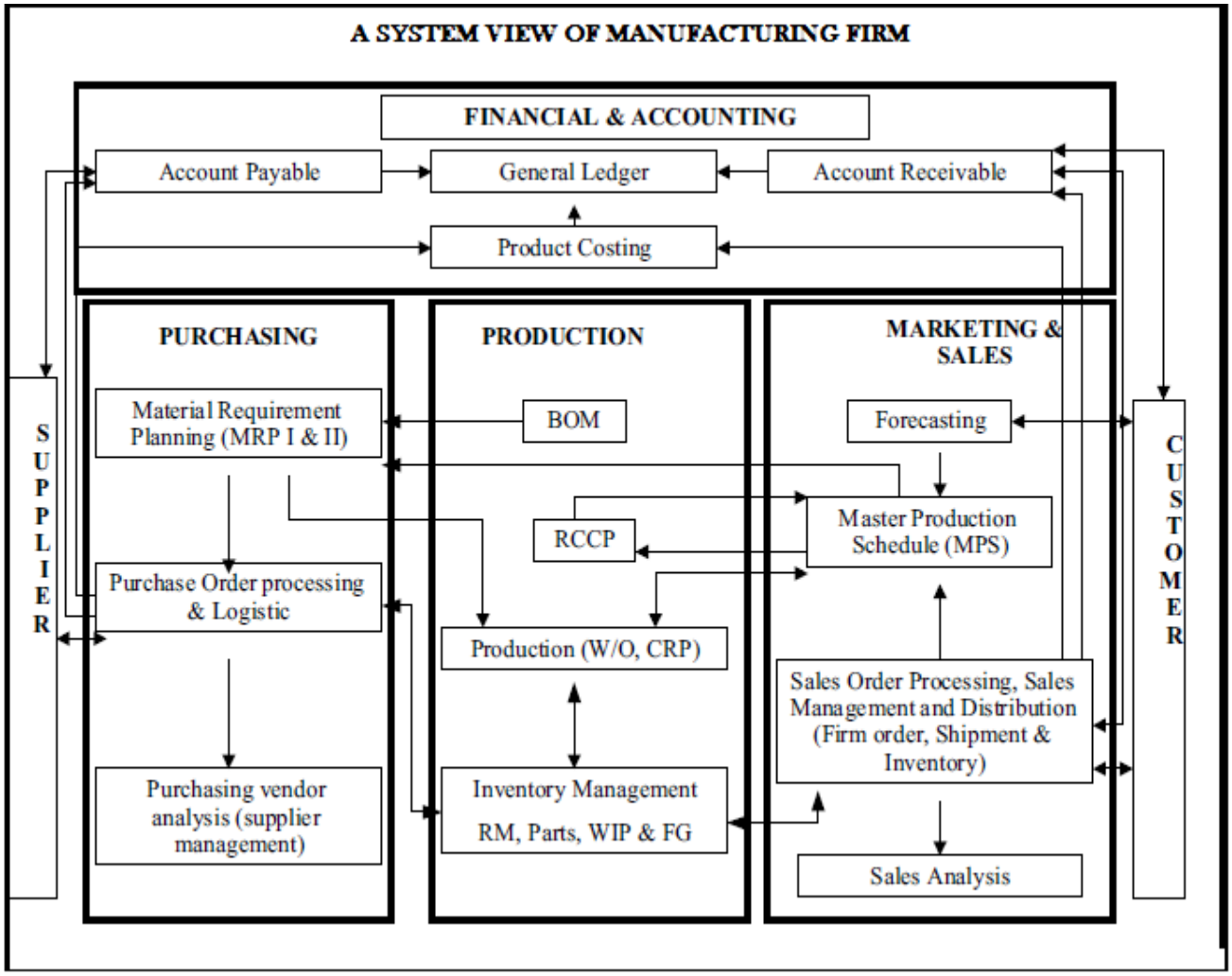

Figure 1.3.2: A Systems view of manufacturing process

Applying the principle of system approach to management typically leads to[7]:

- Structuring a system to achieve the organization's objectives in the most effective and efficient way.
- Understanding the interdependencies between the processes of the system.
- Structured approaches that harmonize and integrate processes.
- Providing a better understanding of the roles and responsibilities necessary for achieving common objectives and thereby reducing cross-functional barriers.

[7] http://www.iso.org/iso/iso_catalogue/management_standards/quality_management/qmp/qmp-5.htm

- Understanding organizational capabilities and establishing resource constraints prior to action.
- Targeting and defining how specific activities within a system should operate.
- Continually improving the system through measurement and evaluation.

1.4 Process of Management and Material Function[8]

Management can be defined *as process* or more precisely as a function involving the responsibility for guiding and supervising the workforce, designing and scheduling the operations and achieving efficiency and effectiveness with regard to well defined objective or goal. The success of any industry rests on the optimum utilization of its key factors of production, namely, men, machines and materials, and rightly considered, industry is a venture in cooperation. Under the central direction of management in order to source an effective inter-working of men, machines and materials, these three factors are essential for the successful working of nay production organization system. The art of dealing with men, i.e., the personnel function, has long been recognized as the prerogative of personnel department, demanding scientific treatment to human relation in industries. The art of dealing with machine and discovering and correcting their faults has been perfect into a science- that of engineering. The task has been duly shared by the engineering and production department. Science relating to materials used in production makes it possible for advance or departure from standards to be corrected. In a cascaded production systems, in which the product passes from the raw-material stage to finished-product stage, the need arises for the management of materials not only in all stages of production operations but problem also occur sufficiently earlier, even before actual production starts, of procurement, planning and scheduling as well as at the end, of storage, distribution and after-sales service to customer. In procuring materials or supplies questions arise as to how much stock to maintain and how much to buy in the face of required inventory investment, possible quantity, discounts and uncertainty of delivery times. A system which might be reasonably efficient for

[8] Anil K Datta, "Integrated Materials Management", S. Chand & Company Limited,1978

controlling inventories of purchased items may be inefficient where production and inventories are under unproductive functions. Simultaneous control of production and inventory requires a clear-cut control system with well specified rules of operations. The effectiveness of control system depends on the ability of the production system to react to change fluctuation in demand and supply.

Any question relating as to how these problems can be solved involves materials management. The Fundamental principles of materials management can thus be stated as follows:

(i) The purchases are made in time to see that the costs are not increased for rush orders.

(ii) There should not be any set-back in production schedule for want of materials, and

(iii) The inventories are kept to the minimum to avoid excess and extra cost of carrying them.

Once problem have been clearly stated, the subject can be viewed from the following aspects:

(a) Functions, and

(b) Organization

The questions already raised need thorough knowledge of the problems that industries face in a price-oriented economic system. And to resolve them the need also arise of the application of scientific techniques and modern tools of control in such functional areas as:

1. Make-or-Buy
2. Purchase-Budgeting and Planning
3. Value Analysis
4. Production- planning, Scheduling and Control
5. Material quantity and Quality Control
6. Demand Forecasting for Sales and Purchases
7. Inventory Management and control

Material Management, therefore, visualize a combination of several managerial arts concerned with the control of materials at all stage of operations. However, when we talk of Management of materials, we mean *Total material control*. Proper materials management involves so many complex problems which could be solved by employing new mathematical techniques like, Operations research-Linear programming, Dynamic programming and simulation techniques.

CHAPTER 2: Forecasting, Objective and the Material Organization

2.1 System Design[9]

As an organization develops plans and strategies to deal with the opportunities and challenges that arise in its particular operating environment, it should design a system that is capable of producing quality services and goods in demanded quantities in acceptable time frames.

Designing the system begins with product development. Product development involves determining the characteristics and features of the goods to be sold. It should begin with an assessment of customer needs and eventually grow into a detailed product design. The facilities and equipment that will produce the product, as well as the information systems needed to monitor and control performance, are part of this system design process. Product development should be a cross-functional decision making process that relies on teamwork and communication to install the marketing, financial, and operating plans needed to successfully launch a product.

Product design is a critical task because it determines the characteristics and features of the product, as well as how the product functions. Product design determines a product's cost and quality, as well as its features and performance. These are important factors on which customers make purchasing decisions. In recent years, new design models such as Design for Manufacturing and Assembly (DFMA) have been implemented to improve product quality and lower costs.

DFMA focuses on operating issues during product design. This can be critical even though design costs are a small part of the total cost of a product, because, procedures that waste raw materials or duplicate effort can have a substantial negative impact on a business's operating profitability. Another innovation similar to DFMA in its emphasis on design is Quality Functional Deployment (QFD).

[9] http://www.inc.com/encyclopedia/operations-management.html

QFD is a set of planning and communication routines that are used to improve product design by focusing design efforts on customer needs.

Process design describes how the product will be made. The process design decision has two major components: a technical (or engineering) component and a scale economy (or business) component. The technical component includes selecting equipment and selecting a sequence for various phases of operational production.

The scale economy or business component involves applying the proper amount of mechanization (tools and equipment) to make the organization's work force more productive. This includes determining:

1) If the demand for a product is large enough to justify mass production;
2) If there is sufficient variety in customer demand so that flexible production systems are required; and
3) If demand for a product is so small or seasonal that it cannot support a dedicated production facility.

Facility design involves determining the capacity, location, and layout for the production ability. Capacity is a measure of an organization's ability to provide the demanded services or goods in the quantity requested by the customer in a timely manner. Capacity planning involves estimating demand, determining the capacity of facilities, and deciding how to change the organization's capacity to respond to demand.

Facility location is the placement of a facility with respect to its customers and suppliers. Facility location is a strategic decision because it is a long-term commitment of resources that cannot easily or inexpensively be changed. When evaluating a location, management should consider customer convenience, initial investment necessary to secure land and facilities, government incentives, and operating transportation costs. In addition, qualitative factors such as quality of life for employees, transportation infrastructure, and labor environment should also be taken under consideration.

Facility layout is the arrangement of the work space within a facility. It considers which departments or work areas should be adjacent to one another so that the flow of product, information, and people can move quickly and efficiently through the production system.

Planning the system describes how management expects to utilize the existing resource base created as a result of the production system design. One of the outcomes of this planning process may be to change the system design to cope with environmental changes. For example, management may decide to increase or decrease capacity to cope with changing demand, or rearrange layout to enhance efficiency.

Decisions made by production planners depend on *the time horizon*. Long-range decisions could include the number of facilities required to meet customer needs or studying how technological change might affect the methods used to produce services and goods. The time horizon for long-term planning varies with the industry and is dependent on both complexity and size of proposed changes. Typically, however, long-term planning may involve determining work force size, developing training programs, working with suppliers to improve product quality and improve delivery systems, and determining the amount of material to order on an aggregate basis. Short-term scheduling, on the other hand, is concerned with production planning for specific job orders (who will do the work, what equipment will be used, which materials will be consumed, when the work will begin and end, and what mode of transportation will be used to deliver the product when the order is completed).

Managing the system involves working with people to encourage participation and improve organizational performance. Participative management and teamwork are an essential part of successful operations, as are leadership, training, and culture. In addition, material management and quality are two key areas of concern.

Material management includes decisions regarding the procurement, control, handling, storage, and distribution of materials. Material management is becoming more important because, in many organizations, the costs of purchased materials comprise more than 50 percent of the total production

cost. Questions regarding quantities and timing of material orders need to be addressed here as well when companies weigh the qualities of various suppliers.

2.3 Integral Control of the flow of Materials[10]

As material cost contribute more than 50% to company's overall cost, a greater benefit can be achieved by better utilization of material resources. It needs be stressed, however, that the scope for improvement is rather higher in this field than any other industrial operation through the complete cycle of the operations from procurement of raw materials including reception and storage, its handling into the process and in between process, and handling of the finished products outwards. This covers all phases including package, storage and distribution and transport of the finished product to the customer.

To have effective and efficient materials management, the materials movement within a plant must be coordinated and all aspects of materials movement from product design to final transportation should be studied. In order to realize the expensive aspect of materials handling, one can only think of the extent of damage, delays, and man hour losses within the plant, apart from the customer dissatisfaction, which can be brought in its trail. Therefore, a well planned integrated system of material handling can contribute not only to be effective plant operations, but also to customer satisfaction. To develop an adequate plan and to integrate all factors into the organization goal so as to ensure its proper working, is, therefore, the heart of any material flow management program.

It may once again be emphasized here that materials cannot be managed in isolation. While observing material-costs and unnecessary investments in materials should be reduced, set ideas of the past and vertical divisions of the Materials functions have hindered its progress towards integration. An integrated approach stems from the possibilities of economies at all phases and takes a critical review of essentiality and urgency, quality and quantity ,and aims at reducing material-costs as well as

[10] Anil K Datta, "Integrated Materials Management", S. Chand & Company Limited,1978.

overall costs while maximizing the value of end-products or costs of the project under review. An integrated point of view is then taken in the original planning for the project as a whole. This system view-point is maintained in the schedule determination, the evaluation of alternate procedures, and in the management control procedures.

In a manufacturing concern, repetitive items would include all raw materials and regular stores needed for continuous manufacturing operations. They would, inter allia, include-

(i) All raw materials and catalytic agents.

(ii) All packaging materials

(iii) Regular stores items including fuel and / or processes sing items.

(iv) All spares needed for maintenance, repairs and operations.

(v) Stationary, printing, and other items needed for welfare activities, etc.

Non-repetitive items are-

(i) Ad hoc purchases for job-lot type of production

(ii) Capital requirement including machineries for major expansion

(iii) Minor capital items not very frequently required

(iv) Items required for major overhaul of plants and machineries.

(v) Non-stock items of small value.

As earlier discussed, procurement and replenishment of inventories can very well be regulated by the application of ABC analysis or SIC based on modern techniques for working out Economic Order Quantities and Safety Stocks.

Non repetitive items, however, need different treatment in so far as their requirements and delivery schedules have to be worked out ad hoc. For these, applying modern techniques of CPM/PERT, arrangements may be made to ensure purchase and to keep delivery schedule well within

requirements. For major non-repetitive purchases CPM/PERT can be used for materials planning and programming with definite results. Bill of Materials with required lead time may be drawn up which will in turn become indents for procurement and act as a guide to delivery and stocking requirements. That is important, however, is to watch that the delivery of matching equipment, spare parts and components, etc, are made on time and that the progress of the project does not hamper for want of materials. Nor should certain materials arrive for too ahead of requirement thereby locking funds unnecessarily and increasing carrying costs.

Normally, there should be no stock in hand long before the beginning of the job and purchase should be so regulated as to match the required quantities in accordance with a plan made on the basis of 'network ' and material lead time analysis. The aim should be 'zero' inventory before the commencement of the project and 'zero' inventory again at the end of the project, so that the aim of planning, programming and purchasing should be to hold average inventory as low as possible during the tenure of the project.

Integral control of Material flow thus involves Production Planning, Purchasing/Procurement, logistics, and Inventory Management / Inventory Control.

Integrated control of Material Flow can have the following benefits:

- Improved Product Quality
- Reduced Purchasing Costs
- Reduced Freight / Transportation Cost
- Reduced Manufacturing Waste
- Increased Production
- Improved Customer Satisfaction
- Reduced Downtime
- Reduced Product Cost

2.3 Forecasting and Planning

Forecasting can be defined as the art and science of predicting the future likely events. The outcomes of forecasting termed as *forecasts* are estimates of the occurrence, timing, or magnitude of uncertain future events. Forecasts are vital for smooth operations of any organization. Organizations working in scenario where there is surplus demand or static demand (like state controlled rationing) may pay less attention to forecasting as what has happened in past is going to be repeated in future also, but in today's liberal world no organization can survive without a good forecast.

Operations manager plan their activities based on demand forecasts, which are often made in coordination with marketing department. The planning based on demand forecast encompass the entire organization, be it Finance, HRD, Operations, Purchase or Marketing. For example, operations manager plan their material and capacity requirement based on expected demand and desired service to the customer. Over-forecast may result in excessive labor, material or capital cost and on the other hand inadequate may result in costs associated with expediting, poor service or lost sales. So a good forecast is always needed for organizational planning. But as we go for better and better forecast the cost associated with the forecasting activities increase and thus there is a tradeoff up to what level one needs to explore the future. Figure below gives the tradeoff between forecasting cost and other organizations cost.

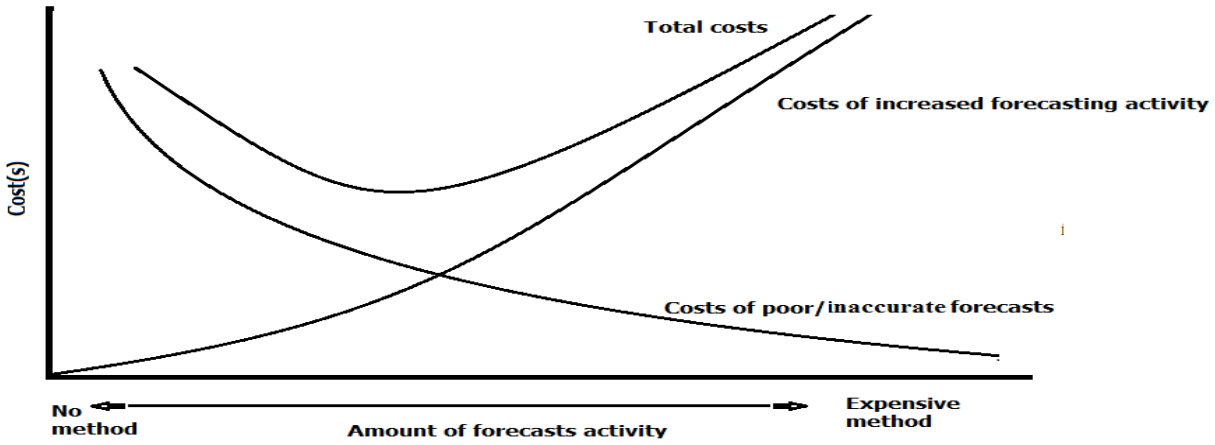

Figure 2.3.1: Cost of forecasting vs other expenses

One thing important about forecast is that they can never tell the future exactly. There will always be some variation in reality and we see to some extent this variation can be absorbed by extra capacity, inventory, or rescheduling of orders. But if the variations are large, they can wreck havoc on the business. For example a large forecast may result in excessive inventory and unutilized capacity.

Since some variation is in-evitable, one needs to have flexibility in its operations to accommodate it. There should be proper estimate of the variation also along with point estimate of demand. It has been observed that lesser the lead time over which forecast are required better it is. Therefore if capacity permits, one needs to forecast closer to the demand period.

We see that all forecast have two elements: (i) the best estimate of the demand (e.g., mean, median, or mode) and (ii) the forecasting error (e.g., standard deviation, absolute deviation, or range). Forecast estimate without second element is incomplete and can lead to difficult situations. The discussion below gives methods for getting these estimates.

Forecasting Methods

All forecasting methods can be divided into two broad categories: qualitative and quantitative. Division of forecasting methods into qualitative and quantitative categories is based on the availability of historical time series data. A time series is simply a set of observations measured at successive points in time or over successive periods of time. The quantitative models are deployed in situations where there is availability of past or historical data relevant to the forecasted event. Quantitative forecasts generally are based on the time series data of sales volume or customer demand. On the other hand Qualitative forecasting methods rely on forecaster's intuition and judgment and not on any specific model. Since they involve individual's subjective decisions, there can be different forecast for the same situation. However, Qualitative forecasting is useful in situations where there is lack of data or when past data are not reliable predictors of future or future situation is going to be somewhat different from past.

2.3.1 Qualitative Forecasting Methods

Qualitative forecasting techniques generally employ the experts in the appropriate field to generate forecasts. As discussed earlier the advantage of these procedures is that they can be applied in situations where historical data are simply not available, like a new type of product or service launched in the market. Even in situations where historical data are available, one cannot blindly follow the quantitative model and the current /future environmental conditions should be qualitatively accommodated. Consider, for example, that historical data on petrol car sales are available. If there is sudden hike in interest rate or increase in petrol prices; one would need to accommodate such developments and make modification on sales forecast generated only on the past data. Qualitative forecasting methods offer a way to generate forecasts in such changed scenarios. Four important qualitative forecasting methods are: the Delphi technique, market survey, scenario writing, and the informed- judgmental approach.

i) Delphi technique:

In the Delphi technique, forecast is developed by a panel of experts answering a series of questions on successive round. The panel members are not identified to each other and anonymous responses of the panel are fed back on each round to all participants. Three to six rounds may be used to obtain convergence on the forecast. It should be noted that the objective of the Delphi technique is not to produce a single answer at the end. Instead, it attempts to produce a relatively narrow spread of opinions—the range in which opinions of the majority of experts lie.

The Delphi technique is useful in obtaining long range forecast for capacity or facility planning. It is also useful in change scenarios like technological forecasting to assess when technological change might occur. As it involves panel of experts to make forecast, it is quite costly technique.

ii) Market Surveys:

This methodology involves usage of Panels, questionnaires, test markets or surveys to gather data on market conditions.

Market surveys are useful in new situations like new product or new service launch, or updating the earlier forecast. It again is a costly technique involving capital and man power, but is much important now a day's owing to competition and frequent short cycle products.

iii) Scenario Writing:

In this approach, the forecaster develops the likely scenarios of the business outcome over a given set of assumptions. The generated different future scenarios corresponding to the different sets of assumptions are presented to the decision maker, who decides which scenario, is most likely to prevail.

iv) Informed Judgmental Approach:

The subjective approach allows individuals participating in the forecasting decision to arrive at a forecast based on their subjective feelings and related market information. This approach is based on the premise that a human mind can arrive at a decision based on factors that are often very difficult to quantify. "Brainstorming sessions" are frequently used as a way to develop new ideas or to solve complex problems. In loosely organized sessions, participants feel free from peer pressure and, more importantly, can express their views and ideas without fear of criticism. Many corporations in the United States have started to increasingly use this approach.

2.3.2 Quantitative Forecasting Methods

Quantitative forecasting methods are used when historical data on variables of interest are available There are two major categories of quantitative forecasting methods. The first type uses the past trend of a particular variable to base the future forecast of the variable. As this category of forecasting methods simply uses time series on past data of the variable that is being forecasted, these techniques are called *time series methods*. The second category of quantitative forecasting techniques also uses historical data, but in forecasting the forecaster examines the cause-and-effect relationships of the variable with other relevant variables. Forecasting techniques falling under this category are called *causal methods*.

Time Series Methods of Forecasting:

A time series is a set of observations of a variable at regular intervals over time. The measurements or observations may be taken every hour, day, week, month, or year, or at any other regular (or irregular) interval. The time series can be decomposed into four separate components: *trend component* (T), *cyclical component*(C), *seasonal component*(S), and *random or irregular component*(R). These four components are viewed as providing specific values for the time series when combined. The combination can be additive or multiplicative as the forecaster may deem fit in given situation. If *Ft* is the forecast value then:

$$F_t = T.S.C.R \qquad \text{Multiplicative model}$$

$$F_t = T + S + C + R \qquad \text{Additive model}$$

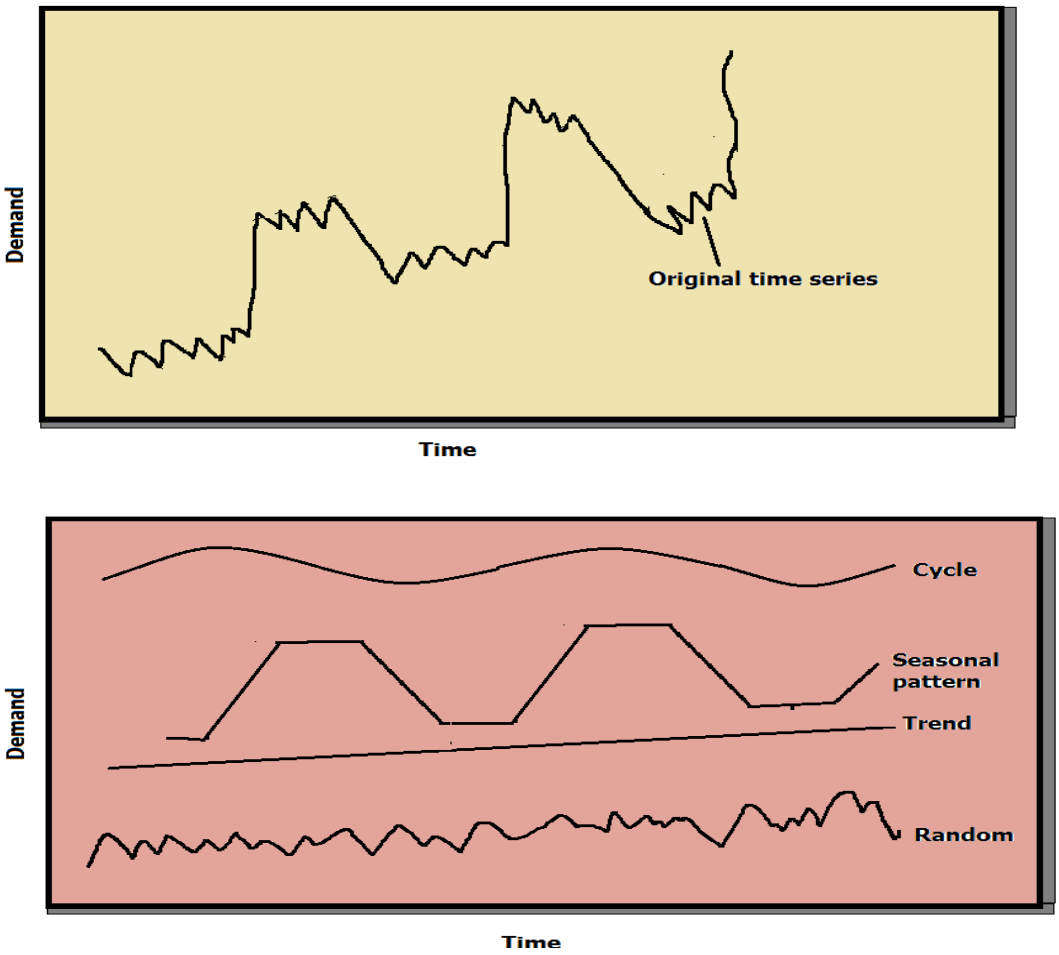

Figure 2.3.2: Components of demand pattern

Trend: While most time series data generally display some random fluctuations, it may still show gradual shifts to relatively higher or lower values over an extended period, which is termed as trend in forecasting language. A trend generally emerges due to one or more long-term factors, like changes in the demographic characteristics of population, changes in population size, etc. Forecasters often describe an increasing trend by an upward sloping straight line and a decreasing trend by a downward sloping straight line. It is not necessary that relationship between time series and forecasted variable be linear, but linear regression is generally attempted first by the statistician, and in many situations they have to resort to fitting non linear function if it fails. But in our discussion here we confine to situations of linear trends.

Cyclical: These are alternating sequences of values lying above and below the trend line with a longer time period cycle. A recurring sequence of points observed above and below the trend line that last more than a year is considered to constitute the cyclical component of the time.

Seasonal: The seasonal component is similar to the cyclical component in that they both refer to some regular fluctuations in a time series, but the key difference is it captures the regular pattern of variability in the time series within one-year periods or even much lesser time domain than cyclical. Seasonals can be quarterly, monthly, weekly, daily, or even hourly indexes. Many economic variables display seasonal patterns.

Trend, cyclical, and seasonal components are considered to account for systematic variations in the time series. Once the effects due to trend, cyclical, and seasonal components are extracted from the time series, the residual left represents the irregular component.

Irregular: The irregular component is also called the random variability in the time series. These may be caused by short-term, unanticipated factors that affect the time series. The irregular component of the time series, by nature, cannot be predicted in advance.

2.3.2(a) Time Series Forecasting Using Smoothing Methods:

The smoothing methods are deployed in forecasting process when the time series data displays no significant effects of trend, cyclical or seasonal components (often called a stable time series). In such situations, the objective is to smooth out the irregular component of the time series by using an averaging process. Once the time series is smoothed, it is used to generate forecasts.

(i) Moving averages method:

The moving averages method is the most widely used smoothing technique. In this method the average of a certain number of adjoining previous data points or periods are taken to arrive at a forecast. The term "moving" refers to the way averages are calculated—the forecaster moves up or

down the time series to pick observations to calculate an average of a fixed number of observations. In calculating moving averages to generate forecasts, the forecaster may experiment with different-length moving averages. The forecaster will choose the length that yields the highest accuracy (the associated least mean squared error) for the forecasts generated.

(ii) Weighted moving averages method:

Weighted moving averages are a variant of moving averages. In the moving averages method, each observation of data receives the same weight. In the weighted moving averages method, different weights are assigned to the observations on data that are used in calculating the moving averages with the most recent observation receiving the maximum weight, with the other descending period terms with weights in decreasing order.

The accuracy of weighted moving averages forecasts is determined in a manner similar to that for simple moving averages.

Example2.3.1: The demand of a gear box assembly of crane, as faced by a supplier is as following:

Month	1	2	3	4	5	6	7	8	9	10
Number of G.B	7	10	8	7	12	14	14	18	16	19

Compute the forecast for the demand in the month 11 using moving average technique and also by weighted moving average with weight of 3 for the most recent data, 2 for the next, and 1 for the oldest.

Solution: The table below gives the simple moving average with three months as averaging period

Table2.3.1: Solution of example problem 2.1.1 using moving average technique.

Month	demand	3-year moving average
1	7	
2	10	8.3
3	8	8.3
4	7	9.0
5	12	11.0
6	14	13.3
7	14	15.3
8	18	16.0
9	16	17.7
10	19	

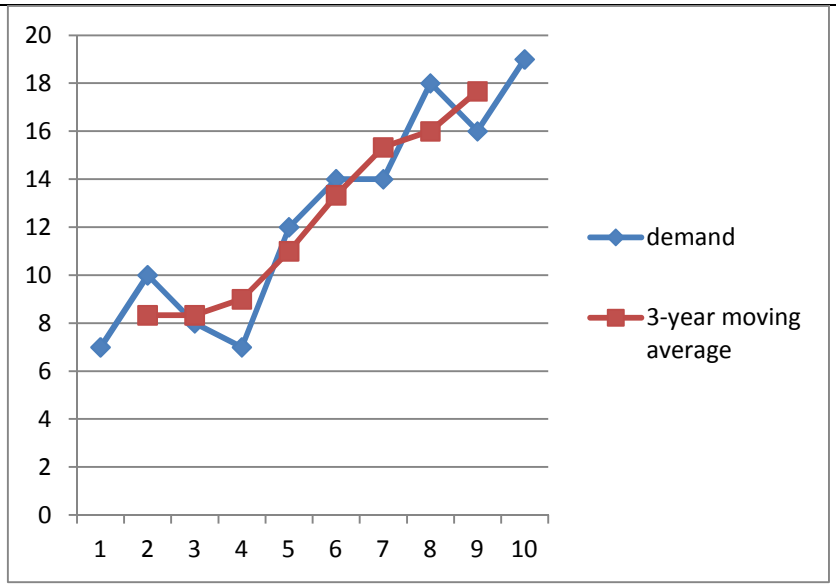

Figure 2.3.3: Smoothing through moving average

The forecast for the month 11 will be = 17.7.

By using weighted moving average we have the relationship as:

$$M.A._{wt=} \frac{\Sigma(wt)X}{\Sigma(wt)} = (19*3 + 16*2 + 18*1)/(3+2+1) = 17.8$$

By weighted moving average we see forecast to be higher as the latest data is having highest value and is also given highest weight.

(iii) Exponential smoothing method:

Exponential smoothing also uses the weighted average concept for smoothing the data. In this the weighted average of all past observations starting from period1 to the current forecasting level is used to generate forecasts for the next period. It assigns the maximum weight to the most recent observation(α) and the weights decline in a geometric series manner as older and older observations are included (reduced by factor(1-α)). So we see that exponential smoothing employs a weighting scheme for the historical values of data that is exponential in nature (factor (1-α)).Again the accuracies of forecasts using exponential smoothing are determined in a manner similar to that for the moving averages method.

With simple exponential smoothing, the forecast F_t is made by updating the last forecast with actual realized demand value as equal to, α times the last period actual demand A_{t-1} and (1-α) times the last period forecast F_{t-1}.

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

Example2.3.2: Use exponential smoothing to forecast the demand for May given the following data of demand in column1 and column2.

Solution:

Table2.3.2: Solution of example problem 2.1.2 using exponential smoothing technique.

Month	Actual Demand (A_t)	Forecasted Demand ($F_{t+1} = F_t + \alpha(A_t - F_t)$)
Jan.	40	Assumed same as current demand as no initial forecast given=40
Feb.	38	=40+0.7(38-40)= 38.6
Mar.	41	=38.6+0.7(41-38.6)= 40.28
Apr.	39	=40.28+0.7(39-40.28)= 39.38
May		

The third column in above table shows the forecast results using exponential smoothening with α=0.7. The reason for taking higher value of α is that the demand pattern seemed somewhat stable and high α will ensure higher weightage to current information.

The forecast for the month of May is 39.38

2.3.2(b) Time Series Forecasting Using Trend Projection

This method uses the underlying long-term trend of a time series of data to forecast its future values. As discussed in definition most often, forecasters assume a linear trend, but if in actuality a nonlinear trend is present, then this misrepresentation can lead to grossly inaccurate forecasts. The principle of lesser forecasting error (least MSE) should be deployed to test which model suits well in the given situation.

Assume that the time series given to us is actually linear and thus it can be represented by a straight line. Mathematical technique most popularly used to find the straight line that most accurately represents the time series is least mean square error technique. This line relates variable to different points over time. If it is assumed that the past trend will continue in the future, future values of the time series (forecasts) can be inferred from this straight line. One should remember that the forecasts without the mention of error are incomplete.

Expression: Let X represent the independent variable, which is time in time series data, and Y the observed variable. We need to fit a straight line on the observed X and Y variables.

$$\hat{Y} = a + b\,X$$

Where

$\hat{Y}$ = estimated value of the dependent variable

X = independent variable (time in trend analysis)

$a = Y$- intercept (the value of Y when X=0)

b =slope of the trend line

Using least mean squared error technique to find the befitting line, we get

$$b = \frac{\sum XY - n\bar{X}\bar{Y}}{\sum X^2 - n\bar{X}^2}$$

and

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

Where

$\bar{Y}$ = mean of the values of dependent variable

$\bar{X}$ = mean of the values of independent variable

n = number of data points in the time series

Example2.3.3: The first two columns of the table below gives the shipments out of a warehouse for the period 200 to 2007.The problem is to project the shipments for the year 2008.

Solution:

Table2.3.3: Trend analysis of example problem 2.1.3

X(Year)	Y(Shipment)	Xt(Scaled)	$Xt\,Y$	X^2
2000	105	-7	-735	49
2001	112	-5	-560	25
2002	123	-3	-369	9
2003	126	-1	-126	1
2004	141	1	141	1
2005	161	3	483	9
2006	180	5	900	25
2007	208	7	1456	49
TOTAL	$\sum Y$ =1156	$\sum Xt = 0$	$\sum Xt\,Y$ =1190	$\sum X^2$ =168
	$b = \frac{\sum XY}{\sum X^2}$ =7.083		$a = \bar{Y}$ =144.5	

*The projection for the year 2008 = 144.5 +7.083 * 9 =208.27*

2.3.2(c) Time Series Analysis Using Trend and Cyclical Components:

This method is an extension of the trend projection method, to highlight the cyclical component of a time series as a percentage of trend-component. Cyclical variation is the component of time series that tends to oscillate above and below the trend line for periods longer than one year. The procedure adopted to identify the cyclical component is residual method.

In this we scale our data on annual periods, so that seasonal variations if present will be absorbed in the annual values and the net effect will be of trend, cyclical and irregular component on the data. Since we can impose trend on the data plot by a trend line, one can easily isolate the cyclical and irregular component from the trend. In this analysis assumption is made that variations in annual data not explained by trend is due to the cyclical component. One should also notice that cyclical analysis

is just a postmortem of the past data to derive useful information of variation of data in its long life cycle, and one may assume similar behavior in related product, but it is never used for forecasting the same product.

The measure of cyclical variation as percentage of trend is given as

$$C = \frac{Y}{\bar{Y}} \times 100$$

Example2.3.4: The first two columns of the table below give the sale of certain brand of product in thousands for eight years**.** Calculate the trend and identify the cyclical component**.**

Solution:

Table2.3.4: Trend and cyclical component analysis of example problem 2.1.4

X	Y	X_t	X_tY	X_t^2
2000	8.5	-7	-59.5	49
2001	8.8	-5	-44	25
2002	9.2	-3	-27.6	9
2003	9.2	-1	-9.2	1
2004	9.4	1	9.4	1
2005	9.4	3	28.2	9
2006	9.7	5	48.5	25
2007	10.1	7	70.7	49
TOTAL	74.3	0	16.5	168
$\hat{Y} = a + bX$	=9.3 +0.1Xt			

X	Y	$\hat{Y}$	$C=(Y/\hat{Y})*100$
2000	8.5	8.6	98.8
2001	8.8	8.8	100.0
2002	9.2	9.0	102.3
2003	9.2	9.2	100.1
2004	9.4	9.4	100.2
2005	9.4	9.6	98.1
2006	9.7	9.8	99.2
2007	10.1	10.0	101.3

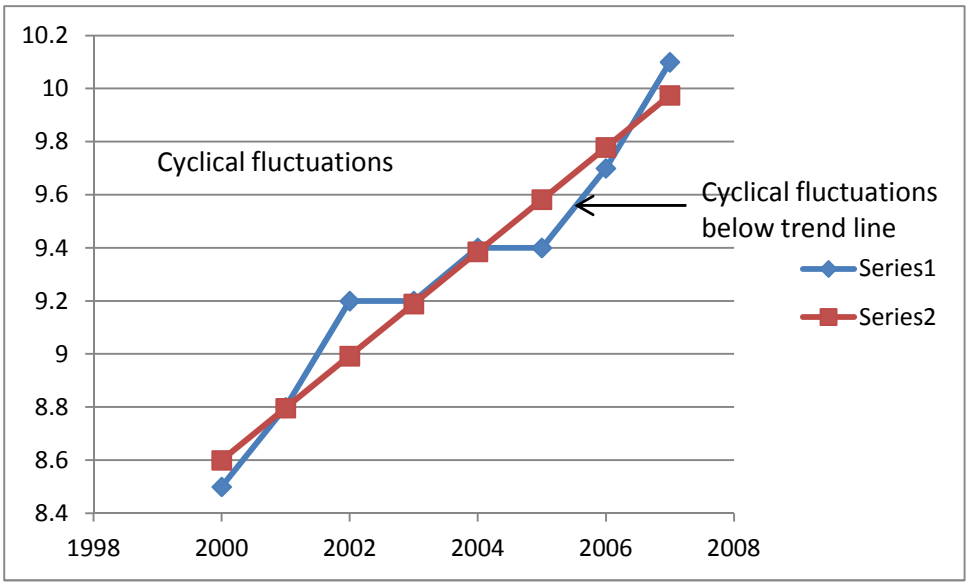

Figure 2.3.4 Cyclical Fluctuations

2.3.2(d) Time Series Forecasting Using Trend and Seasonal Components:

Besides trend and cyclical variation, a time series data also includes seasonal variations. Seasonal variations are repetitive and predictive movement around trend line in time dimension within a year This method is a variant of the trend projection method discussed earlier, taking time units smaller for analysis (period within a year) such as days, weeks, months or quarters. The strategy adopted is the

moving average technique to smooth out the seasonal effect or the seasonal component from the time series and then identifying the trend on the averaged data set. The number of data points taken in the moving average is the number of time periods needed to get back at the same type of time period. This step is often referred to as de-seasonalizing the time series for trend analysis. Then, using this trend line, forecasts for trend component of future periods is generated. The final step under this method is to reincorporate the seasonal component of the time series (using what is known as the seasonality index) to adjust the forecasts based on trend alone. In this manner, the forecasts generated are composed of both the trend and seasonal components.

Example2.3.5: The table below shows the sales in thousands of a book retailer. Find the seasonality indices. If the trend value for the 2nd quarter of 2005 is 2101 what will be the forecast, keeping seasonality in mind.

Table2.3.5: Quarterly sales of a bookseller

Year	I	II	III	IV
2000	1860	2200	2420	1910
2001	1920	2350	2510	1990
2002	1840	2160	2100	1800
2003	1840	2030	2300	1970
2004	2080	2420	2340	1970

Solution: The data given is quarterly and hence will have in it the seasonal effect of different quarters. Therefore to analyze the trend, one needs to first de-seasonalize the data. For this we rearrange the above table in first two columns of table below as

Table2.3.6: Trend and seasonal component analysis of example problem 2.1.5

Year	Quarter	Goods Sold	4 quarter moving average	Centering the moving average on quarters (De-Seasoned data)	Seasonality Index = De-seasoned data/Actual	Corrected Seasonality Index
	1	1860				
2000	2	2200	2097.5			
	3	2420	2112.5	2105	114.9644	114.5
	4	1910	2150	2131.25	89.61877	89.3
	1	1920	2172.5	2161.25	88.83748	88.5
2001	2	2350	2192.5	2182.5	107.6747	107.3
	3	2510	2172.5	2182.5	115.0057	114.6
	4	1990	2125	2148.75	92.61198	92.3
	1	1840	2022.5	2073.75	88.72815	88.4
2002	2	2160	1975	1998.75	108.0675	107.7
	3	2100	1975	1975	106.3291	105.9
	4	1800	1942.5	1958.75	91.89534	91.6
	1	1840	1992.5	1967.5	93.5197	93.2
2003	2	2030	2035	2013.75	100.807	100.4
	3	2300	2095	2065	111.3801	111.0
	4	1970	2192.5	2143.75	91.89504	91.6
	1	2080	2202.5	2197.5	94.65301	94.3
2004	2	2420	2202.5	2202.5	109.8751	109.5
	3	2340				
	4	1970				

The average seasonality index of the second quarter is 108, therefore the forecast for the second quarter of 2005 will be=1.08 *2101 =2269

2.3.3 Causal Method of Forecasting

The causal methods attempt to find out use the cause-and-effect relationship between the variable whose future values are being forecasted and other related variables or factors. The mathematical method which is widely used for such analysis is called regression analysis. The variable that is being forecasted is called the dependent or response variable and the variable or variables that help in forecasting the values of the dependent variable are called the independent or predictor variables. Regression analysis that employs one dependent variable and one independent variable and approximates the relationship between these two variables by a straight line is called a simple linear regression. Regression analysis that uses two or more independent variables to forecast values of the dependent variable is called a multiple regression analysis.

Having identified the regression line, and assuming that the relationship based on the past data will continue, future values of the dependent variable (forecasts) can be inferred from the straight line based on the past data. So if the forecaster has some clear idea about the value of dependent variable in the coming year, an estimate of future value of dependent variable (say sales) can be generated. Again to iterate the forecasts based on any method should also be judged on the basis of a measure of forecast errors.

Expression: Let X represent the independent variable and Y the variable to be forecasted whose value varies in some relation to the variation in values of X. We need to fit a straight line on the observed X and Y variables.

$$\hat{Y} = a + b\,X$$

Where

$\hat{Y}$ = estimated value of the dependent variable

$X =$ independent variable assumed to be the cause of $\hat{Y}$

$a = Y$- intercept (the value of Y when X=0)

$b =$ slope of the regression line

2.3.4 Forecasting Accuracy

Although quantitative analysis can be very precise, it is not always appropriate. Although Least Squared Error technique is often used to take care of the error component, but some experts in the field of forecasting are against the use of mean square error to compare forecasting methods. We list below some commonly used error estimate in the forecasting field.

The forecast error $'E_t'$ is the difference between the actual value and the forecasted value for the corresponding period.

$$E_t = Y_t - F_t$$

Where, E_t is the forecast error at period t, Y_t is the actual value at period t, and F_t is the forecast for period t.

Table2.3.7: Measures of aggregate error:

Mean absolute error (MAE)	$MAE = \frac{\sum_{t=1}^{N} \lvert E_t \rvert}{N}$
Mean Absolute Percentage Error (MAPE)	$MAPE = \frac{\sum_{t=1}^{N} \left\lvert \frac{E_t}{Y_t} \right\rvert}{N}$
Mean squared error (MSE)	$MSE = \frac{\sum_{t=1}^{N} {E_t}^2}{N}$
Root Mean squared error (RMSE)	$RMSE = \sqrt{\frac{\sum_{t=1}^{N} {E_t}^2}{N}}$

2.4 Organization of Material Management[11]

Materials management is simply the process by which an organization is supplied with the goods and services that it needs to achieve its objective of buying, storage, and movement of materials. Materials management is related to planning , procuring, storing and providing the appropriate material of right quality, right quantity at right place in right time so as to co-ordinate and schedule the production activity in an integrative way for an industrial undertaking.

Seeing the objectives above one can imagine the scope of material management spanning vast domain like the identification and specification of materials, identification and association with the right sources of supply, negotiation, purchasing, in bound transport arrangement, receiving, inspection, efficient storage and issue to respective manufacturing departments, maintaining continuity, maintaining proper records, and in some cases disposal of scrap, and surplus/obsolete materials and components. Therefore, organization structure for such complex and diverse functional management aspect will not be simple. An organization structure is an essential tool of management. As a system of responsibility and of formal interrelations it is concerned with two of the elements, namely, planning and coordination. Its chief purpose is to ensure smooth and balanced working of the organization. Obviously the size of the unit must affect the way in which management and other activities are carried out. Clearly, a large organization will be able to use, and will need to use, techniques and procedures of a different kind and higher degree of complexity than those of the medium or smaller firm. In other words, there will be difference in methods or routines according to differences in size, but the fundamental principles of management and the approach necessary for the attainment of effective management are the same, irrespective of size. Few principles behind the organizational structure design are:

(1) The determination of the basic objectives.

(2) The determination of the area of activity

(3) The determination of ideal structure to accomplish the desired activities

(4) Authority and Responsibility

[11] Anil K Datta, "Integrated Materials Management", S. Chand & Company Limited,1978

(5) Span of control

(6) Personal ability

(7) Unity of command

(8) Job assignment

(9) Regulations

(10) Two –way communication

(11) Flexibility

(12) Staff and Line activity

For the design of material organization, it is to be recognized that purchase is the most important activity within its ambit, and hence the purchasing executive must be made responsible to the Materials Manager with the delegation of authority must be cleared. However, much depends on the organization of his own department and the link which he maintains with other department. In many organizations, Materials Control Department is either linked with purchase or production planning department. Materials manager's closed association with the stores department helps control over inventories. The quantity of materials store has to receive against requisition, and in finding out the most economical ordering quantity, Material Control Department helps the purchase department to determine the materials to be purchased during a particular period, rate of consumption, etc. The Production Planning will give the ordering multiples, that is, how much to be kept into stock and also in the case of a new product, will approve the Bill of materials which it receives from the Engineering Department.

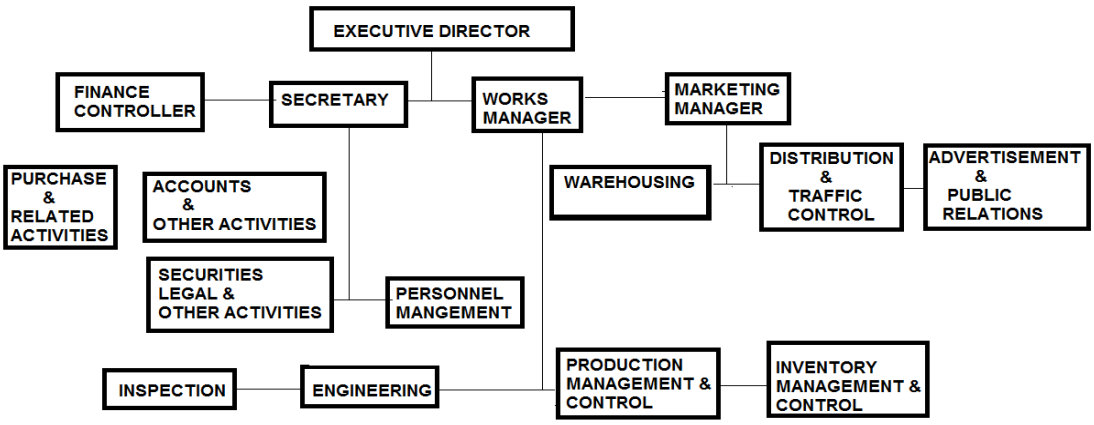

Figure 2.4.1: Organizational structure fro Materials Management (Datta, 1983)

Every organization has to make materials decision at some stage or the other. As materials management objective are interrelated, in many concerns these decisions are taken by the different functional specialists. Purchase decision are made by the purchase manager, inspection, engineering, production and inventory decisions are taken by the works manager, ware housing and traffic activities are probably controlled by the marketing manager, who is responsible for marketing the final products of the company. The so called overall materials management job is thus divided among some divisional heads to fit into the organization structure. But as the activities are dispersed, overall objective is hard to achieve if company's immediate objective is cost-reduction, everybody has to be made cost-conscious, but probably nobody can be made responsible if the materials objective is not achieved. In the organization structure shown in figure, it may be executive director who is ultimately answerable for the non achievement of the overall objective, but having so many other functions under his control, it may not be easy for him to catch up with his important objective. Anybody, whom he may sanction, will have his own alibi, "passing the buck" on others.

As an analysis will disclose materials decision are taken at least at three different functional levels viz., purchase manager making for buying decision, works manager taking inspection, engineering, production and inventory decisions, and marketing manager making his own choice for sales and the ultimate distribution of the company's product. Here, therefore, materials managements is a highly uncoordinated activity. Traffic control and ware housing are the ancillary operation of the marketing manager making him responsible for the management of materials at finished stage. Executive director's role over the activities of these specialists are manifestly controlled by the decision of the specialist themselves which have grown into ambit on the ground that they know the best that is safe from the view point of their performance as well as the company's objectives. Within the budget provision the discretionary contents of the executive director's role is thus to conform to the decision of these specialists. Thus his ultimate materials management objectives get blurred and his responsibility to the board of directors and shareholders in general for the economical management of the company's material, loses its dynamic nature. The tendency for these functions moving out of

adjustment more often leads to unstable situations. Very often systematic analysis requires to be done to bring them into line with each other. Taking the simplest possible situation, investigation may show the marketing manager was making decision by accepting orders from the customers thus, committing his colleagues' say, the works manager –in-charge of production, to manufacture them. In doing so, he in fact , was giving instruction to the works manager and the decisions as to, what and how much should be manufactured and sold was being taken requisitely by him, which, however , was the executive director's role. Arising from such an investigation in terms of materials specifications, size, dimensional accuracy, design from the view point of the marketing manager, of the customers' choice, the materials decision were again being taken by the works manager. It therefore, constituted a large area intermittently done by the managers, which requisitely belonged to the executive directors. In fact, it ought to have belonged to an enlarged and more highly skilled materials division.

Some of the gains from the organization approach on functional basis may be as follows:

(i) Greater consistency of material management arising out of a concerted action.

(ii) The changes which will emerge as a result of this approach may be obvious, and therefore necessary.

(iii) Reduction in feeling of confusion and frustration stemming from the increased sense of control.

(iv) Increased adaptability of the other functions infused through an approach of optimal level of material performance.

The kind of re-organization described here can only be carried through by allotting it to a specialist division at the necessary level of sophistication. As a result of such an attempt to understand what really happens to materials organization in such a changed situation, we may have to form an organizational frame-work in terms of company's thinking of overall materials objective. Such an organization structure in order to facilitate the optimum discharge of material management work may look very different.

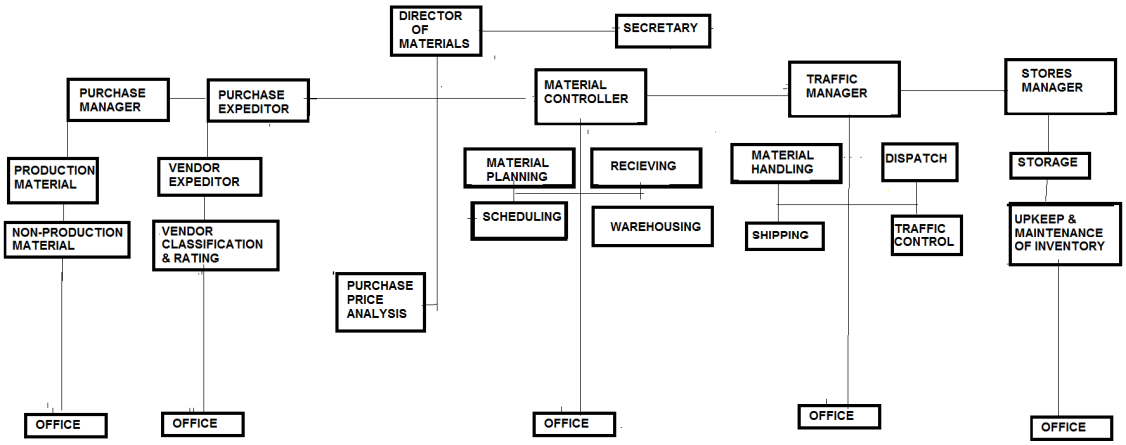

Figure 2.4.2: Organizational structure for Materials Managementunder new Set-up (Datta, 1983)

2.5 Material Planning

In any Integrated Materials Management environment, planning for availability of materials is the starting point. Material planning sets the procurement function and the subsequent material functions rolling. A material planning involves managing sales forecasts, creating master schedules, and based on master schedule identifying the need of material and arranging for its proper timely supply.

In *nutshell, one can say balancing future supply and demand.*

The issues related to material planning are [12]

(i) Materials identification

Material department has to closely and continuously coordinate with departments like the engineering and design, production and process to help identify the materials, sub-assembly, spare parts, tool and equipments needed in the process and manufacture of end products. It guides these departments with the available options of material in the market and among these options the production and R&D

[12] IGNOU, "Production/Operations Management", Block5-Unit14

jointly make decisions as per efficiency and effectiveness criteria. This exploration and assessment is a continuous process depending on new materials, substitutes, supply conditions or internal change in the products, process methods, design or schedules.

(ii) Standardization

Standardization is the process of reducing the number of parts over a given range of product within the same organizational settings. The idea is to achieve inter-changeability of parts.

(iii) Make or Buy decision

From time to time the material management department needs to review whether certain items may be more advantageously manufactured in house or to be brought from outside. Engineering and design, production, finance departments etc along with materials department jointly take this decision. A decision to make an item in house has long term implications because the company's funds are to be invested into fixed assets to create the manufacturing facilities. Such a decision is very difficult to reverse later on.

(iv) Coding and Classification

Codification and Classification of materials is necessary for keeping the track of the material in its flow from supply to stores and later issue to various departments of production. All items in the material list are properly classified and codified to prevent mixing of one type of materials with the other and minimize the cost of retrieval. Materials are classified according to nature in appropriate categories, for example metal items may be grouped as, bronze, copper, steel, and mild steel etc., and each category is further classified suitably. Further classification can be based on functional and other usage attributes. To save time in handling of materials, a written document known as material manual, is prepared in which description and code number to each store item is given. Material planning process is smoothened due to this aspect only.

(v) Quality specification:

The material used in the production or assembly process has to perform certain function in the final product and it becomes a necessary task of Material planning to ensure that right product is secured for this. Material department, engineering and design department, production department, collectively decide on required quality standards for every item. The agreed quality standards are included as part

of the product or material codification and classification process. The suppliers are made aware of the required quality standards and proper inspection and testing strategy is devised to ensure the right delivery.

(vi) Environmental factors:

Global factors such as price trends, business cycles, government's import and export policies, etc., also influence the material planning process. For example credit policy of the government is a critical factor as banks follow these guidelines only while extending financial support to a business entity. There can be factors existing within the organization such as corporate policy on inventory holding, production strategy, investments, delegation of power, etc, impacting planning decisions.

Techniques of planning materials:

Among the a few available techniques, two most commonly used are:

(1) Materials Requirement Planning (MRP).

(2) Requirement based on past consumption.

CHAPTER 3: Purchasing in materials Management Concepts

3.1 Purchasing principles, Procedures, Policies and Practices

Raw materials and purchased components typically account for two third of the final cost of manufactured goods, and therefore, controlling their costs can influence profitability of an organization to a great extent. Purchasing which plays a main role in arranging these material for smooth operations at economical costs, thus strategically is an important function.

The procurement policy of any organization should aim at obtaining the most suitable goods and services at the most reasonable contract prices, ensuring delivery when and where required. With increasing complexities in materials characteristics and their usage vis-à-vis competition and globalization, the purchasing function in today's context has emerged as a very specialized activity.

There are three main basic principles[13], which any purchase process should follow:

(i) Value for money.

(ii) Open and effective competition

(iii) Purchasing ethics and code of conduct.

(i) Value for money:

This principle calls for weighing up the benefits of the purchase against the cost of the purchase. Value for money factors needs to be specifically included in evaluation criteria and may include assessing whether to make in house or outsource. This principle calls for specifying the standards on which the procured part should comply fulfilling the fitness of purpose. The supplier selection should be done on capacity, adoptability, technology and accessibility. For example one may go for local supplier which results in shorter delivery times, lesser transportation cost, local backup and servicing and in the long run potential for creating partnership and cooperative development. Whereas going for

[13] http://www.purchasing.tas.gov.au/buyingforgovernment/getpage.jsp?uid=F5E74B20DEF74E68CA256C750016BC87

global supplier can be advantageous on technical and capacity front, though may result in larger delivery time and inventory (due to large orders).One needs to evaluate the cost of incurring purchase based on return in terms of better fitness of product, quality assurance ,lead time, cost, backup and partnership.

(ii) Open and effective competition:

The purchasing process should ensure impartial, open and competitive environment. That is using transparent, open, purchasing processes so that potential contractors and the customers can have confidence in the outcomes. This also brings effectiveness and efficiency in purchase process. The purchase officer should adequately test the market, either by open tender or by seeking quotations to get better pricing estimates. The standards should be laid based on fitness of purpose and not biased to favor some, providing equal level ground for all potential suppliers.

(iii) Purchasing ethics and code of conduct.

The purchasing process should ensure that all purchasing is undertaken in a fair and unbiased way and suppliers act ethically and in accordance with appropriate legislation.

This includes -

(a) Purchase officer being fully accountable for the purchasing practices used and the decisions made;

(b) Ensuring that decisions are not influenced by self interest or personal gain (Officer must not accept gifts or any other benefits from suppliers);

(c) Identifying, dealing with and documenting issues relating to actual or perceived conflicts of interest;

(c) Maintaining confidentiality; and

(d) Ensuring that all purchasing is undertaken in accordance with Organizational policies

The procedures and practices of purchase function[14] can be studied using block diagram shown in the figure below:

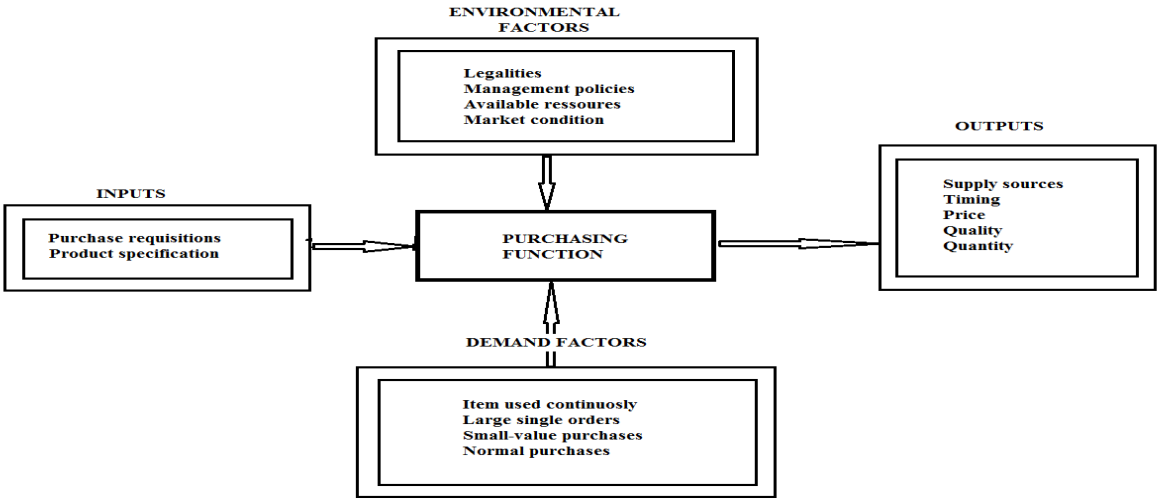

Figure3.1.1 Purchase Decision Function

The inputs to purchasing come in the form of requisition or indent from various departments and units of the organization. The requisition also accompanies product specifications. The purchasing department work is based solely on these inputs and it has to clearly understand these inputs and standards, before making any decision for their availability. After processing the input, the output of Purchase department is purchase order containing all specifications / performance criteria which goes to various agencies, viz. supplier, store, account, planning and requesting department.

The traditional requisition methodology (before MRP/ERP) has been of sending the requisition forms to the purchase department, which can be grouped into standard purchase requisition form , travelling purchase requisition form and Bill of material:

(a) Standard Purchase requisition form: This form is standard for a given organization and elaborates all the product specification along with demanding shop schedule. It also suggests potential suppliers and associated costs. Generally it is used for non-recurring requirement of items.

[14] IGNOU, "Management of Machines and Materials", Block6-Unit16

(b) Travelling purchase requisition: It is a condensed form of standard form and is used for recurring requirement for materials and standard parts. The form is in form of card, which can be used for many requisitions. Whenever the stock position drops to or below the re-order point, the card is sent to the supplier for replenishment.

(c) Bills of materials (BOM): BOM is the list of all part in a final product, which is derived from the engineering drawing of the product. The Production Planning department (PPC) sends production schedule along with BOM to the purchase department, from which the parts are exploded into material requirement plan, specifying quantity and timing of each part. Thus BOM eliminates the necessity of typing numerous requisitions for large number of items.

The environmental factors condition the purchasing department decisions, i.e. alternatives get limited. These factors include legal considerations, management policies, budget constraints, market conditions, etc. The contextual or demand factors include product attributes, frequency of use, storage space, etc.

The Purchase department has to identify suppliers who can provide the right product at the right time, and to bind them by this obligation many a times through contracts. These contracts have to be laid down on foundation of laws and rules of the land and company's policies. Also it is not always that the purchase is done based on best economic lot sizing model, and is restricted by budget constraints, priorities for other tasks and management policies. Market conditions also influence procurement policies, for example in turbulent phase, the purchasing strategy may be to ensure continuous supply than bother for the price. So we see that purchasing policies and practices in its objective of maintaining balance between supply and demand, has to cope with variety of factors , and to anticipate and understand these conditions requires a great deal of professionalism by the purchase personnel.

3.2 Fundamental Objectives of Purchasing[15]

The main objectives of the Purchase department are

[15] IGNOU, "Management of Machines and Materials", Block6-Unit16

(i) To buy materials of right quality, in the right quantity, in right price from the right place and at the right time.

(ii) To lay down the clear specifications and standards for communicating the right quality. For this function it works in collaboration with the user or planning department, elaborating the availability of quality of materials in the market.

(iii) To integrate the requirements of all the departments of organization in order to take advantage of economy of scale wherever possible and to also avoid duplication of purchases resulting in wastes and obsolescence.

(iv) To secure suitable source of supply, i.e. to procure at the lowest possible cost consistent with quality and service requirements. To ensure continuity of the supply so that scheduled activities are not interrupted.

(v) To maintain good mutually beneficial buyer-supplier relation. In this regard it explores contractual methodology, vendor rating methodology, etc.

(vi) To explore market continuously for better and better options for supply.

(vii) To explore minimum overhead expenses options involved in supply process, viz. transportation, inspection, storage, etc.

3.3 Sources of Supply and Supply selection[16]

To find a suitable source of supply is an important function of the purchase department. This process involves systematic investigation and comparison of available resources, the evaluation and monitoring of performance in terms of agreed standard and development of procedures and obligations with suppliers. Often for repeat orders it is advisable to continue with the existing source as supplier loyalty and performance are well documented. In case there has been discrepancies in performance like lead time fluctuations, failure to meet specifications and other issues related to declining vendor rating, then one goes for alternate or multiple sources. So going for single or multiple sources is again a question of demand and organizational context, but it's always better to

[16] Ray Wild, "Operations Management", THOMSON Publications, 2007

have multiple sources. Often an investigation of possible sources of supply of new items and materials reveal several alternatives, and hence there the question of single or multiple sourcing often arises (as the new set of suppliers is yet to be tested on performance). Factors to be considered in this respect include the following:

(a) *Effect on Price*: Single sourcing may result in reduced price as single large order going to a single supplier providing advantage of economy of scale. Alternatively, in certain circumstances, multiple sourcing may in fact reduce price as a result of suppliers competing for orders.

(b) *Effect on supply security*: The organization of procurement process will be simple with single supplier, but there is always a greater supply risk as a result of any disruptions, like strike, etc.

(c) *Effect on supplier motivation*: Large business from the buyer organization results in motivation to perform better and better to ensure continuity of place, but it has been observed that in competitive environment also motivation to perform better exists.

(d) *Effect on market structure*: Single sourcing may in the long run result in development of monopolistic situation with the eventual elimination of all sources of supply.

These considerations are taken into consideration along with company's policies to arrive at procurement strategy by purchase department.

The supplier selection process starts with inviting competitive bids and also analyzing on the same time the existing set of suppliers capacity and performance. The arrived bids and proposals are compared with respect to price and delivery offers and often the priority is given to the existing supplier, if there is not much variation. The factors on which detailed analysis done are:

(i) *Price and cost factors*, i.e. cost, delivery cost, insurance cost, price breaks, etc.

(ii) *Delivery factors*, including delivery lead times, delivery quantities and delivery frequencies.

(iii) *Capability* to meet specifications and quality control/assurance practices.

(iv) *Legal factors* e.g. warranty, in terms of condition, etc.

The flow chart given below illustrates the simplified process of supplier selection.

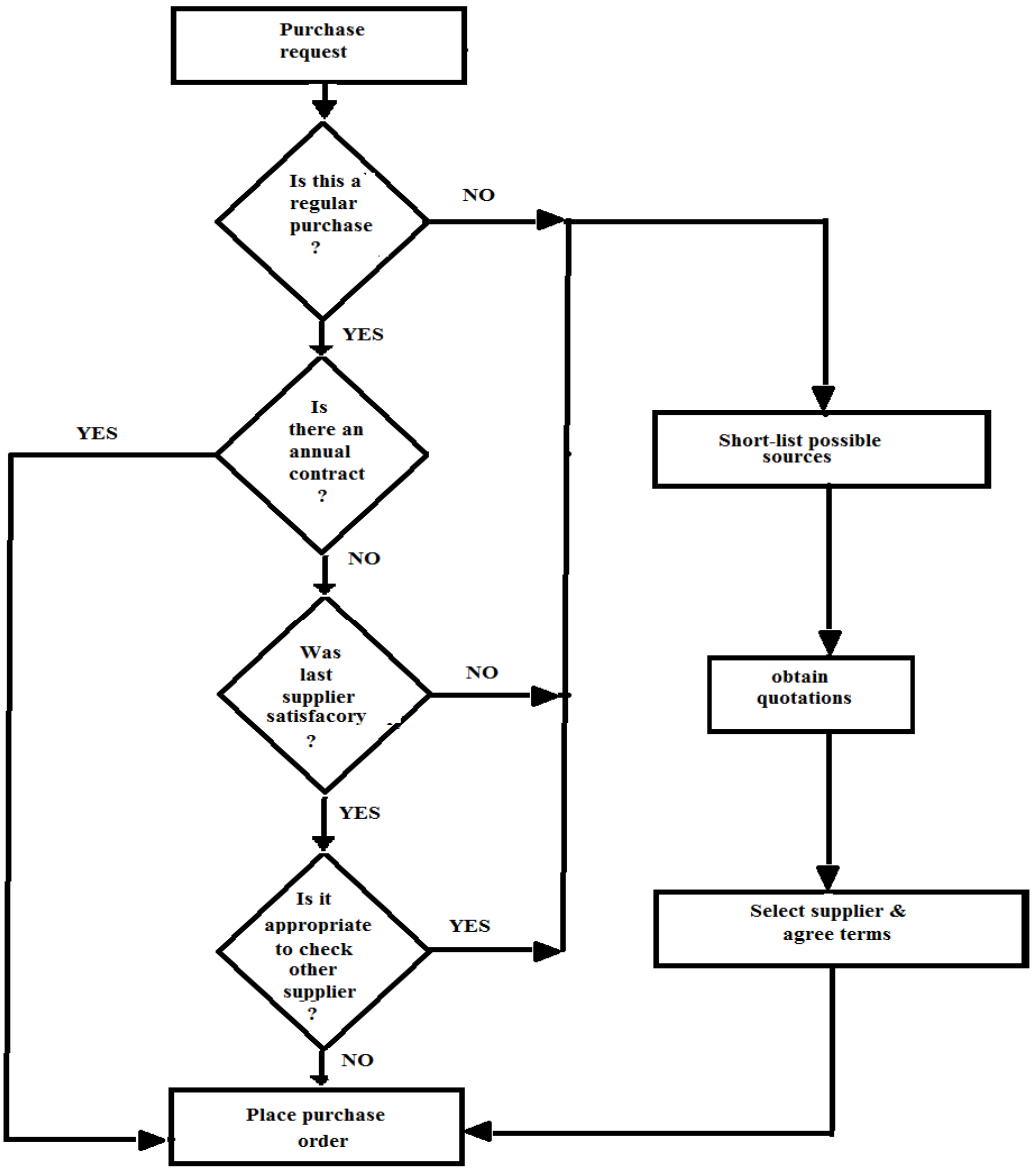

Figure 3.3.1: Outline of procedure for selecting a supplier (Ray Wild. 2003)

3.4 Purchase Budgets and Statistics[17]

A budget is a coordinated financial forecast of the income and expenditure of an organization. The purpose of the budget is to plan and control the activities of various departments in order to achieve certain objective and also to have an idea of the final results at the beginning of the budget period.

[17] N.K. Nair, Purchasing and Materials Management" , Vikas Publishing House Pvt. Limited,2004

Control is obtained by fixing achievement targets and expenditure limitations of each department and by periodical comparison of these with the progressive results and taking corrective measures if necessary. Every organization big or small should have budgetary control system so that management could assess from time to time how the organization is running.

The purchase budget which is a part of the whole budget is used by the organizations that have products in stock or inventory, as the value of inventory plays a large role in a complete purchase budget. A purchases budget is created to keep track of the business' inventory value and the amount of goods sold. It is also used to help keep track of desired ending inventory value each month, since this is often a goal set by organizational policy. It is just a representation of what the business plans to buy for the inventory and how much inventory it plans to grow or hold over a given period of time.

The purchase department activities are covered by (i) Purchase budget for different items and (ii) Purchase department operations budget. While the operations budget will show the estimated cost of running the department, savings that will be effected in the purchase, etc., the purchase budget gives an idea of the materials to be bought and also month to month requirements of finance to make payments to the suppliers. The purchase budget covers:

(a) Capital Items
(b) Tools
(c) General Stores (indirect items)
(d) Production materials i.e. raw material and purchased parts(direct materials)

Capital items include machine tools, work benches, etc., required by the engineering department; bins, racks, etc., required by stores; tables, chairs, etc., required by any department, construction or extension of buildings, etc. The requirements will be worked by the respective departments. Prices of the items may not be readily available and will have to be ascertained from the suppliers. Thereafter the payment schedule will be prepared on the basis of delivery dates for the equipment or likely progress of the projects and the payment terms. If necessary delivery of certain expensive equipment

or date of commencement of certain projects will be postponed so that too much pressure on finance can be avoided.

In the case of tools and general stores, if too many items are involved and if the monthly purchases are within small amounts the approximate payments o be made per month can be worked out on the basis of an average. For example, if the value of tools consumed and replaced during the last three years is around Rs. 600,000 a year, the value of monthly receipts and payments to be made per month may be taken as approximately Rs. 50,000. General stores items can be treated in a similar manner. As the expenditure in respect of tools and general stores is comparatively small, minor differences in the budget figures will not significantly affect the cash-flow position. However, adequate provision should be made for purchase of new items or increase in the holdings of existing items on account of increase in production.

With regard to raw materials and purchased parts, as they account for the major portion of the expenditure in the purchase budget, the month to month requirement of finance will be worked out by preparing a detailed statement showing the production program, requirements of each item per month, provisioning limit in terms of quantity, quantity in stock, quantity on order, quantity to be ordered, delivery schedule when payment is to be made, etc. The statement will be prepared class-wise in code number order or according to sub-group, i.e., all bearings together; all springs together; all nuts together and so on.

The schedules prepared for compiling the budget figures can also act as a medium to counter-check whether the purchase requisitions are being received from the stock control at the right time and for the right quantities. It will also show whether any item is having unnecessary huge stocks.

Like other budget has to be approved by the management. In the case of capital expenditure, in addition to the financial sanction from the Board of Directors, the administrative approval from the management is necessary for the purchase of the items or commencement of the work to ensure that sufficient cash are available at a given time to meet the expenditure. Also additional sanctions may be necessary under the following circumstances;

(a) If there is increase in production not envisaged when formulating the budget and purchase of larger quantities of materials is necessary.

(b) If stockpiling is necessary to avoid shortage of important materials.

(c) If prices have gone up considerably.

(d) Similarly if there is cut I the production during the budget period the requirements are to be recalculated taking into account in stock, quantity on order etc.

(e) A price variance report is also prepared by the Purchase department at the end of every month for the information of all concerned.

Illustration: The estimate for purchase budget for materials is given by the desired ending inventory plus the cost of goods sold minus the value of the beginning inventory. For example, if we want Rs.100,000 worth in ending inventory and the estimated/planned cost of goods sold is around Rs. 50,000, we add these two values and subtract the value of the current inventory from the total(Rs. 150,000 here) , to arrive at purchase budget. If the value of the beginning inventory is Rs.30, 000, for example, the final amount of total purchase budget will be Rs.120, 000.

3.5 Price Forecasting, Determination and Price Cost Analysis

The price determination and forecasting is an important function of *the sourcing department* operating under Supply Chain or Purchase. The price forecasted should be stable at-least for the contracted period of supply and provisions should be made in contract for making adjustments. The purchase price forecasting analysis can be grouped in two step process **cost analysis** and **price analysis**.[18]

Price Analysis is the process of deciding if the asking price for a product or service is fair and reasonable, without examining the specific cost and profit calculations the vendor used in arriving at the price. It is basically a process of comparing the price with known indicators of reasonableness.

When adequate price competition does not exist, some other form of analysis is required. Some reasons that could affect adequate price competition are: specifications are not definitive, tolerances are restrictive, or production capacity limits those eligible to bid.

[18] http://www.research.fsu.edu/contractsgrants/documents/cpaexpl.pdf

Examples of other forms of price analysis information include:

• analysis of previous prices paid

• comparison of vendor's price with the in-house estimate

• comparison of quotations or published price lists from multiple vendors

• comparisons with industry standard prices and practices

Along-with cost-function factorial analysis, there are various techniques and methods adopted by purchase department for ascertaining the right price in a given situation, like exploring previous purchases, price lists, telephonic enquiry, tender/ quotations, negotiation, etc.[19] The process of obtaining quotation involves a certain amount of work and this should be justified by the order size. Small value items should, therefore, be combined to make the value of the order sufficiently large or should be purchased in cash.

The purchase section must ensure the sanctity of the tender. Late offers should not be accepted and except in special cases, that are cases for negotiations, must be considered as final at the price submitted. Allowing revision of quotation will in the long run spoil the confidence which suppliers have in the buying organization of the company.

Tender Committee: For the purpose of evaluating quotations and selecting and suppliers, tenders may be divided into

(a) Those decided directly by the head of the purchase department.

(b) Those decided by tender committee, which may consist of the head of the purchase department, a representative from the accounts, and the Departmental head against whose purchase requisition, materials are being procured.

(c) Those which will be decided by the Management or jointly by the Management and the Tender committee.

The limits will be laid down by the Management and will be contained in the instructions issued to Purchase section. An example of the limits would be

1. Up to Rs. 1,000 for (a)

[19] N.K. Nair, Purchasing and Materials Management" , Vikas Publishing House Pvt. Limited,2004

2. Rs. 10001 to Rs 10,000 for (b)

3. Rs 10,001 and upwards for (c)

Different groups of tenders may be distinguished by suffix A, B, or C to the enquiry number as for example, PS/1051/A, PS/1734/B or PS/6386/C. Separate boxes will be kept for different groups of tenders.

Al the tenders will be opened at the time and date specified in the presence of the Head of Purchase Section or the Tender Committee as the case may be and in certain cases in the presence of the tenderers. As each tender is opened, it will be initialed by the tender committee and will be entered in a comparative schedule of quotation or tender register which will also show the date and time of opening the tender. The tender committee will initial the entries made in the register or schedule.

Comparative schedule is prepared from (i) Price lists, (ii) Telephone enquiries confirmed in writing, (iii) Quotation against written enquiries or tenders. It should contain the description of the materials, specification, the rates received from the various bidders; the price previously paid, packing charges, delivery time, special conditions if any of the tenders, payment terms, time limit if any for accepting the offer, etc. Therefore, it enables one to see at a glance the merits of the various offers received and to choose the best.

Price Cost Analysis is done when no competition is received. Typically, this occurs when procurement is sole source justified or when we solicit competition but receive only one response.

A Cost Analysis looks at the individual elements of the price (labor rates, direct & indirect materials and overhead, G&A expenses, profit/fee) and analyzes these to arrive at a decision. It is the element-by-element examination of the estimated or actual cost of contract performance to determine the probable cost to the vendor. The goal is to form an opinion on whether the proposed costs are in line with what reasonably economical and efficient performance should cost.

Cost or pricing data, which should be provided by the subcontractor, are the means for conducting cost analysis. Such data provide factual information about the costs that the subcontractor says may be incurred in performing the contract. Cost analysis should be performed in those situations where price

analysis does not yield a fair and reasonable price and where cost data are required in accordance with prime contract clauses.

Cost analysis techniques are used to break down a contractor's cost or pricing data so as to verify and evaluate each component. Some of the cost elements examined for necessity and reasonableness are materials costs, labor costs, equipment and overhead. These costs can be compared with actual costs previously incurred for similar work, the cost or pricing data received from other vendors, and independent cost estimate breakdowns.

The Engineering drawing of the new product received from the PPC is put to cost analysis to arrive at the minimum price to be accepted from the suppliers. The Cost behavior is the result of many forces. Determination of the functional relationships of costs to each major force provides the informational foundation for the various cost forecasts that are useful for pricing decisions. Knowledge of cost functions provides a foundation on which such analysis can be done. Some of the more important determinants of cost functions are: (1) rate of demand, (2) size of lot, (3) size of plant or capacity, (4) wage rates and material prices, and (5) technology. On analysis of cost curves one can find that different problems call for different kinds of cost conjectures. Projection on a scientific basis involves knowledge of the relationship of cost to each of these factors. This framework of knowledge of cost curves makes it possible to combine factors flexibly and thus produce with-out special research a variety of cost estimates suitable for various purposes.

A simple explanation of above factors without mathematical cost function relationship can be like for high rate of input one may demand high capacity of the supplier and hence both are positive correlated and their impact on price will be similar. Similarly higher lot size result in better economy of scale. Based on engineering drawing, the sourcing personnel explore the types of operation that will be carried out on the part and with available standard rate of operations one computes the production cost of the part. Similarly material cost can be obtained from the market or industry data. The company may also have the data base of that material through its regular raw material purchases. For complex parts usage of high technology may be required in that case adjustments in prices are

done. Since the objective of the procurement policy is to have healthy buyer-supplier relation a suitable provision for suppliers profit/expenses should be incorporated in deciding price over this costing.

Something more required over Price-Cost Analysis:

When the buyer wishes to be sure of the quality, selected suppliers should be requested to submit samples. These samples must be approved by the inspection department of the buyer's firm or by the person indenting the material or by some other competent person. The approved samples should be sent to the receiving section for comparison with the bulk supplies and the rejected ones should be returned to the suppliers. When repetitive purchases or periodical deliveries against a standing order are made, supplies should be checked to ensure that there is no deterioration in quality.

Negotiation is an important process in arriving at price settlement which will be dealt in detail in the following section.

3.6 Buying Negotiation & Buying Ethics

3.6.1 Buying Negotiation

As already discussed the impact of procurement costs are significant on company's profit and also the availability of brought out parts are essential for smooth operations of the production process. Hence the purchase officers at times have to negotiate prices with the suppliers. Negotiation is the exchange of views either verbal or written between the buyer and the prospective supplier over quality, rate of delivery, price, etc., in order to reach a conclusion satisfactory to both the parties. Negotiation, generally, includes the suppliers to effect a good reduction in price, if not; it will at least enable the buyer to understand the reason for the supplier's inability to price reduction. But as already mentioned, efforts to bring price reduction through negotiation should center on high value items.

Negotiation may take place before obtaining the quotation, after obtaining the quotation, when a repeat order is to be placed, when there is a price increase, etc.

The purpose of negotiation before obtaining a quotation is to enable a prospective supplier to understand the buyer's specialized requirements. An example is the construction of a building in which various features are required. It is advisable in such situations to invite quotations after explaining the requirements to the contractors.

Although Sourcing Department is the main instrument in negotiating price, often senior members of the management take part in the negotiation of high price and high off-take items. It is however, important that for successful negotiation, the buyer or any other negotiator on behalf of the purchase department should possess sound knowledge of the use of the materials and of their market conditions in the case of market commodities or of the manufacturing techniques in the case of manufactured items.

The negotiation process requires both the individual convincing skills and also the knowledge of the supplier and market conditions. So it demands studying the supplier and the market inside and out. Competitor's offers also act as strong negotiating tool. Suppliers with a long-standing history of quality products and timely deliveries are potential candidates for strategic partnership and can be easily convinced for capacity enhancement or technology improvement.

In negotiating, one should not get into arguments or fights even if there is no agreement on the price - because in the future, one may probably need to deal with that supplier again. On should not lose sight of big picture that the organization is going to make a decent profit when it sells the finished product and thus should be flexible enough to accommodate any such difference. One should understand that supplier also needs to make profit and so negotiate a price that is fair to both.

3.6.2 Buying Ethics[20]

Purchasing being money driven activity, like any other processes that directly influence or influenced by money, ethics comes into danger frequently. Hence the issue of ethics is much higher in purchasing than other fields where money is not the major driving agent. It is not an easy job to keep

[20] http://procurense.com/?p=105

the ethics high and fair in purchasing. It needs specific attention, dedication and motivated minds to keep up the ethics within the purchasing process.

If one wants to have strong and longer relation with suppliers, ethical and fare practices in dealings are must. Unethical deals may earn short term benefits, but in the long run that will be harmful to the business interest.

To have an ethical work culture most important thing is leadership vision and commitment. The senior leadership should value it and distill the same to lower most in the hierarchy. Adherence should be acknowledged and rewarded, and no adherence should be penalized appropriately. Ethical guideline should be part of the purchasing polices and should be published appropriately in all the relevant occasions. Below are listed a few:

1) All dealings should be transparent and candor. Even for closed competitive bidding, the allowed players should be dealt equally.

2) The entire transactions should be recorded and tracked.

3) The decisions taken should be data driven.

4) The good performance should get rewarded.

5) The working should be high on compliance to rules, regulations and government laws.

6) No cooking the books or numbers.

7) Recognition of social and environment responsibilities.

8) Aiming at genuine long term relationship with the suppliers

3.7 Legal Aspects of Purchasing

The Purchase department should be able to understand and anticipate the legal impact of purchasing decisions, as there can be issues of dispute or non-performance. As the purchasing department is directly involved with various issues (like contracts, freight issues and anti-competition laws) affecting the relationship between buyer and seller, it should be aware of relevant laws in this context. The important relevant laws[21] which they should be aware off are (i)Law of Agency, (ii) Law of Contract, (iii) Law pertaining to sale of goods, including Patent laws ,Warrantees, Trademarks, etc., and (iv) Arbitration. Professional legal advice should be sought on above issues as large sum of money and time (imports etc) are involved in the procurement process.

In Indian context, The Indian Sale of Goods Act, 1930 and The Indian Contract Act1872 cover some important legal aspects. Indian Chamber of commerce and International Chamber of Commerce have codified general business terminology to minimize the friction between buyer and seller.

The transaction of purchase is a sort of a contract and should satisfy the following requirement[22]:

Legal capacity of parties: The persons performing the buying and selling should have the legal capacity to enter into contract. In other words, they should be persons duly authorized by their employers or principals to enter into commitments on their behalf. Generally, letters signed by the persons concerned stating their designations will give an idea whether they have the authority to commit their company. Otherwise, it may be necessary to make enquires.

Legality of subject matter: This means that the transactions should not be illegal or opposed to public, such as buying at prices higher than those fixed by the Government, buying from unlawful sources, etc. Similarly, an agreement to do an illegal act is void.

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[21] IGNOU, "Management of Machines and Materials", Block6-Unit16

[22] N.K. Nair, Purchasing and Materials Management", Vikas Publishing House Pvt. Limited,2004

Offer and acceptance: In a contract to buy or sell, there should be an offer to buy or sell and the acceptance of such offer .they are complete when(a)a quotation(which is an offer) is submitted and a purchase order is sent in response to this quotation within the specified period of time, if time is stipulated or within are a reasonable time, if no time is stipulated, and (b)a repeat order prepared from catalogues, price lists, etc., is accepted by the supplier(price lists and catalogue by themselves are not offers). An acknowledgement of the order or proof from postal authorities that the communication of acceptance, i.e. telegram or letter, has been dispatched fulfils the requirement of law. The offer can be withdrawn any time before it is communicated to the offered.

If the terms of purchase order differ from the quotation or if the terms of the order issued by the seller differ from the terms of the purchase order, there is no acceptance but only counter offer and it must be accepted by the party concerned to make the contract concluded, or binding on them.

Part supply against an order constitutes an acceptance by the supplier of the terms and similarly acceptance of the goods by the buyer is tantamount to acceptance of the suppliers" terms and conditions unless he has protested at the time of receiving the goods.

Consideration: Another important requirement of a contract is consideration. A contract by which only the seller is obliged to supply certain goods is not enforceable. There should be a cores pending agreement on the part of the buyer to pay certain consideration which, here, is the price. Remarks such as "at lowest rate" or "at actual cost plus 10 percent" although legally valid, should be avoided as possible as the final price in such cases is open to dispute.

Other important aspects are summarized below:

Authority: The persons authorized to sign the orders and the extent of their authority should be specified by the Management. In the absence of any written authority, the purchasing agent derives certain implied authority by virtue of the nature of work.

Employer's liability: The commitments of the purchasing agent are binding on his employers when such commitments are made within the authority vested in him and if he has exercised reasonable care and prudence in discharging his duties.

If the purchasing agent has been exceeding the expressed authority conferred on him by his employers in his dealings with third parties over a long period and if the company has not repudiated such transactions, the question if implied authority arises and the third parties will be right in considering that purchasing agent is acting with authority. In such circumstances the company is bound by similar action of purchasing agent.

Signature: In signing purchase order, the purchasing agent should make it clear that he is acting on behalf of his company by prefixing the word "for" to the name of the company and by putting his signature and designation below the name of the company as shown below:

For A & B Co.

Sd/-k.ram

Purchase officer.

Personal responsibility: The purchasing agents will be liable for any loss which his firm may sustain, if he has acted outside the scope of the authority given to him either expressed or implied. Similarly, he will be personally responsible in the eye of law for any illegal act committed by him even though such an act is do ne under the instructions of his employer for, no one has authority to order another to do an illegal act irrespective of their official relationship.

Delivery date: If no date is fixed for delivery of goods, the seller is bound to deliver them only within a reasonable time. Therefore, a definite delivery date on the order is essential if the buyer wishes to retain the right to cancel the order for delay in delivery. Words such as "urgent" and "immediate" are vague and are liable to be questioned in a court of Law.

Place of delivery: The rule is that unless there is an agreement to the contrary, the delivery is to be taken at the place at which the goods are at the time of sale or at which they are manufactured. Therefore, if the buyer wants delivery at his works or elsewhere, the purchase enquiry and the order should stipulate the place where delivery is to be effected.

Mode of dispatch: Unless otherwise instructed by the buyer, the seller may make his own arrangements on behalf of the buyer for transport of the goods but the seller must ensure that the mode of dispatch is satisfactory for the type of goods to be sent and is the one usually adopted by similar dealers.

Packing: The buyer may hold the seller responsible for damage of goods in transit if such damage has occurred owing to inadequate packing or non-compliance of the packing regulations such as those of the railways.

Bailment: Bailment is the delivery (handing over) of goods by one person to another for some purpose, say safe custody, transportation, etc. (The term "goods" excludes immovable property and money).

The person to whom the goods belong is the bailer and the party who accepts the goods (for example, the transport carries for transporting from one place to another) is the bailee.

The bailee is responsible for the safety of the goods except if the loss or damage is due to Act of God like floods, earthquake, etc., inherent characteristics of the commodity like rusting of or on articles, authority of law, i.e., when the goods are removed from his custody by legal process, default of bailer such as inadequate packing, etc.

F.O.B, F.O.R., and C.I.F.: When sales are made F.O.B. (FREE on board) and F.O.R. (free on rail) seller's end, the price includes packing, transportation and loading charges from the seller's works to the point of dispatch. The buyer pays the freight as well as arranges for insurance. The seller, must, however, in from the buyer within a reasonable time regarding the dispatch so that the latter can make arrangements for the insurance.

When sales are made on F.O.R. buyer's end or C.I.F. (cost, insurance and freight) basis, the seller pay transportation charges and freight to the destination as well as arranges for insurance.

Title to goods: Generally the title passes when the parties to the contract intend it to pass. If the intention cannot be determined, the normal rules which are given below are applicable. If the delivery is actual, the title passes at the time of delivery.

When goods are sent through carriers, such as steamer companies, railways, road transport corporations, etc. if the documents of title (bill of lading, railway receipts, consignment notes, etc.) raised in favor of the buyer, i.e., if the buyer is the consignee, generally the title passes as soon as the goods are handed over to the carrier and a clean bill of lading or railway receipt as case may be is obtained. However, if there is an agreement that the buyer shell take control over the goods only after certain conditions are fulfilled, say after payment is effected, the title will pass only when the conditions are fulfilled even though the buyer may take delivery of the goods.

If the seller states on the bill of lading that the goods shall be delivered only to the order of his bank or in the case of railway receipt if he states that the consignee is self, the title will pass to the buyer only when the document is fully endorsed in his favor.(generally after the payment is made)

Passing of Risk: The general rule is that "risk follows title" and until the ownership passes to the buyer, the goods remain at the seller's risk.

Sales Tax: In India there are two types of sales tax, local sales tax (SVAT) AND Central sales tax (CEN-VAT). Local sales tax varies from state to state.

Sales which occasion movement of goods from one state to another or which takes place by transfer of document from during inter-state movement of goods are inter-state sales. These are liable to be taxed under the central sales tax act.

Express Warranty: is one, where the seller expressly guarantees, or assumes responsibility for same special quality, or characteristic of the goods, such as performance, speed, capacity, etc.

Implied warranty: In all purchase agreements, it is implied that (a) where the purchase is agreed to by description, the goods should correspond to description, (b) where the purchase is agreed to by sample, the supply should correspond to the sample, and (c) where the buyer makes know to the seller the particular purpose for which goods are required, the goods supplied shall reasonably be suitable for such purpose.

Right of Examination; If the goods have not been previously examined , the buyer has a right to examine the goods at the time of delivery or within a responsible time, for the purpose of ensuring that they are in accordance with the order.

Wrong Quality: Unless otherwise proved, mere acknowledgements of the gods by the buyer will not absolve the seller from a liability regarding quality for the goods supplied; but the buyer should notify the seller within a reasonable time of any defect. If the defects are noticeable while delivery is being effected, the rejection must not be delayed.

Return of rejection: Unless otherwise stated in the contract, the buyer is not obliged to make agreements for the return of defective or ejected goods to the seller. It is sufficient if he notifies the seller o the rejection within a reasonable time.

As is and where is: when goods are brought under "as is" conditions it is implied that there is no guarantee as regards the quality or fitness of the goods similarly when goods are bought under "where is" condition, the responsibility for packing ,transporting, etc. is that of the buyer.

Part or excess supply: the buyer is not bound to accept goods when delivered in part or excess unless so mentioned on the order but if accepts the goods , he shall pay for the them at the price on the purchase order.

Liquidated damages: This is the amount payable by one party to another by way of compensations for any loss sustained on account of failure of the other party to fulfill his part of the obligation (e.g., if the seller does not supply the goods in time or if the buyer cancels the order from his own convenience), if such a provision has been made in the contract.

Force majeure: This is a condition usually included in purchase contracts to protect both the seller and buyer for non-performance of the contract due to reason beyond control such floods, fire, lock-out, etc. The party relying on this clause should notify the other regarding suspensions of the performance revive the obligations as soon as conditions are normal.

Escalator clause: Suppliers generally include this clause in their quotation or acceptance or order for the supply of certain items, especially capital equipment having long delivery to arrive at the final price, depending upon the labor and material cost at the time of delivery. When a quotation is subject to an escalator clause, it would be a good thing if the buyer stipulates that any price increase on account of material or labor should be supported by public notification from an appropriate authority.

Cancellation: A quotation may be cancelled by a seller prior to its acceptance by the buyer or an order may be cancelled by the buyer prior to its acceptance by the seller. Once accepted cancellations mat be made by either the buyer or seller only by manual consent. Otherwise it may result in litigation and may spoil the business relationship of the two firms.

Settlement of disputes: The buyer may include in the terms and conditions of the purchase order the manner in which any dispute should be settled (like item 10 form 14). Usually, method of arbitration and jurisdiction of courts are specified.

Purchase order terms; If the terms and conditions are printed on the back of the order, this fact should be prominently indicate don the face of the order above the signature, by remark such as " this order is placed subject to the terms and condition printed on the reverse".

CHAPTER 4: Purchasing and Quality Assurance

Purchasing and procurement generally refers to the collection of activities that result in obtaining things necessary for an organization. The things are usually materials, parts, subassemblies, etc. and these are necessitated by different functional departments within an organization. In this chapter, we will primarily deal with the concept of value analysis, supplier quality assurance, the relationship between the buyer and suppliers, quality awareness, and determining quality. First we summarize the concept of value analysis and value engineering.

4.1 Value Analysis and value Engineering

Value Engineering (VE) or Value Analysis (VA) are two interchangeable terms, signifying the same approach that can improve the performance of products, services, systems, or procedures. Value Engineering ensures that such improvements happen without jeopardizing desired functions along with cost reduction. Value engineering is also known as Value Management and as well as Value Assurance. Value Analysis concept was put-forth by Lawrence D. Miles, and the birth place is considered as General Electric Company (GEC) during World War II. The first organization to implement VE was United States Navy Bureau of Ships. In fact, US Department of Defense (USDOD) emphasizes the application of VE in most of its defense projects and many success stories have been reported so far.

The classical definition of Value Engineering by Miles (1961)[23] states that "an organized creative approach which has for its purpose the efficient identification of unnecessary cost, i.e., cost which provides neither quality, nor use, nor life, nor appearance, nor customer features". The term ‘organized creative approach’ implies an organized systemic study. Its goal is the systematic application of recognized techniques that identify the functions of a product or service, establish the worth of those functions, and provide only the necessary functions to meet the required performance

[23] Miles, L.D., "Techniques of Value Analysis and Engineering", LD Miles Value Foundation, 1961.

at the lowest overall cost. Put in simple terms, the goal is to achieve better or at least equivalent performance by reducing cost, while maintaining the same quality.

Lack of organized effort is usually the main reason why products, services, procedures, and systems end up with poor value. The main driver is the highly stressed and compressed timeframe within which the product or service gets designed or created; which forces the designers to play-safe by exclusively emphasizing on technical feasibility. Many a times, this results in introduction of costly materials or unnecessary functions that are not needed by the customer. Also, ad-hoc decisions that are taken during the inception phase under duress get permanency because of the non-existence of a review process. Coupled along with lack of information, habits, and attitudes, a strangling web of inefficiencies get embedded into the product or service.

The reduction in cost is accomplished in Value Engineering by identifying and removing such hidden or invisible, and unnecessary costs associated with a product, or service, or system, or procedure. VE eliminates, or minimizes the waste of material, time, and product cost, which improves the value to the customer. This prompted many practitioners to drub VE as a Lean technique as well.

Traditionally, Value Engineering has been used in the traditional areas of manufacturing and product design extensively. Of late, the VE principles are applied in the service industries, project management, systems engineering, etc. Though sometimes, VE gets interpreted as a mere cost reduction technique, especially in the software industry; the perception is not true. The fact that the cost reduction is obtained without any sacrifice in quality, reliability, maintainability, availability, etc. of the product or service; itself suggest the comprehensive nature of the approach. Now, let us consider the cornerstone concepts of Value Analysis, i.e., Functions and Values.

Concepts of Functions and Value

The term value is used confusingly by many as a synonym for cost, or more specifically the monetary price of the product or service. It has more to do with worth or utility of a product or service, which is a composite of performance (or quality) and cost. Thus in simple mathematical sense, value can be considered as a ratio of positive and negative aspects of a product or service; or the ratio of performance to cost. Thus as a ratio, if we reduce the cost of the product or service without changing the performance (or quality); the value of the product or service will improve. Better put, value can be increased by either increasing the performance or decreasing the cost. The important constraint on the performance increase is that it will only increase the value of the product or service if and only if the customer needs or wants, and is willing to pay for the additional performance. There are four major types of value, viz., **use value, esteem value, cost value,** and **exchange value.**

Use value relates to the properties and qualities of a product or service that is necessary to accomplish a useful purpose. Similarly, properties or features present in a product or service that causes end-user to want to own a product or service is usually called as **esteem value**. The sum total of labor, material, time, and other costs required to produce the product or service is considered as **cost value**. The properties and qualities of a product or service that enable the exchange of it with something else that is necessary are called as the **exchange value**.

Value engineering is a functional approach, which is customer oriented. By function, the purpose or use of a product or service is implied. Since VE deals with functions, identification of functions is an important aspect of the process. Functions are of two major types.

1. Basic functions - are those functions of a product, service, item, or system that defines the primary functions of it.

2. Secondary functions - are those functions that are supporting in nature, whose absence will not affect the primary purpose.

Introduction of redundant and unnecessary functions, as well as inability to understand the functions clearly will result in poor value of the product or service. Once the functions are identified, they can be critically evaluated against its cost. The critical questioning process, established by L. D. Miles, is

aimed at establishing whether there is scope of value improvement. As established by experts, these questions, when honestly applied will identify the room for improvement in most of the products and services. They are:

1. Can a part be eliminated by redesign?
2. Are all the features necessary?
3. Can the item be procured at a lower cost?
4. Is there a better alternative available for the same purpose?
5. Any lower-cost method available for making a usable part?
6. Can any standard part be used instead?
7. Are tooling proper for the desired quantities to be manufactured?
8. Any new materials available that can be used, resulting in cost reduction?
9. Any parts are combinable into one to reduce the assembly steps or eliminate unnecessary steps in between?
10. Can any specifications be changed, with customer consent, so that the cost can be reduced?

By applying the value test questions, specific areas of the product or service that is resulting in poor value may be identified. The areas could be product design, procurement, storage, material handling, production operations, packaging, shipping, and distribution of final product. Once such areas are identified, specific methods can be used to identify the unnecessary features and eliminate them to increase the value. The formal process model of Value Engineering that allows for value increase of a product or service is called as the job plan.

Job Plan

Initially, L.D. Miles proposed job plan as a modification of the work study method. Since then, the process has been modified and different variations of the same exist. Whichever format being used, the following seven steps are essential to the job plan approach.

1. General phase – This phase creates the right environment within which the VE process gets applied. There are five major techniques associated with this phase:

a. Use good human relations – fosters good personal interactions that will facilitate the whole process, and good human relations will result in assistance in the place of resistance.

b. Inspire team work – One of the hardest aspects to accomplish, as team members conducting the VE should take ego out of their mind and work for the interest of the group.

c. Work on specifics – Concrete data and information on specific problems must be created; avoiding opinions and gut feelings as well as all encompassing general statements.

d. Overcome roadblocks – Identify the roadblocks that could arise during the process, and means to tackle them. One best practice is to identify the dissent group and manage them so that the process continues smoothly.

e. Apply good business judgement – Business decisions should be only based on facts, devoid of emotions. Participating members should be educated to remove personal bias and feelings from the decision making process.

2. Information gathering - this steps primarily aims at collecting details on what is being done as of now, or what is going on. VE is based on the time tested management principle of "one cannot manage what cannot be measured". Specific enquiries on the person accomplishing the activity, the primary and secondary functions, and most importantly what should not be done are also determined during this phase. This phase has three sub-steps:

a. Secure facts – where the authenticity of the facts have to be established, which is one of the hardest thing to accomplish. The information will include technical specifications, environmental specifications, engineering drawings, production sample, production data, cost data, work specifications, customer preferences, testing and service records, scrap rates, etc.

b. Determine costs – To have any improvement in value, the costs need to be reduced or at least kept the same for an increase in quality. Clearly identifying the costs allows for the identification of promising areas where VE can focus to obtain best results.

c. Fix costs on specifications and requirements - the relationship between cost and specifications and as well as cost and requirements are established in this step. This also allows for quantitatively evaluating both specifications and requirements. If the cost estimates are accurate, then the evaluation of specifications and requirements will also be accurate.

3. Function phase - Main objective of this phase is to define the functions that a product actually performs and is required to perform. Also the cost and/or worth of providing these functions are then cross linked to the respective functions. Additionally, the alternatives to the functions are quantified as part of this step. Specifically, possible alternate or alternative ways of accomplishing the desired functions or meeting the requirements are documented. The major two techniques of this phase are:

a. Define function – functional analysis method requires functions to be described as a verb-noun phrase. This restriction is aimed at generating clear descriptions of the functions; reducing the possibility of semantic elaboration. This forces a rational approach and eliminates ambiguity. The major rules of function definition are:

i) Determine users' need for the product or service

ii) Use only one verb-noun phrase, which should answer the question "What does it do?" It is advised that the noun should be measurable and verb be action oriented.

iii) Refrain from using passive or indirect verbs

iv) Avoid goal like phrases like improve, maximize, minimize, optimize, etc.

v) List all possible alternatives and options for the verb-noun phrase and choose the best from the list.

b. Evaluate function relationship – The relative importance of various functions are quantified in this step. Once the quantification is over, a list of functions in the descending order of the relative value and importance is created. The most common method used in this evaluation is the paired comparison technique. If there are n functions then there are $n\ (n-1)/2$ pairs to be compared. For example if two functions X and Y, where X is compared with Y, a score of X-5 implies X has more significance than Y. Similarly, when Y is compared with X, and of the score is Y-1 results, it implies that Y is important than X, but with a little margin only.

4. Creation phase - This phase analyzes all the information collected, to establish what should be done and how much will it cost to do it. Then the costs of functions necessary for all established alternatives/alternates are detailed, and in the process any un-necessary functions and/or activities identified. This is the first step in attempting to answer the question "What else will do?" Creativity is the focal point of this step. To have creativity, atmosphere for positive thinking is to be created. For that, avoid judging an idea, especially when it is incepted. The end result is an extensive and exhaustive list of ideas. Techniques like check-lists, idea simulations, etc. can be used for the ideation purpose.

5. Evaluation phase - This step is aimed at further evaluating the most promising ideas generated in the previous phase. Once the first screening is over, the resulting ideas need to be subjected to the following criteria:

a. Will the idea work?

b. Is the new idea cheaper than the present design?

c. Is the new idea feasible to implement?

This phase and the supporting documents generated during this phase should be done with due diligence, because the critical judgment aspect is bought into action. Typically, there are four major sub-steps for this phase:

a. **Refine and combine ideas –** practicality of the idea is emphasized and to ensure practicality, either idea refinement or idea combinations are carried out to obtain the desired result.
b. **Establish cost of all ideas –** As ideas get refined, the estimated cost of the idea is to be calculated, with focus on cost of implementing the idea and the potential savings by doing so.
c. **Develop function alternatives –** This step permit the generation of total solution from individual functional solutions that are generated during the evaluation phase.
d. **Evaluate by comparison –** When the total solutions generated have cost figures that are quite similar, individual comparison of solutions are conducted to identify the solution having the greatest value advantage.

The important thing to remember is that the evaluation of alternatives is conducted on both tangible and intangible attributes. The most common technique for conducting such evaluations is the decision matrix technique. Thus technique assigns relative importance for each criteria and a normalized score is assigned to each alternative on each attribute. Then the total weighted score for each alternative is calculated and the one with greatest score becomes the preferred alternative. An example is included in figure below.

6. Investigation phase – This phase is aimed at further refining the outcomes of the evaluation phase into workable and acceptable solutions; providing lower cost methods for performing the desired function. The three major aspects of this phase are:

a. **Use industry standards** – The main reason for using standards is the underlying fact that standards usually provide a proven solution to a problem. When established standards are used, the implementation of the alternative becomes easy.

b. **Consult vendors and specialists –** Many times valuable insights to the capabilities of a product can be given by the vendor. If convinced, it might be better to procure the item from the vendor rather than producing it in-house. Similarly suppliers can help with cost reduction and quality improving ideas. Specialists are helpful with the specialized knowledge can suggest better alternatives like cheaper material substitute, new manufacturing process that reduces cost, etc. In VE philosophy, consulting with others increases synergy and opens-up new avenues for improvement.

c. **Use specialty products and processes** – In many cases, specialty products and processes can reduce the cost of the alternative functions. But before adopting them, care should be taken to ensure that cheaper alternatives are not available in the standard products, processes, and procedures.

7. Recommendation phase – This is the final phase of the Job Plan where the selected best alternative is recommended for acceptance and implementation. The success of the Job Plan depends upon the acceptance of the recommendation, which in many cases is based on how the recommendation is presented to the higher management. The two major techniques associated with this phase are:

a. **Present facts –** Just stating the facts will usually speak for it and allow the decision making authorities to see things clearly.

b. **Motivate positive action –** This is an elaboration where facts along with benefits, cost savings, and long term strategic importance which motivates the group to take positive action.

In any case, presentations can be either verbal or written. Combination of both is usually the best strategy as it minimizes the ambiguities associated with assumptions. Also, it allows for immediate clarifications of any questions that the decision makers may have while going through the facts and

details. Though, Job Plan is an effective method that is used in Value Engineering, another method with similar popularity is called as FAST diagram.

Benefits of Value Engineering

In simple terms, VE allows for improving the efficiency and effectiveness of the systems and products under consideration. Additionally:

a. It allows for specific identification of the areas that need attention and improvement.
b. Specific method for creating and evaluating alternatives for solution to a specific problem in hand.
c. It is an effective way of initiating and sustaining dialogue.
d. Creates comprehensive documentation on the rationale behind the decisions.
e. It is a way to improve the value of goods and services.

4.2 Supplier Quality Assurance Program

The supplier quality assurance program as defined by Joseph Moses Juran is a nine steps process:

1. Defining the product's quality requirements,
2. Examining and evaluating the available alternatives (i.e. suppliers).
3. Selection of the most appropriate supplier,
4. Conduction of joint quality planning,
5. Cooperation during relationship period,
6. Validation of conformance to requirements,
7. Certification of qualified suppliers,
8. Conduction of quality improvement plans,
9. Creation and use of supplier ratings.

4.3 Buyer- Supplier Relationship

Present day economics, which are highly competitive, warrants buyers and suppliers to work together as partners. In practice, getting buyers and suppliers to work together as a team with a common goal is quite hard. They view each other as adversaries due to contradictory goals and therefore fail to consider the benefits of working together. The contradictory goals come from the fact that buyers want the lowest possible prices, whereas suppliers want better profits.

A successful partnership is based on mutual economic gain along with mutual respect and clear understanding of each other's roles and responsibilities, both parties sincerely strive to win by having business responsiveness to each other's needs and to those of the end-user. This requires openness, honesty, integrity, fairness, professionalism, mutual reliability, interdependence and knowledge sharing. Thus it is fair to say that successful partnerships are ongoing and consistent and not limited to a special program.

As we said before the relationship between a supplier and buyer is a complex one, both aiming to maximize its time, resources, and cash investment; these contradicting priorities can strain the relationship. Striking a balance, which is necessary for a partnership implies not driving for the lowest possible price with no regard for the true expense, rather recognizing that the success of one partner facilitates the success of the other. The three critical aspects for creating a successful partnership are:

1. Compliance with local and international regulations
2. Conduct that breeds honesty, respect and open dialogue
3. Strategic financing that benefits both parties.

These three critical aspects are elaborated below:

4.3.1 Compliance

The first step of any new relationship is to know well the partner with whom the business is going to be conducted. This is not just limited to knowing its customer and supplier; but their suppliers and customers as well. There are multiple methods to accomplish the screening of involved parties in a new relationship, including subscribing to the issued lists and their corresponding updates directly, or increasingly common, utilizing a third party provider to perform this service. As many businesses outsource pieces of the supply chain, outsourcing the screening function is also a logical step.

In globalized competitive era, many suppliers are aware of the responsibility to know the identity of the final recipient and intended use of the goods and also the importers are adopting the "best practice" of screening all their suppliers, both domestically and internationally. In addition, by adopting such procedures, a company is sending the message to its partners that it is serious about compliance and taking responsibility for supply chain security.

4.3.2 Conduct

Once the potential new partner succeeds the clearance test, an organization can move on to the next level of approval. Today, suppliers for larger organizations are subject to rigorous reviews than ever. Less-than-ethical labor practices have had severe impacts at major brands with aspects like child labor, minimum wages, etc. coming to lime light. As companies have to fulfill social responsibilities, they have to be cognizant of the ethical practices throughout the supply chain; and need to ensure goods are sourced from suppliers that are fulfilling their codes of conduct; thus maintaining their own level of financial, environmental and social responsibility.

To begin with; a company should scrutinize potential suppliers' general and financial operational practices. Such a review could start with a questionnaire concerning the company's business practices, employee benefit information and facility information. Insight also can be gained through a site visit and by interviewing a selection of the company's employees. The chosen supplier could then be placed on probation for a given time frame until they have proven themselves to be an ethical, conscientious and compliant member of the organization's global supply chain. From there, periodic

physical audits are recommended to ensure conduct remains at the agreed level; thus further developing the relationship. By having a supplier code of conduct in place, businesses demonstrate their commitment to maintaining high ethical standards which will resonate with their end customers as well.

4.3.3 Strategic Finance

The third critical is the financial issues around which the entire relationship revolves. While the buyer aims to get a fair (again, not always lowest) price, the supplier has to ensure that the costs are covered, and he makes profit. Negotiating down to the least price is not beneficial to the buyer because it results in lack of trust and locality from supplier. Price should be just one factor in the negotiation; quality and timely delivery are equally or sometimes more important. Classical examples include defense companies, aircraft manufacturers, fashion stores, etc.

Another issue in financial aspect is payment terms. Some example are like allowing payment at sight of documents, or payment at FOB port, or sight plus 15 days, etc. For an international shipment, the goods are typically paid for well before they arrive at the final destination. Alternative payment methods include traditional letter of credit, Private Label Letter of Credit,Open Account payment process, etc. As with other aspects of the buyer-supplier relationship, changing payment terms leads to tradeoffs. One benefit of moving away from letters of credit is lower transaction fees from the banking channel and less paperwork; tradeoffs include reduced access to financing for the supplier, as well as increased transactional risk to both parties.

To reduce the risk of currency fluctuations it is advisable to buy the goods in local currency. Typically most buyers in United States of America purchase their goods in U.S. Dollars. Contracts and prices are negotiated months in advance; in some cases a negative fluctuation could spell the difference between profit and loss for a supplier. In an accommodating partnership, any unfavorable situations for either of the partner from a financial loss standpoint is usually addressed by mutual consensus and participation

It is important to realize that companies invest a lot of time, effort, and money to find qualified suppliers. Once the buyer secures a relationship with such a supplier, it Sis beneficial to constantly nurture the relationship with an intention to grow further. This can only be accomplished when both the supplier and buyer develop a relationship that emphasizes compliance with international regulations, mutually acceptable conduct guidelines and strategic financing options.

4.4 Quality Awareness and Determinants of Quality

Keeping the customer wants and needs in consideration and fulfilling it is the key feature of being successful. Such an approach is called as customer centric approach. To build such customer centric processes and systems, it is not only important to adopt methodologies like Lean and Six Sigma to create defect free products, services, and robust processes; but it also calls for building a customer oriented culture within the organization. Hence, it is very important that any organization should have an organization wide quality awareness program, where all employees come together as a team and understand the importance of giving the best they have for customer satisfaction. To realize the customer satisfaction at highest level, the following things are to be focused on:

4.4.1 Leadership

It is very important for someone in the organization to take up the leadership of building customer oriented system and processes. This initiative need not come from the top management, but anyone who is in direct contact with customer can take this initiative. The leader should ensure that the customer continuously has a better experience each time dealing with the organization.

4.4.2 Risk

Starting a business is many times synonymous to risk taking. But risk taking is the only way to increase the profits for an organization. An organization, while taking risk, should be calculative of

risk and try different kinds of initiatives that would enhance customer's experience in some way or the other. The employees will also appreciate something new, different, and better to impart to their customers which will positively influence customer experience.

4.4.3 Subject knowledge

Building a team of subject ensures that the training provider clearly knows what is expected of them for the organization and also the learning outcome that they expect from the training provider. The subject experts should be able to get the best training onboard by checking to what extent the training providers are customizing the program, based on their organizational need. Only the best fit programs should be adopted.

4.4.4 Passion

Any initiative will remain as a mere activity, if not done with passion. Customer focused culture will prevail when employees are willing to go that extra mile and give customers nothing but the best. Such people, who think about the customer, should be made responsible for driving the quality initiative. Passion is contagious, so the training program will help to create an enthusiastic work environment, focused on quality thus ensuring customer satisfaction.

4.4.5 Team building

A customer oriented culture can only be built if the whole organization works as a team. This will make sure that the customer has the consistent experience at every interaction with the organization. The people of one department or business interest should think about the people of the other departments before giving customer a bad experience. Such team building exercises should also become a part of the whole quality initiative.

4.4.6 Simulations

A training program is more effective if it is based on live scenarios. This can be brought about with the help of simulations during the training program where people will enact the real-time processes and deal with customers and their feedbacks through various ways, etc. Real time feedbacks are an excellent way of learning the effect of actions and act as eye opener to many situations.

4.4.7 Feedback

Constructive feedbacks given by the participants during or post the training programs should be immediately adopted by the organization so that the people will feel that the organization really feels for the customers and have not organized the program just for the sake of it. Feedback mechanisms usually allow for discovery of problems, and hence result in solving them as well. Thus having a strong feedback system is necessity for quality assurance.

4.4.8 Deming's 14 Points for quality control and awareness

1 - Create constancy of purpose
2 - Adopt philosophy of prevention
3 - Cease mass inspection
4 - Select a few suppliers based on quality
5 - Constantly improve system and workers
6 - Institute worker training
7 - Instill leadership among supervisors
8 - Eliminate fear among employees
9 - Eliminate barriers between departments
10 - Eliminate slogans
11 - Remove numerical quotas
12 - Enhance worker pride
13 - Institute vigorous training & education programs
14 - Implement these 13 points

4.4.9 Determinants of Quality:

1. *Performance characteristics* of the product or service

2. *Aesthetics* appearance, feel, smell, taste, etc.

3. *Conformance* - customer's expectations

4. *Special features* - extra characteristics.

5. *Safety* - risk of injury or harm

6. *Reliability* - consistency of performance

7. *Durability* - useful life of the product or service

8. *Perception* - reputation

9. *Service after the sale* - handling of complaints, customer satisfaction

CHAPTER 5: Material Quality Control

5.1 Concept of Quality Control

Quality, as defined by American National Standards Institute (ANSI) is "the totality of features and characteristics of a product or service that bears on its ability to satisfy given needs". This implies that quality can have many definitions depending upon who is defining it, giving it many different perspectives. The two major perspectives of quality are the customer perspective and the producer's perspective. In simple terms, the customer perspective amounts to the fitness for its intended use of a product or service, whereas the producer's perspective is mostly about conformance to specifications. The meaning of quality can be depicted using the following diagram[24].

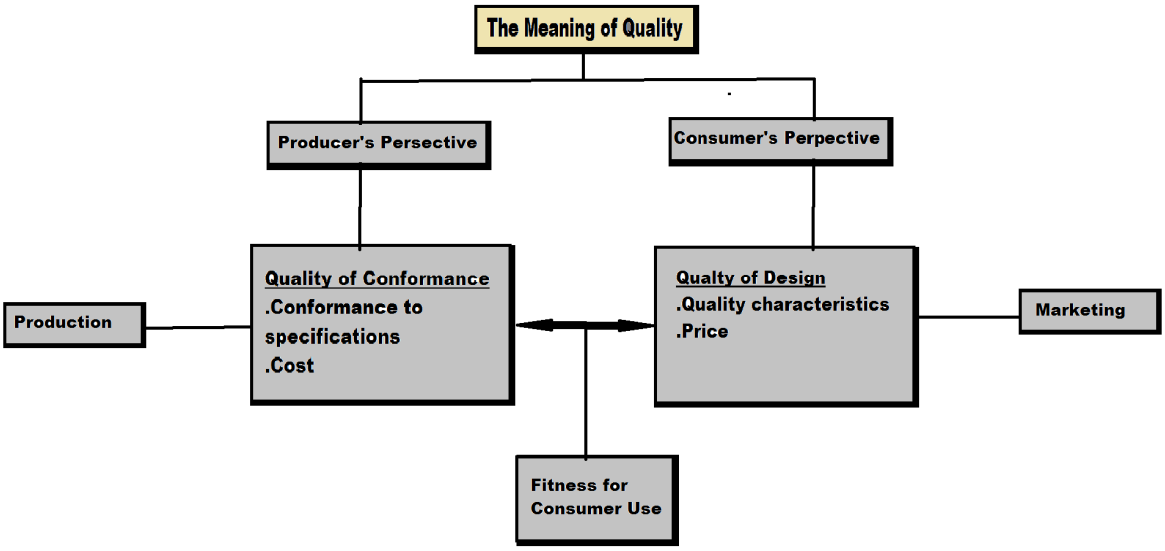

Figure5.1.1: The meaning of Quality

Thus, in a way, quality does not mean being the best of the possible; but it does mean being efficient (so things happen on time and on cost) and effective (serving the purpose well intended for). For efficiency and effectiveness there are specified values or standards which a given product or service should comply.

[24] Adapted from "Productions and Operations Management" by Russell and Taylor

Quality control (QC) is a procedure or set of procedures intended to ensure that a manufactured product or performed service adheres to a defined set of quality criteria or meets the requirements of the client or customer. QC is similar to, but not identical with, quality assurance (QA). QA is defined as a procedure or set of procedures intended to ensure that a product or service under development (before work is complete, as opposed to afterwards) meets specified requirements. It also involves the systematic measurement, comparison with a standard, monitoring of processes and an associated feedback loop that confers error prevention. This can be contrasted with Quality "Control", which is focused on process outputs. Two principles included in QA are: "Fit for purpose", the product should be suitable for the intended purpose; and "Right first time", mistakes should be eliminated. QA includes management of the quality of raw materials, assemblies, products and components; services related to production, and management, production and inspection processes.

QA is sometimes expressed together with QC as a single expression, quality assurance and control (QA/QC).

In order to implement an effective QC program, an enterprise must first decide which specific standards the product or service must meet. Then the extent of QC actions must be determined (for example, the percentage of units to be tested from each lot). Next, real-world data must be collected (for example, the percentage of units that fail) and the results reported to management personnel. After this, corrective action must be decided upon and taken (for example, defective units must be repaired or rejected and poor service repeated at no charge until the customer is satisfied). If too many unit failures or instances of poor service occur, a plan must be devised to improve the production or service process and then that plan must be put into action. Finally, the QC process must be ongoing to ensure that remedial efforts, if required, have produced satisfactory results and to immediately detect recurrences or new instances of trouble.

5.1.1 CONTROL CHARTS

The primary tool used in SPC to determine if processes are in control or not is the control chart.

Control charts are graph that visually show if sample results are within statistical **control limits**.

They have two basic purposes, to establish the control limits for a process and then to monitor the process to indicate when it is out of control. Control charts exist for attributes and variables; within each category there are several different types of control charts. We will present four commonly used control charts, two in each category: mean (X) and range ® control charts for variables and p-charts and c-charts for attributes. Even though these control charts differ in how they measure process control, they all have certain similar characteristics. They all are visually alike, with a line through the centre of the graph that indicates the process average and lines above and below the center line that represent the upper and lower limits of the process, as shown in Figure 5.1.2

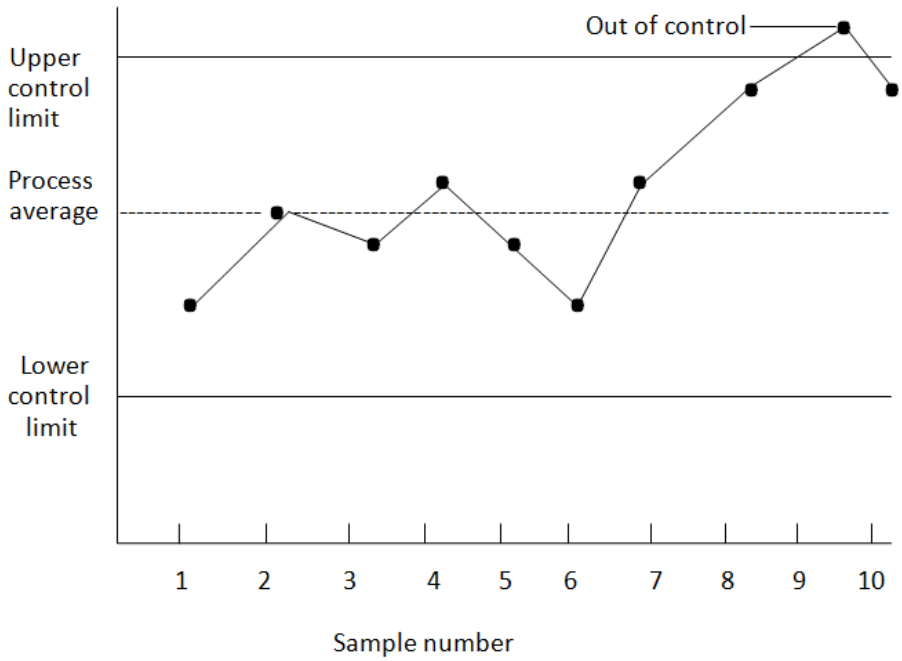

Figure 5.1.2: Meaning of Control Chart

Each time a sample is taken, the sample average is recorded as shown in Figure 5.1.2. In general, a process is in control if the following occur:

1. There are no sample points outside the control limits
2. Most points are near the process average (i.e., the control line), without too many close to the control limits.
3. Approximately equal numbers of sample points occur above and below the center line.

4. The points appear to be randomly distributed around the center line (i.e., no discernible pattern).

If any of these guidelines are violated the process may be out of control. Thus, the reason must be determined, and if the cause is not random, the problem must be corrected.

Since the sample average obtained for sample 9 in Figure 5.1.2 is beyond the upper control limit, the control chart suggests the process is out of control. The cause for this occurrence is not likely to be random, so management should attempt to find out what is wrong with the process and bring it back in –control. Note that, although the results for all the other sample generally display some degree of variation from the process average, they are usually considered to be caused by normal, random variability in the process and are thus in control. However, it is possible for sample observations to be within the control limits and for the process to be out of control anyway, if the observation display a discernible, abnormal pattern of movement. We discuss such patterns in a later section.

Theoretically, a process control chart should be based only on sample observation from when the process is in control so that the control chart reflects a true benchmark for an in-control process. However, it is not know whether the process is in control or not until the control charts initially constructed. Therefore, when a control, chart is first developed and the process is found to be out of control, if nonrandom causes are the reasons for the out-of-control observations, these observations (and any others influenced by the nonrandom causes) should be discarded. A new center line and control limits should then be determined from the remaining observation. This “corrected” control chart is then used to monitor the process. It may not be possible to discover the cause(s) for the out-of-control sample observations. In this case a new set of samples can be taken, and a completely new control chart can be constructed. Alternatively it may be decided to simply use the initial control chart assuming that it accurately reflects the process variation.

5.1.2 Control Chart Pattern

Even through a control chart may indicate that a process is in control, it is still possible that the sample variations within the control limits are not random. If the sample values (i.e., sample ranges or means) display a consistent pattern, even through the values are within the control limits, it suggests that this pattern has a nonrandom cause that might warrant investigation. In other words, we expect the sample values in a control chart to "bounce around" above and below the center line, reflecting the natural, random variation in the process we know will be present. However, if the sample values are consistently above (or below) the center

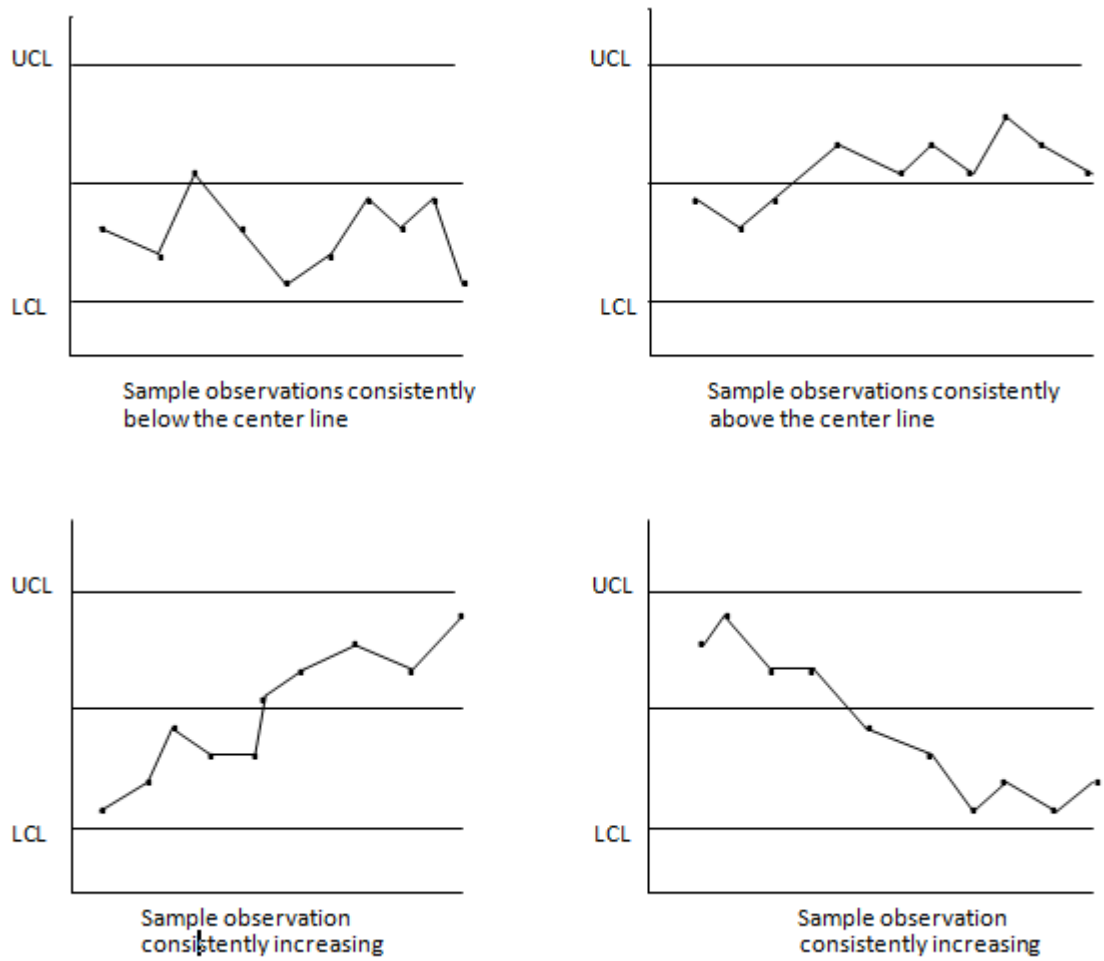

Figure 5.1.3 Control Chart Pattern

A pattern in a control chart is characterized by a sequence of sample observations that display the same characteristics (also called a run). One type of pattern is a sequence of observations either above or below the center line in a control chart. For example, three values above the center line followed by two values below the line represent two runs of a pattern. Another type of pattern is a sequence of sample values that consistently go up or go down within the control limits. In both cases, a test is available to determine if the pattern is nonrandom or random.

The z pattern test, or run test determines the number of standard deviations the observed number of pattern runs in a control chart is from an expected number of runs. The z test is computed according to the following general formula:

$$\mathbf{Z_{test}} = \frac{observed\ runs - expected\ runs}{\sigma}$$

Substituting various formulas for the expected number of pattern runs and the standard deviation into this formula results in the following computation for each type of pattern: runs above and below (A/B) the center line and runs up and down (U/D) within the control limits.

$$Z_{A/B} = \frac{r-[N/2+1]}{\sqrt{(N-1)/4}}$$

$$Z_{U/D} = \frac{r-[(2N-1)/3]}{\sqrt{(16N-29)/90}}$$

Where

r = the observed number of runs

N = sample size

These computed test values are subsequently compared to a z value for a specified level of variability. For example, if it is assumed that 95 percent of the pattern runs are the result of random causes and are thus acceptable, then the situation coincides with a range of values of±1.96 (from Table A.3 in Appendix A).

A second type of pattern test divides the control chart into three "zones" on each side of the center line, where each zone is one standard deviation wide. These are often referred to as 1-sigma, 2-sigma, and 3-sigma limits. The pattern of sample observation in these zones is then used to determine if any nonrandom patterns exist. Recall that the formula for computing an $\overline{x}$-chart uses A_2 from Table 5.1.1, which assumes 3-standard deviation control limits (or 3-sigma limits). Thus, to computer the dividing lines between each of the three zones for an $\bar{x}$-chart, we use $\frac{1}{3}A_2$. The formulas to compute these zone boundaries are shown in Figure 4.3

There are several well-known general rules associated with the zones for identifying patterns in a control chart, where none of the observations are beyond the control limits:

1. Eight consecutive points on one side of the center line
2. Eight consecutive points up or down across zones
3. Fourteen points alternating up or down
4. Two out of three consecutive points in zone A but still inside the control limits
5. Four out of five consecutive points in zone b or beyond the 1-sigma limits

5.1.3 Control Charts for Variables

The quality measures used in variable control charts are for continuous variables reflecting measurements, such as weight or volume. Two of the more commonly used variable control chart, also known as the $\bar{x}$-chart, and the range chart, or R-chart. A **mean ($\overline{x}$-) chart** indicates how sample result relate to the process average or mean, whereas a **range (R)-) chart** reflects the amount of dispersion that is present in each sample. These charts are normally used in conjunction to determine if a process is in control.

5.1.3(a) Mean ($\overline{x}$-) Chart

For an x-chart, each time a sample is taken, the mean of the sample is computed and plotted on the chart; that is, the control points are the sample means. Each sample mean is another value of x. The

sample taken tends to be small, usually around 4 or 5. The center line of the chart is the overall process average.

The x-chart is theoretically based on the normal distribution. It is assumed, from the central limit theorem, that the sample means are normally distributed if the process distribution is also normal. Even if the process is not normal, the distribution of the sample mean will be if the sample size is sufficiently large. This enables us to use the following formulas for constructing control limits for an $\bar{x}$ –chart (where z occasionally equals 2, but is most frequently 3, standard deviations):

$$UCL = \mu + z\sigma_{\bar{x}} \qquad LCL = \mu - z\sigma_{\bar{x}}$$

These formulas assume that the process average, μ, and the standard deviation, σ, are both known. In this case the sample standard deviation, $\sigma\bar{x}$ is computed as

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

When the process means, μ, is not known, the average of the sample means, $\bar{\bar{x}}$, can be used instead:

$$\bar{\bar{x}} = \frac{\overline{x_1} + \overline{x_2} + \cdots + \overline{x_n}}{n}$$

In most cases, an R-chart and an x-chart are used in conjunction with each other. In those cases the computation of the x-chart is based on the range values. We provide an example of the joint application of these two charts following our presentation of the range chart in the next section. For now, demonstrate the use of the mean chart alone in the following example.

EXAMPLE 5.3: Constructing a Mean Chart

Problem Statement: The Goliath Tool Company produces slip-ring bearings. These bearing (as opposed to more familiar ball bearings) look like flat doughnuts or washers. They production process for a particular slip-ring bearing that fits around the drive shaft of a large truck motor has a mean diameter of 5 centimeters and a standard deviation of 0.04 centimeters . The company wants to

develop a mean chart for this production process that will include 99.74 percent (i.e., three standard deviations) of the process variability using sample of size 20.

Solution:

The control limits are computed as follows:

$$UCL = \mu + z\left(\frac{\sigma}{\sqrt{n}}\right) = 5 + (3)\left(\frac{0.04}{\sqrt{20}}\right) = 5.027 \text{ cm}$$

$$LCL = \mu - z\left(\frac{\sigma}{\sqrt{n}}\right) = 5 - (3)\left(\frac{0.04}{\sqrt{20}}\right) = 4.973 \text{ cm}$$

If a sample is taken and the sample mean falls outside of these control limits, it suggests that the process is out of control, so the cause is probably nonrandom and should be investigated.

5.1.3(b) Range (R-) Chart

In an R-chart, the range is the different between the smallest and largest values in a sample. This range reflects the process variability instead of the tendency toward a mean value, as the $\bar{x}$-chart does. However, the distributed of sample ranges cannot be as assumed to be normally distributed as in the

$\bar{x}$-chart, although the formula for determining control limits are somewhat similar:

$$UCL = D_4\bar{R} \qquad LCL = D_3\bar{R}$$

In these formulas $\bar{R}$ is the average range for the sample taken. D_3 and D_4 are table values for determining control limits that have been developed based on range values rather than standard deviations. They generally provide control limits comparable to three standard deviations for different sample sizes. These tables are readily available from a variety of sources and are included in many texts on operations management and quality control. Table 5.1 includes values for D_3 and D_4 for sample sizes up to 25.

EXAMPLE 5.4: Constructing an R-Chart

Problem Statement: Consider again the Goliath Tool Company from Example 5.3. The company has taken 10 sample (during a 10-day period) of 5 slip-ring bearing (i.e., n= 5). The individual observation from each sample are shown as follows

	OBSERVATIONS (SLIP_RING DIAMETER, cm)						
SAMPLE k	1	2	3	4	5	$\bar{x}$	R
1	5.02	5.01	4.49	4.99	4.96	4.98	0.08
2	5.01	5.03	5.07	4.95	4.96	5.00	0.12
3	4.99	5.00	4.93	4.92	4.99	4.97	0.08
4	5.03	4.91	5.01	4.98	4.89	4.96	0.14
5	4.95	4.92	5.03	5.05	5.01	4.99	0.13
6	4.97	5.06	5.06	4.96	5.03	5.01	0.10
7	5.05	5.01	5.10	4.96	4.99	5.02	0.14
8	5.09	5.10	5.00	4.99	5.08	5.05	0.11
9	5.14	5.10	4.99	5.08	5.09	5.08	0.15
10	5.01	4.98	5.08	5.07	4.99	5.03	0.10
						50.09	1.15

TABLE 5.1 Factors for Determining Control Limits for $\bar{x}$- and R-Charts

Sample Size	Factor for $\bar{x}$-Chart	Factor for R-Chart	
n	**A2**	**D3**	**D4**
2	1.88	0	3.27
3	1.02	0	2.57
4	0.73	0	2.28
5	0.58	0	2.11
6	0.48	0	2.00
7	0.42	0.08	1.92
8	0.37	0.14	1.86
9	0.34	0.18	1.82
10	0.31	0.22	1.78
11	0.29	0.26	1.74
12	0.27	0.28	1.72
13	0.25	0.31	1.69
14	0.24	0.33	1.67
15	0.22	0.35	1.65
16	0.21	0.36	1.64
17	0.20	0.38	1.62
18	0.19	0.39	1.61
19	0.19	0.40	1.60
20	0.18	0.41	1.59
21	0.17	0.43	1.58
22	0.17	0.43	1.57
23	0.16	0.44	1.56
24	0.16	0.45	1.55
25	0.15	0.46	1.54

The company wants to develop an R-chart to monitor the process variability.

Solution:

R is computed by first determining the range for each sample by taking the different between the higher and lowest values. These ranges are summed and then divided by the number of samples, k, as follows:

$$\bar{R} = \frac{\sum R}{k} = \frac{1.15}{10} = 0.115$$

$D_3 = 0$ and $D_4 = 2.11$ Table 4.1 for n = 5. Thus, the control limits are computed as

$$\mathbf{ULC = D_4\bar{\bar{R}} = 2.11\ (0.115) = 0.243}$$

$$\mathbf{LCL = D_3\bar{R} = 0\ (0.115) = 0}$$

These limits define the R-chart shown in the following figure. The R-chart indicates that the process seems to be in control; that is, the variability observed is a result of natural random occurrences.

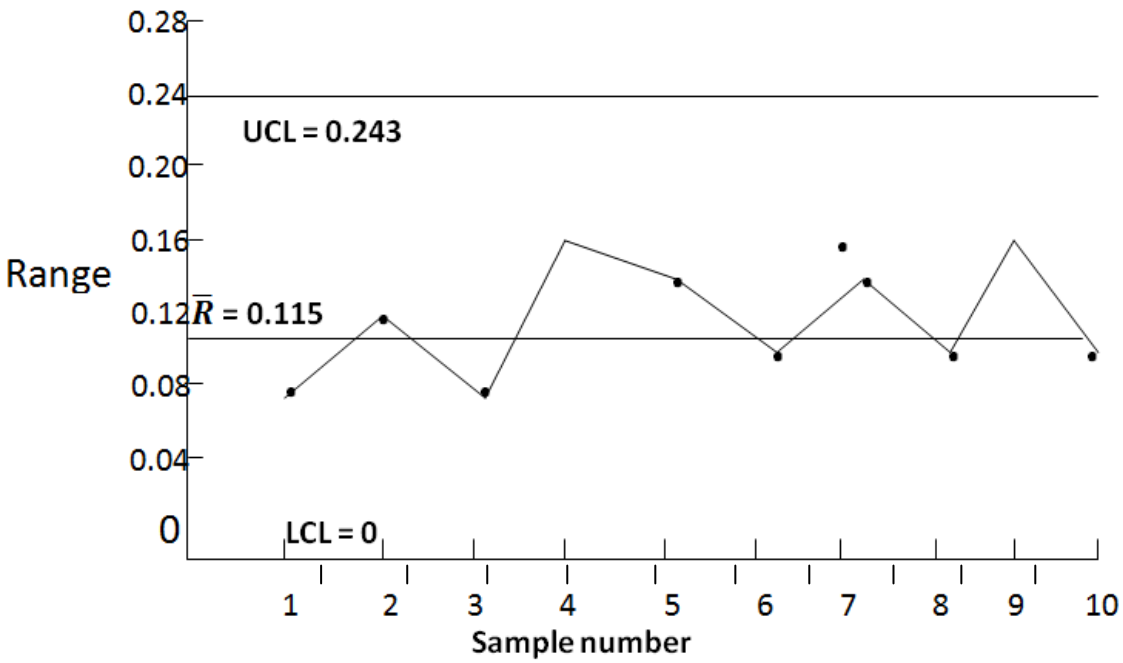

Figure 5.1.4 R Chart

5.1.4 Control Charts for Attributes

The quality measures used in attribute control charts are discrete values reflecting a simple –decision criterion such as good or bad. As we mentioned earlier, we will present two of the more commonly used attributes control charts, p-charts and c-charts. A **p-chart** uses the actual number of defective items in a sample statistic, whereas a **c-chart** uses the actual number of defective items in a sample. A p-chart can be used when it is possible to state the number of defectives as a percentage of the whole. However, in some processes, the proportion defective cannot be determined. For example, when counting the number of blemishes on a roll of upholstery material (at periodical intervals), it is not possible to computer a proportion. In this case a c-chart is required.

5.1.4(a) p-chart

With a p-chart a sample is taken periodically from the production process and the proportion of defectives items in the sample is determined to see if the proportion falls within the control limits on the chart. Since a p-chart employs a discrete attribute measure (i.e., defectives items), it is theoretically based on the binominal distribution. However, as the sample size gets larger, the normal distribution can be used formulas based on the normal distribution to compute the upper control limit (UCL) and lower control limit (LCL) of a p-chart.

$$\boldsymbol{UCL = p + z\sigma_p}$$

$$\boldsymbol{LCL = p - z\sigma_p}$$

where

z = the number of standard deviation from the process average

p = the population proportion defective, also referred to as the process average

σ_p = the standard deviation of the sample proportion

The sample standard deviation is computed as

$$\sigma_p = \frac{\sqrt{p(1-p)}}{n}$$

where n is the sample size

If the population proportion defective, $\bar{p}$, is not known, then an estimate of the proportion defective, $\bar{p}$, can be computed from the samples. In that case, $\bar{p}$ would replace p in the preceding formulas for control limits and standard deviation.

In the control limit formulas for p- charts (and other control charts), z is occasionally equal to 2.00 but most frequently is 3.00. A z value of 2.00 corresponds to an overall normal probability of 95 percent and z = 3.00 correspond to a normal probability of 99.74 percent. The smaller the value of z, the more narrow the control limit are and the more sensitive the chart is to changes in the production process. Control charts using z = 2.00 are often referred to as having "2-sigma" (2σ) limits (referring to two standard deviations), whereas z = 3.00 means "3-sigma" (3σ) limits.

Management usually selects z = 3.00 because if the process is in control they want a high probability that the sample values will fall within the control limits. In other words, with wider limits management is less likely to (erroneously) conclude that the process is out of control when points outside the control limits are due to normal, random variation. Alternatively, wider limits make it harder to detect changes in the process that are not random and have an assignable cause. A process might change because of a nonrandom, assignable cause and be detectable with the narrower limits but not with the wider limits. However, as we mentioned, management traditionally uses the wider control limits.

The following example demonstrates how a p-chart is constructed.

EXAMPLE 4.5: Construction of a p-chart

Problem Statement: The Western Jeans Company produces denim jeans. The company wants to establish a p-chart to monitor the production process and maintain high quality. They believe that approximately 99.74 percent of the variability in the production process (corresponding to 3-sigma limits, or z = 3.00) is random and thus should be within control limits, whereas .26 percent of the process variability is not random and suggests that the process is out of control.

The company has taken 20 sample (one per day for 20 days), each containing 100 pairs of jeans (n = 100), and inspected them for defects, the result of which are as follows.

Sample	Number of Defectives	Proportion Defectives
1	6	.06
2	0	.00
3	4	.04
4	10	.10
5	6	.06
6	4	.04
7	12	.12
8	10	.10
9	8	.08
10	10	.10
11	12	.12
12	10	.10
13	14	.14
14	8	.08
15	6	.06
16	16	.16
17	12	.12
18	14	.14
19	20	.20
20	18	.18
Total	200	2

The proportion defective for the population is not known. The company wants to construct a p-chart in order to determine when the production process might be out of control.

Solution:

Since p is not known, it can be estimated from the total sample:

$$\bar{p} = \frac{Total\ defectives}{Total\ sample\ observations}$$

$$\frac{= 200}{20\ (100)} = 0.1$$

The control limits are computed as follows.

$$UCL = \bar{p} + z\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

$$= 0.10 + 3.00\ \sqrt{\frac{0.10(1-0.10)}{100}} = 0.1$$

$$LCL = \bar{p} - z\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

$$= 0.10 + 3.00\ \sqrt{\frac{0.10(1-0.10)}{100}} = 0.010$$

The resulting p-chart, including the sample points, is shown in the following figure.

5.1.4(b) c- chart

A c-chart is used when it is not possible to compute a proportion defective and the actual number of defects must be used instead. For example, when automobiles are inspected, the number of blemishes (i.e., defects) in the paint job can be counted for each car, but the proportion of blemishes cannot be computed, since the total number of possible blemishes is not known (i.e., it is infinite).

Since the number of defects per sample is assumed to derive from some extremely large population or continuous region, the probability of a single defective item is very small. These characteristics allow for the use of the Poisson distribution. However, as with the p-chart, the normal distribution can be used to approximate the Poisson distribution. The process average for the c-chart is

the mean number of defects per sample, $\bar{c}$, can be estimated by dividing the total number of defects by the number of samples. The value of $\bar{c}$ can also be used to estimate the standard deviation. The following formulas for the control limits are used:

$$UCL = C + Z\sigma_C$$

$$LCL = C + Z\sigma_C$$

Example 5.6: Construction of a c-chart

Problem Statement: Barrett Mills in North Carolina produces denim cloth used by manufactures (such as the Western Jeans Company) to make jeans. The denim cloth is woven from thread on a weaving machine, and the thread occasionally breaks and is repaired by the operator, sometimes causing blemishes (called "picks"). The operator inspects rolls of denim on a daily basis as they come off the loom and counts the number of blemishes. Following are the result from inspecting 15 rolls of denim during a 3-week period.

Sample	Number of Defects
1	12
2	8
3	16
4	14
5	10
6	11
7	9
8	14
9	13
10	15
11	12
12	10
13	14
14	17
15	15
Total	190

The company believes that approximately 99 percent of the defects (corresponding to 3-sigma limits) are caused by natural, random variations in the weaving process, with 1 percent caused by nonrandom variability. They want to construct a c-chart to monitor the weaving process.

Solution:

Since c, the population process average, is not known, the sample estimate $\bar{c}$, can be used instead:

$$\bar{c} = \frac{190}{15} = 12.67$$

The control limits are computed using z = 3.00, as follows.

$$\text{UCL} = \bar{c} + z\sqrt{\bar{c}} = 12.67 + 3(\sqrt{12.67}) = 23.35$$

$$\text{LCL} = \bar{c} + z\sqrt{\bar{c}} = 12.67 - 3(\sqrt{12.67}) = 1.99$$

All the sample observations are within the control limits, which suggest that the weaving process is in control. This chart would be considered reliable to monitor the weaving process in the future.

5.1.5 The cost of quality

All of functional area in the production system incurs cost as part of a quality management program. For example the marketing incurs a cost for performing consumer research to determine what quality characteristics the consumer wants; purchasing must monitor and test incoming parts and materials to make certain they confirm to specifications resulting in costs; engineering incurs cost in designing quality characteristics; personal incurs costs for quality training programs; inspection is direct cost

for monitoring the quality of finished goods; costs are incurred by packaging for making sure products are not damaged in transit to the customers and so on alternatively, poor quality products result in costs for returned items, discarded products (including part and material), and reward products in general, quality costs fall into major categories, the cost of achieving good quality also known as *cost of quality assurance*. And the cost associated with poor quality products are also referred to as *cost of nonconforming* to specifications

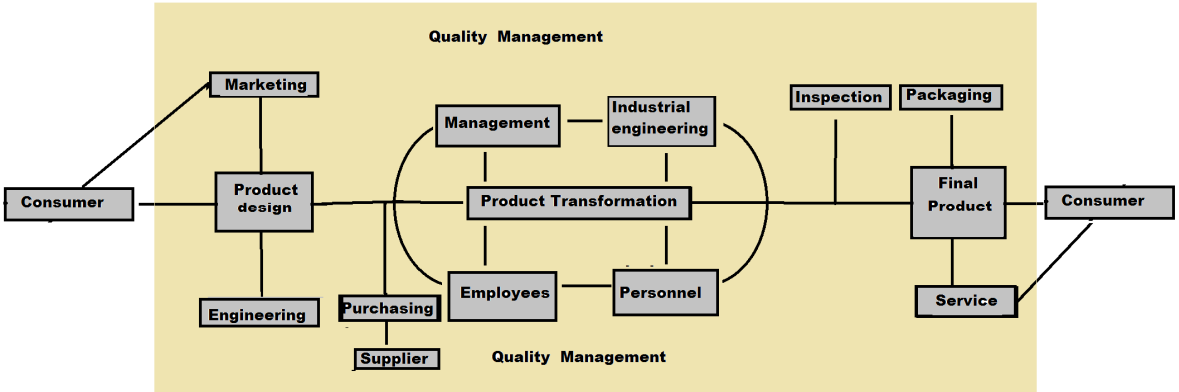

Figure 5.1.5: Quality Management[25]

5.1.5(a) The Cost of Achieving Good Quality

The cost of maintaining an effective management program can be divided into two categories, prevention cost and appraisal costs. **Prevention costs** result from the efforts of the company during product design and manufacturing that prevent non conformance to specifications. Prevention reflects the quality philosophy of "do it right the first time," and it is the ultimate goal of most quality management programs. Examples of prevention cost include the following

Quality planning costs: The cost of developing and implementing the quality management program

Product design costs: The costs of designing products with quality control characteristics.

Process costs: The cost expended to make sure the production process conforms to quality specifications.

[25] Adapted from "Productions and Operations Management" by Russell and Taylor

Training costs: The cost of developing and putting on training programs on quality fro operators, staff, and management.

Information costs: The cost of acquiring and maintaining (typically on computers) data related to quality and development and analysis of reports on quality performance.

The second category of costs related to a quality management program is appraisal costs. These are the costs of measuring, testing, and analyzing materials, parts, products, and the production process to ensure that product quality specifications are being conformed to. Examples of appraisal costs include the following:

Inspection and testing: The costs of testing and inspecting materials and parts as they come from the supplier/vendor, the product at various work-in-process stages, and the final product.

Test equipment costs: The cost of maintaining equipment used in testing the quality characteristics of products in good working order.

Operator costs: The cost of the time spent by the operator to gather data for testing product quality, to make equipment adjustments to maintain quality, and to stop work to assess quality.

5.1.5(b) The Cost of Poor Quality

The second major category of quality costs are the cost associated with poor quality, also referred to as the cost of non conformance, or failure costs. In general the cost of failures is the difference between what it's actually costs to produce a product or deliver a service and what it would costs if there were no failures. This is generally the largest quality cost category in a company, frequently accounting for 70-90% of total quality costs. As a result, it is the area in which the greatest improvement is possible.

The cost of poor quality can be categorized as ***internal failure costs*** and ***external failure costs***.

Internal failure costs: Internal failure costs are incurred when poor quality products are discovered before they are delivered to the customers. Examples of internal failure cost include the following

- *Scrap costs*: The cost of poor quality products that must be discarded including labor, material, and indirect costs.
- *Rework costs*: The cost of fixing defective products that do not conform to quality specifications.
- *Process failure costs:* The cost of determining why the production process is reducing poor quality products.
- *Process downtime costs*: The e costs of shutting down the manufacturing process to repair equipment, replace or train operators, or replace material that are causing poor quality.
- *Price downgrading costs*: The cost of discounting poor quality products. selling products as "seconds".

External failure costs: External failure costs are costs that are incurred of after the customer has received a poor quality product and are primarily related to customer service. Examples of external failure cost include the following:

- *Customer complaint costs*: The costs of investigating and satisfactorily responding to a customer complain resulting from a poor quality product.
- *Product return costs*: The costs of handling and replacing poor quality products return by the customer.
- *Warrantee claims costs:* The cost of complying with product warranties.
- *Product liability costs*: The litigation costs resulting from product form product liability and customer injury.
- *Lost sales cost*: The cost incurred because customers are dissatisfied with poor quality products and do not make additional purchase.

5.2 Purchase and sampling inspection

Different studies have shown that purchasing amounts to around 50% of the total manufacturing costs in many countries[26]. This number is quite similar, ranging 40% to 60% in the service organizations like electricity boards, public works department, corporations, and developmental agencies. Put in simple terms, purchasing is that activity where an organization (or company) obtains products and services from other organizations in exchange of money. In this chapter, we will focus on the purchase of materials. For example, manufacturing organizations require raw materials, components, and equipments for production, whereas the service industries require spare parts, and supplies for running the maintenance operation, etc.

Purchasing also ensures that the parts and raw materials necessary are to the specifications and of desired quality. This makes purchasing an important aspect of any organization that values quality. The famous management acronym "GIGO: Garbage In Garbage Out" is relevant here because if poor quality parts and materials are used in the process, the final product will be of poor quality.

One of the main duties of purchasing is the selection of vendors that share the company's commitment to quality and have its own quality assurance program implemented to provide quality materials and parts. Mostly, the quality of the incoming items is monitored by the purchase division through the receiving department. The receiving department relies mostly on statistical quality control procedures to ensure the quality of parts, materials, and services that are purchased by the company.

There are many models existing here, where the two major approaches are:

The quality of the input is ensured by the company through rigorous control procedures at the receiving department, where items failing the inspection process gets returned to the supplier. This model is mostly followed in organizations that purchase from different suppliers, where the main aim is to make the purchase independent of any supplier uncertainty and as well as availing better competitive pricings.

[26] "The Japanese lesson in quality" by R. E. Cole in Technology Review, Vol. 83, No. 7, 1981, pages 29-40

The quality of the supplies are ensured by the supplier as the company and the supplier have an existing partnership, where the supplier is expected to monitor the quality and the company needs not to conduct any quality inspections at the time of receiving. This model is usually followed under the Total Quality Management (TQM) approach, which fosters the concept of single-sourcing. By single-sourcing, we mean that a company will purchase from very few suppliers and in many cases from only one supplier.

There are pros and cons to both approaches. While many of the Japanese firms like Toyota have adopted the single-sourcing approach, citing better control over the quality performance of the supplier. But, to make such model work, the volume of quantity ordered by the company becomes a critical parameter; because the supplier might agree to such conditions if majority of its orders are from the company. Additionally, the involvement of the supplier in the product or service design is another appealing aspect of the single-sourcing approach. In fact, in many cases of single-sourcing, the supplier is given the responsibility of designing a new component of the product or service to specific quality standards and features outlined by the company.

Thus we can see that with the advent of new materials and parts along with increased competition, purchasing has become a more specialized activity in many organizations. Though in the grand schema of things, purchasing is considered as a supportive function; but in the modern times it should be treated as one of the functional areas for better functioning of the organization.

It is the responsibility of the Purchase department to sensitize the various departments of the organization from time-to-time on the range of quality of materials available in the market along with its best price. This will help them in making more accurate technical specifications for the product or service the company is producing.

Minimize the expenditures in purchase related service operations like transportation, inspection, storing, record keeping, etc.

Ensure continuous supply of materials so that the planned activities of the company continue to run without any disruption.

Identify the economies of scale for the organization by consolidation of requirements from all departments across the company. This will help in minimizing duplications in purchases of relative items and as well as reduce waste and obsolete.

Nurture healthy buyer-supplier relationship that will benefit the organization on the long run.

To meet the purchasing objectives specified in the previous section, necessary inputs, restrictions, checks-and-balances are to be identified by the purchasing department. The purchasing function is responsible for a lot of important decisions, like Make or buys decisions, Value analysis on purchases, Purchase Specifications and Vendor rating and development

The detailed description of the characteristics and features of an item that needs to be purchased is called as the purchase specification. The responsibility of providing the specification is on the department that initiates the purchase process. Purchase specifications allow the purchase department to understand the exact features in the item, convey the exact need of the buyer to the supplier, and allow for easier and accurate verification of the item purchased upon delivery. The major types of specifications are:

- Market grade
- Commercial standards
- Trade or brand names
- Material specifications
- Performance specifications
- Samples
- Blueprints
- Combined specifications

5.3 Sampling types, methods and techniques

Any sampling application must distinguish whether the purpose is to accumulate information on the immediate product being sampled or on the process, which produced the immediate lot at hand. Accordingly, two types of sampling have been distinguished:

Type A: Sampling to accept to reject the immediate lot of product at hand

Type B: Sampling to determine if the process, which produced the product at hand was within acceptance limits

The type of sampling will determine the appropriate probability distribution to be used in characterizing the performance of the plan. In addition, the type of data generated will also play a role. In acceptance sampling, data can be of the following types:

Attributes – go no-go information

- Defectives - usually measured in proportion or percent defective. This refers to the acceptability of units of product for a wide range of characteristics.
- Defects - usually measured by actual count or as a ratio of defects per unit. This refers to the number of defects found in the units inspected, and hence can be more than the number of units inspected.

Variables – measurement information

Variables usually measured by the mean and standard deviation. This refers to the distribution of a specific measurable characteristic of the product inspected.

5.3.1 ACCEPTANCE SAMPLING

In acceptance sampling, a random sample of the units produced is inspected, and the quality of this sample is assumed to reflect the overall quality of all items or a particular group of items, called a lot. Acceptance sampling is a statistical method, so if a sample is random, it ensures that each item has an equal chance of being selected and inspected. This enables statistical inferences to be made about the population (i.e., the lot) as a whole. If a sample has an acceptable number or percentage of defective items, it is accepted, but if it has an unacceptable number of defects, it is rejected.

Acceptance sampling is a traditional approach to quality control based on the premise that some number of defective items will result from the production process. The producer and costumer agree upon the acceptable number of defects. The number of acceptable defects is normally measured in

terms of a percentage. However, in the remarks introducing this chapter and at other points, we have noted that the nation of a producer or customer agreeing to any defects at all is anathema to the adherents of TQM. The primary focus for companies that have adopted the TQM philosophy and management principles is to achieve zero defects.

Acceptance Sampling Procedure: Sampling plans can be classified in two categories: attributes plan and variables plans.

5.3.1(a) Attributes Plan

In these plans, a sample is taken from the lot and each unit classified as conforming or nonconforming. The number nonconforming is then compared with the acceptance number stated in the plan and a decision is made to accept or reject the lot. Attributes plans can further be classified by one the two basic criteria:

1. Plans which meet specified sampling risks provide protection on a lot-by-lot basis. Such risks are:
    a. A specified quality level for each lot (in terms of percent defective) having a selected risk (say0.10) of being accepted by the consumer. The specified quality level is known as the lot tolerance percent defective or limiting quality (p_2); the selected risk is known as the consumer's risk (β)
    b. A specified quality level for each lot such that the sampling plan will accept a stated percent age (say 95 percent) of submitted lots having this quality level. This specified quality level is termed the acceptable quality level (AQL). The risk of rejecting a lot of AQL quality (p_1) is known as the producer's risk (α).
2. Plan that provides a limiting average percentage of defective items for the longs run. This is known as the average outgoing quality level (AOQL).

Acceptance sampling has traditionally been used when the cost of inspection is very high relative to the cost of allowing a defective item to escape. The inspection cost may not be simply the cost of the

inspectors or the machinery used for inspection, but may also be a result of the inspection process. It may require units of the product to be destroyed, such as when a sample of food is tasted, a bottle of wine is opened, a battery is used up, or a roll of film is exposed.

When sample is taken and inspected for quality, the items in the sample are being checked to see if they conform that some predetermined specification. The evaluations of these specifications generally take one of two forms, either attributes or variable measures.

5.3.1(b)Variables Plan

In these plans, a sample is taken and measurements of specified quality characteristics are made on each unit. These measurements are then summarized into a simple statistic (e.g., sample mean) and the observed value compared with an allowable value defined in the plan. A decision is then made to accept or reject the lot. When applicable, variable plans provide the same degree of consumer protection as attributes plans while using considerably smaller samples.

Attributes plans are generally applied on a percent defective basis. That is, the plan is instituted to control the proportion of accepted product which is defective or out of specification. Variables plans for percent defectives are also used in this way. Such plans provide sensitivity greater than attributes but require that the shape of the distribution be used to translate the proportion measurements must be known and stable. The shape of the distribution is used to translate the proportion defective into specific values of process parameters (mean, standard deviation), which are then controlled.

Variables plans can also be used to control process parameters to gives levels when specifications are directed toward the process average or process variability to percent defective. These variable plans for process parameter do not necessarily require detailed knowledge of the shape of the underlying distribution of individual measurements. Sampling plans in the reliability and in the sampling of bulk product are generally of this type.

Published plans in the reliability area, however, usually require detailed knowledge of the shape of the distribution of lifetimes. Some of the important features of attributes and variables plan for percent defective are compared in Table below.

The principal advantage of variable plans for percent defective over corresponding attributes plans is a reduction in the sample size needed to obtain a given degree of protection. Table below shows a comparison of variable sample sizes necessary to achieve the same protection as the attributes plan: n=125, c=3 (sample size of 125 units, allowable number of defectives of 3).

Table 5.3.1: Sampling Methods

	SAMPLING METHOD		
Method	**Definition**	**Uses**	**Limitations**
Cluster sampling	**Units in the population can often be found in geographical groups or clusters e.g. Schools, households etc.** **A random sample of cluster is taken, and then all units within those clusters are examined.**	**•Quicker, easier and cheaper than other forms of random sampling.** **•Does not require complete population information.** **•Useful for face-to-face interviews.** **•Works best when each cluster can be regarded as a microcosm of the population.**	**•Larger sampling error than other forms of random sampling.** **•If cluster are not small it can become expensive.** **•A larger sample size may be needed to compensate for greater sampling error.**
Convenience Sampling	**Using those who are willing to volunteer, or cases that are presented to you as sample.**	**•Readily available.** **•The larger the group, the more information is gathered.**	**•Sample result cannot be extrapolated to give population results.** **•May be prone to volunteer bias.**

Judgment Sampling	**Based on deliberate choice and excludes any random process.**	**•Normal application is for small samples from a population that is well understood and there is a clear method for picking the sample.** **•Is used to provide illustrative examples or case studies.**	**•It is prone to bias.** **•The sample is small and can lead to credibility problems.** **•Sample results cannot be extrapolated to give population results.**
Multi-stage Sampling	**The sample is drawn in two or more stages (e.g. A selection of offices at the first stage and a selection of claimants at the second stage).**	**•Usually the most efficient and practical way to carry out large surveys of the public.**	**•Complex calculations of the estimates and associated precision.**
Probability Proportional to size	**Samples are drawn in proportion to their size giving a higher chance of selection to the larger items (e.g. The more claimants at an office the higher the office's chance of selection).**	**•Where you want each element (e.g. Claimants at an office) to have an equal chance of selection rather than each sampling unit (e.g. Offices).**	**•Can be expensive to get the information to draw the sample.** **•Only appropriate if you are interested in the elements.**
Quota sampling	**The aim is to obtain a sample that is representative of the population.** **The population is stratified by important variables and the required quota is obtained from each stratum.**	**•It is a quick way of obtaining a sample.** **•It can be fairly cheap.** **•If there is no sampling frame it may be the only way forward.** **•Additional information may improve the credibility of the results.**	**•Not random so stronger possibility of bias.** **•Good knowledge of population characteristics is essential.** **•Estimates of the sampling error and confidence limits probably can't be calculated.**

Simple random Sampling	**Ensures every member of the population has an equal chance of selection.**	**•Produces defensible estimates of the population and sampling error.** **•Should reduce the error due to sampling.**	**•Need complete and accurate population listing.** **•May not be practicable if a countrywide sample would involve lots of audit visits.**
Stratified sampling	**The population is sub-divided into homogenous groups, for example regions, size or type of establishment.** **The strata can have equal sizes or you may wish a higher proportion in certain strata.**	***•Ensures units from each main group are included and may therefore be more reliably representative.*** ***•Should reduce the error due to sampling.***	**•Selecting the sample is more complex and requires good population information.** **•The estimates involve complex calculations.**
Systematic sampling	**After randomly selecting a starting point in the population between 1 and n, every n^{th} unit is selected, where n equals the population size divided by the sample size.**	**•Easier to extract the sample than simple random.** **•Ensures cases are spread across the population.**	**•Can be costly and time consuming if the sample is not conveniently located.** **•Can't be used where there is periodicity in the population.**

5.4 Types of sampling plans and choosing a sampling plan

A **sampling plan** established the guidelines by which sample is taken and the criteria for making a decision regarding the quality of a product lot. A sampling plan can be developed for either attributes or variable measures and for one or more samples. In the following discussion, we focus on the simplest form of sampling plan, a single- sample attribute plan.

5.4.1 Single- Sample Attribute Plan

A single-sample attribute plan has as its basis an attribute that can be evaluated with a simple, discrete decision, such as defective or not defective or good or bad.

The plan includes the following structural components:

N=the lot size

N= the sample size (selected randomly)

C=the acceptable number of defective items in a sample

d= the actual number of defective in a sample

The decision- making criteria in such a plan are straightforward. A single sample of size n is selected randomly from a larger lot, and each of the n items is inspected. If the sample contains d>c defective items, the entire lot is accepted: alternatively, if d > c, the lot is rejected.

However, although the sampling plan includes only a few components, which are not difficult to understand, management must still decide the values of these components that will result in the most effective sampling plan. In addition, management must also determine what constitutes an effective sampling plan. These are all design considerations. In addition, management must also determine what constitutes an effective sampling plan.

In addition, management must also determine what constitutes an effective plan. These are all design considerations. The design of a sampling plan includes both the structural components (the sample size, ***n*** the decision criteria, etc.) and performance measures. These performance measures include the producer's risk, the acceptable quality level, and the lot tolerance percent defective. In the following section we discuss these measures individually.

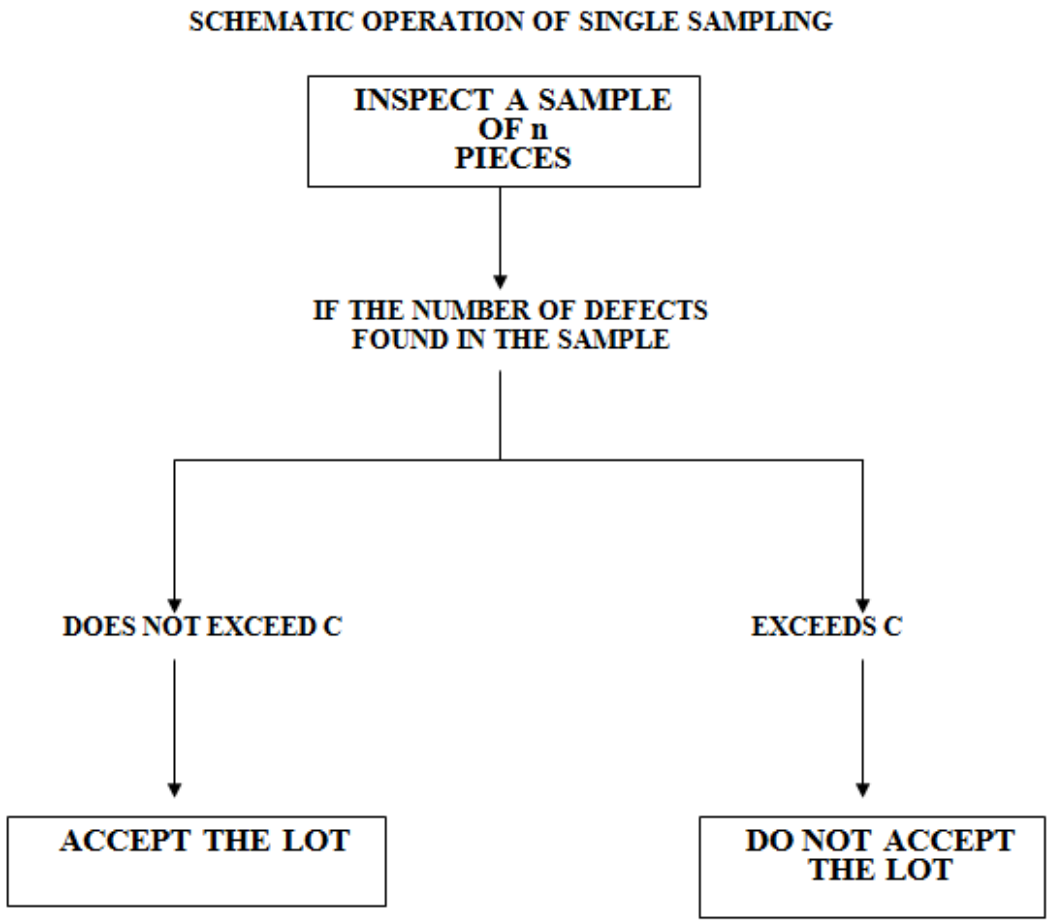

Figure 5.4.1: Schematic of single sampling.

In practice, the lot not to be accepted may be repaired, junked, etc. Sampling tables usually assume that the lot is detail- inspection and the defective pieces are all repaired or replaced by good pieces.

5.4.2 Double- Sample Attribute Plan

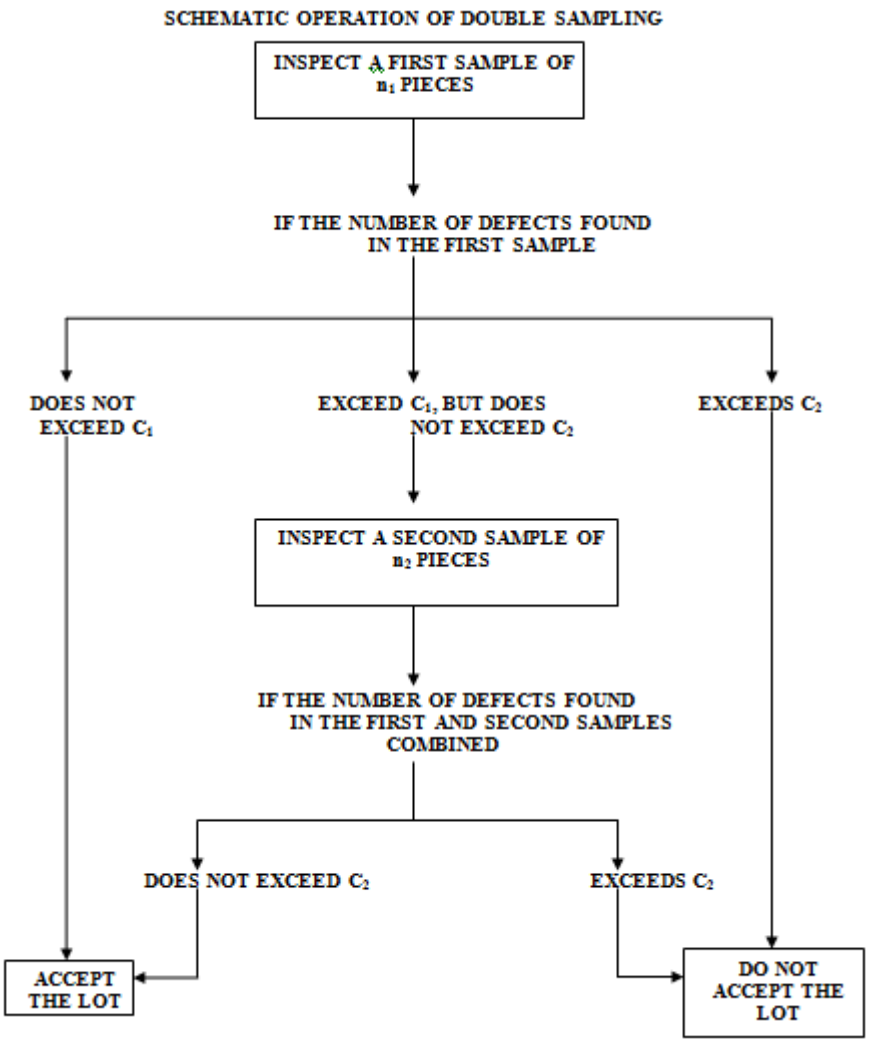

Figure 5.4.2: Schematic of double sampling.

In regard to the lot not to be accepted, inspect the remainder of the pieces, replacing or repairing those defective.

5.4.3 Multiple- Sample Attribute Plan

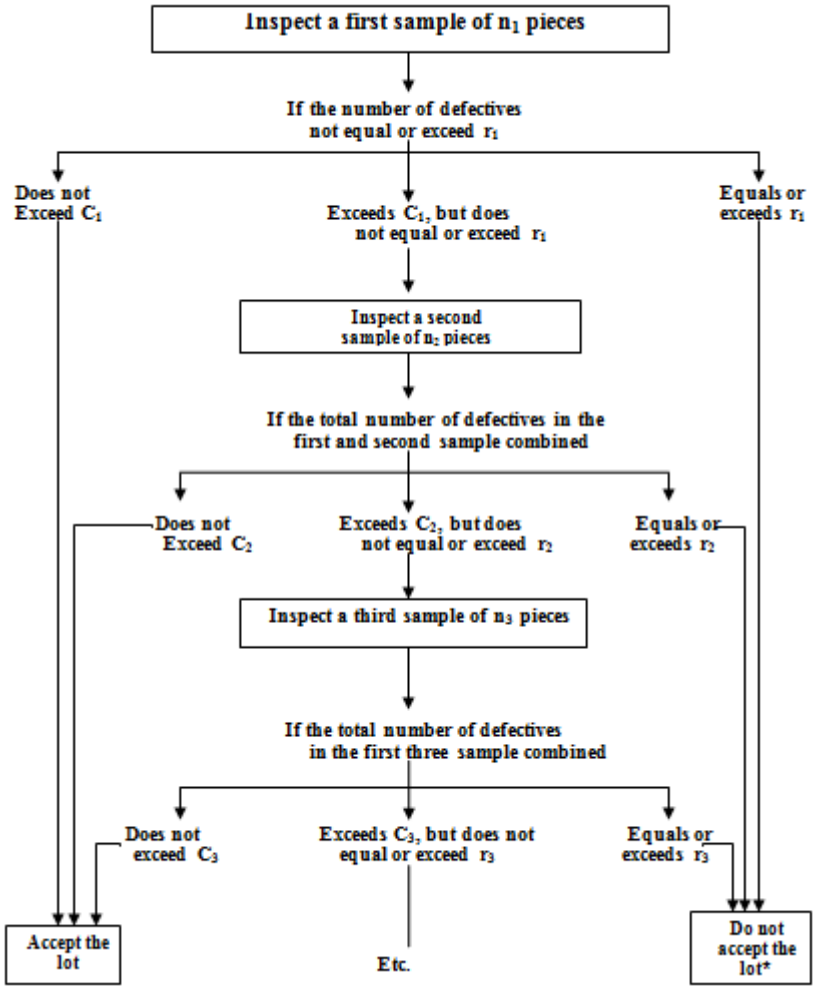

Figure 5.4.3: Schematic of multiple sampling.

The asterisk means some of these plans continue to the "bitter end", i.e., the talking of sample continues if necessary until the lot is fully inspected unless the plan has meanwhile "made up its mind". Other plans, described as "truncated," are designed to force a decision after a certain number of inconclusive sample have been examined.

5.4.4 Comparison of Single, Double, and Multiple Sampling

Table 5.4.1: Comparative Advantage and Disadvantage of Single, Double, and Multiple Sampling

Feature	Single sampling	Double sampling	Multiple sampling	Sequential
Acceptability to producer	Psychologically poor to give only one chance of passing the lot	Psychologically adequate	Psychologically open to criticism as being indecisive	Psychologically open to criticism as being more indecisive than multiple
Number of pieces Inspected per lot	Generally greatest	Usually (but not always) 10 to 50% less than Single sampling	Generally (but not always) less than double sampling of the order of 30%	Minimum over all attributes plans
Administration cost in training, personnel records, drawing and identifying samples, etc.	Lowest	Greater than single sample	Greater	Greatest
Information about prevailing level of quality in each lot	Most	Less than single sample	Less than double	Least

*This is not to be confused with total cost of inspection, which includes administration cost of the plan.

5.5 Risks of Sampling

Producer's and Consumer's Risks: When a sample is drawn from a production lot and the items in the sample are inspected, management hopes that if the actual number of defective items exceeds the predetermined acceptable number of defective items (i.e.; d>c) and the entire lot is rejected, then the sample result have a accurately portrayed the quality of the entire lot. Management would hate to think that was actually acceptable was erroneously rejected and wasted. Conversely, management

hopes that an actual bad lot of items is not erroneously accepted if d<c. An effective sampling plan attempts to minimize the possibility of wrongly rejecting good items or wrongly accepting bad items.

When an acceptance- sampling plan is designed, management specifies a quality standard commonly referred to as the acceptable quality level, or AQL. The AQL reflects the consumer's willingness to accept lots with a small proportion of defective items. The AQL is the fraction of defective items in a lot that is deemed acceptable. For example, the AQL might be two defective items in a lot of 500, or 0.004.the AQL may be determined by management to be the level that is generally acceptable in the marketplace and will not result in a loss of customers. Or, an individual customer as the quality level it well accepts may dictate it. In other words, the AQL is negotiated.

As indicated previously, management hopes that the sampling results will not result in a lot that meets the AQL being erroneously rejected. The probability of rejecting a production lot that has an acceptable quality level is referred to as the producer's risk and is commonly designated by the Greek symbol α. In statistical jargon, α is the probability of committing a type I error.

There will be instances in which the sample will not accurately reflect the quality of a lot and a lot that does not meet the AQL will pass on to the consumer. Although the consumer expects to receive some of these lots, there is a limit to the number of defective items the consumer will accept. This upper limit is known as the **lot tolerance percent defective**, or **LTPD** (LTPD is also generally negotiated between the producer and consumer). The probability of accepting a lot in which the fraction of defective items exceeds the LTPD is referred to as the **consumer's risk** and is designated by the Geek symbol β. In statistical jargon, β is the probability of committing a type II error.

In general, the customer would like for the quality of a lot to be as good as or better than the AQL but is willing to accept some lots with quality level no, worse than the LTPD. Frequently, sampling plans are designed with the producer's risk (α) about 5 percent and the consumer's risk (β) around 10 percent. Be careful not to confuse α with the AQL or β with the LTPD. If α equals 5 percent and β equals 10 percent, then management expects to reject lots that are as good as or better than the AQL

about 5 percent of the time, whereas the customer expects to accept lots that exceed the LTPD about 10 percent of the time.

5.6 Governmental Purchasing, Practices and Procedures[27]

Every Ministry / Department spends a sizeable amount of its budget for purchasing various types of goods to discharge the duties and responsibilities assigned to it. It is imperative that these purchases are made following a uniform, systematic, efficient and cost effective procedure, in accordance with the relevant rules and regulations of the Government. The Ministries / Departments have been delegated powers to make their own arrangements for procurement of goods under the Delegation of Financial Power Rules, which have to be exercised in conformity with the orders and guidelines issued by competent authorities covering financial, vigilance, security, safety, countertrade and other regulatory aspects.

At the apex of the legal framework governing public procurement is Article 299 of the Constitution, which stipulates that contracts legally binding on the Government have to be executed in writing by officers specifically authorized to do so. Further, the Indian Contract Act, 1872 and the Sale of Goods Act, 1930 are major legislations governing contracts of sale/ purchase of goods in general. There is no law exclusively governing public procurement of goods. However, comprehensive rules and directives in this regard are available in the General Financial Rules (GFR), 2005,(especially chapter 6; *Delegation of Financial Powers Rules (DFPR); Government orders regarding price or purchase preference or other facilities to sellers in the Handloom Sector*, *Cottage and Small Scale Industries and to Central Public Sector Undertakings etc.)* and the guidelines issued by the Central Vigilance Commission to increase transparency and objectivity in public procurement. DGS&D, the Central Purchase Organization of Government of India lays down the standard and contracts to be followed in public procurement. All these provide the regulatory framework for the public procurement system.

[27] Manual on Policies and Procedures for purchase of goods by government agency: Link:http://www.du.ac.in/fileadmin/DU/DUCorner/MPProc4ProGod.pdf

It may be useful to refer to the following provisions in the General Financial Rules, 2005:

Rule 137. Fundamental principles of public buying : *Every authority delegated with the financial powers of procuring goods in public interest shall have the responsibility and accountability to bring efficiency, economy, transparency in matters relating to public procurement and for fair and equitable treatment of suppliers and promotion of competition in public procurement.*

The procedure to be followed in making public procurement must conform to the following yardsticks :-(i) the specifications in terms of quality, type etc., as also quantity of goods to be procured, should be clearly spelt out keeping in view the specific needs of the procuring organizations. The specifications so worked out should meet the basic needs of the organization without including superfluous and non-essential features, which may result in unwarranted expenditure. Care should also be taken to avoid purchasing quantities in excess of requirement to avoid inventory carrying costs;

(ii) offers should be invited following a fair, transparent and reasonable procedure;

(iii) the procuring authority should be satisfied that the selected offer adequately meets the requirement in all respects;

(iv) the procuring authority should satisfy itself that the price of the selected offer is reasonable and consistent with the quality required;

(v) at each stage of procurement the concerned procuring authority must place on record, in precise terms, the considerations which weighed with it while taking the procurement decision.

An authority which is competent to incur contingent expenditure may sanction the purchase of goods required for use in public service in accordance with Schedule V of the Delegation of Financial Rules, 1978, following the general procedure mentioned above.

A demand should not be split into small quantities for the sole purpose of avoiding the necessity of taking approval of the higher authority required for sanctioning the purchase of the original demand.

In case a Ministry / Department do not have the required expertise or manpower, it may send its indent to the Central Purchase Organization (e.g., DGS&D) with the approval of its Secretary.

DGS&D,[28] the Central Purchase Organization of Government of India is an important support institution of government of India which prior to liberalization was the sole authority behind all government purchases, and still continues a strong guiding force. It is now an attached office of Department of Commerce (Supply Division), Ministry of Commerce & Industry. DGS&D has two professional cadres namely the 'Indian Supply Service' and the 'Indian Inspection Service' for carrying out procurement and quality assurance work. The functions of DGS&D are carried out through its Supply wing & Quality Assurance (QA) wing. Supporting services are provided by Administration, Vigilance, Complaints and Public Relations, Planning & Co-ordination, Internal Work Study Unit, Management Information Services, Registration, Litigation, Import & Shipping and Computerization & Training Directorates. The organization Chart of DGS&D is given below in figure

[28] Annual report of DGS&D 2007-2008

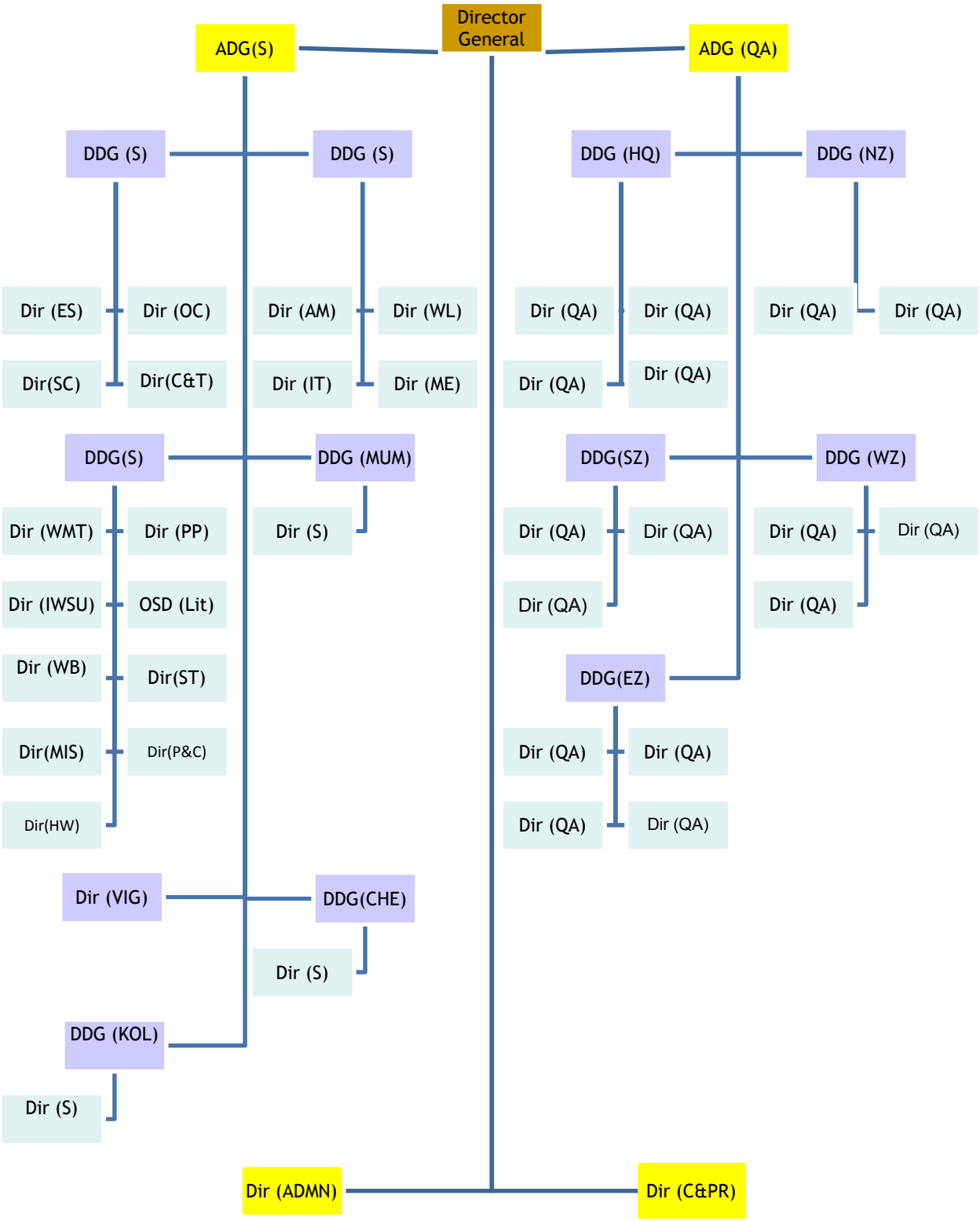

Figure 5.6.1: DGS&D Structure(Annual report of DGS&D 2007-2008)

Supply Wing has eleven commodity-wise Purchase Directorates at New Delhi, they are Information Technology, Electrical Stores, Mechanical Engineering, Automobiles, Steel & Cement, Structural Engineering, Hardware, Workshop & Machine Tools, Wool & Leather, Paper & Paper Products, Oil & Chemical and Regional supply offices at Kolkata, Mumbai and Chennai. The handling of work commodity-wise facilitates maintenance of data bank on prices, vendors, specifications, market trends etc.

Quality Assurance Wing of DGS&D (formally known as Inspection Wing) is the Inspection Agency of the Govt. of India and is a technical arm of DGS&D providing complete support in purchase activity by laying down specifications, assessing the vendors, technical evaluation of bids & assuring quality of stores for their conformity. QA wing is headed by Additional Director General (QA) who is part of the Organization of DGS&D at New Delhi and consists of a team of professionally qualified experts, trained in India & abroad in various disciplines of engineering. QA wing has officers in four zones and each of the zones is headed by a Deputy Director General (QA) with two to three Directorates and further sub-offices in each zone. In all there are 28 field offices across the country including NI circle at Delhi, covering all major centers of Industrial activities, for handling the field activities.

The DGS&D officers are authorized by the President of India in exercise of the powers conferred by Clause (1) of Article 299 of the Constitution to make contracts for services, supply or work on behalf of the Central Government. DGS&D is also authorized to make similar contracts on behalf of the State Governments where so authorized by the State Governments, and on behalf of Government sponsored companies or corporations or local bodies where so authorized by such companies or corporations or local bodies.

Note: More than 3000 contracts had been issued by DGS&D IN 2007-08. The total value of DGS&D purchases during the year 2007-08 up to December 07 was Rs. 3272 Crore. DGS&D has 311 product categories with more than 30,000 items (excluding spares and accessories) on rate contracts.

Apart from purchase and contract, the DGS&D performs following functions and has directorates and offices all over the country, operating under the supervision of four regional offices at Kolkota, Mumbai, Kanpur and Chennai with head quarter at New Delhi.

1) Public relations and Publications
2) Standardization and Quality control.
3) Development of indigenous sources of supplies.
4) Purchases from cottage and small scale industries.
5) Registration of suppliers.
6) Termination, Suspension, and Black-listing of suppliers.
7) Indent processing.
8) Foreign purchases.

CHAPTER 6: Inventory and Control

6.1 Introduction

An inventory can be defined as a stock of materials used to facilitate production or satisfy customer demand. In the context of manufacturing system it comprises of raw materials, work in process and finished goods, whereas in retail sector, the available stock for sale.

The fundamental problem of inventory management can be described as: a) how much to order, b) when to order. The major difference between various policies is on the treatment of customer demand. In some situations, demand is known with reasonable accuracy. However, in most real life situations, demand is uncertain and difficult to predict.

Every inventory lies between two activities or processes, which we can call *the supply process* and *the demand process*.

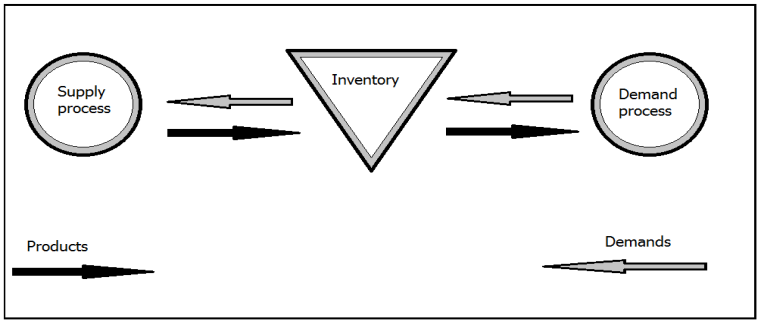

Figure 6.1.1: Inventory between demand and supply points (Zipkin,2000)

The supply process comprises the production, transportation like activities that add new stock to inventory, while the demand process consists of activities like sales etc., that subtract material from the inventory.

6.1.1 Purpose of inventories

The primary purpose of inventory is to uncouple the various phases of operations. Raw materials inventory uncouples a manufacturer from its vendors; work in process inventory uncouples the

various stages of manufacturing from each other; and finished goods inventory uncouples a manufacturer from its customer (Schroeder 2000).

There are four primary reasons to carry inventory:

1. **To protect against uncertainties**: In inventory systems, there are uncertainties in supply, demand, and lead time. Safety stocks are maintained in inventory to protect against those uncertainties.

2. **Economies of scale:** It is often economical to produce material in lot, as

- it allows spreading the setup cost to large number of items.
- it permits the use of same production equipment for different products.

A similar solution holds for the purchase of raw materials-owing to ordering cost, quantity discount and transportation costs.(At times it is economical to purchase in large lots, even though part of this lot is then held in inventory for later use)

The inventory resulting from the purchase or production of materials in lots is called cycle inventory, since the lots are produced or purchased on a cyclic basis.

3. **To cover anticipated changes in demand or supply:**

- There is a price trend visible of raw material.
- Sale promotion requiring piling up of finished products for display.
- Seasonal demand products.

4. **To provide for transit**: In case of materials being imported from a foreign country or from a faraway vendor within the country, one can save a lot in terms of transportation cost by buying in bulk and transporting as a container load or a full truck load. Part shipments can be costlier and also can take larger time, where the freight forwarder waits for other loads to fill the container which can take several weeks.

6.1.2 Inventory costs

Generally the inventory cost structure consists of four types of costs:

(1) **Cost of items(C):** The cost of buying or producing the inventory items. There can be quantity discounts associated with the ordered quantity.

(2) **Ordering Cost or Setup Cost (O):** is the cost associated with ordering or producing a batch or lot of items. It does not depend on the number of items ordered, but assigned to entire batch or lot.

The ordering cost may typically include – inviting tender, typing or preparing the purchase order, expediting the order, transportation cost, receiving cost, etc.

For production systems, setup cost may include –paper work, preparation of equipment for producing particular type of item, etc. In situations setup cost amounts to lakhs of rupees.

(3) **Holding Cost or Carrying Cost (H**): is the cost associated with keeping item inventory for a period of time. It is typically expressed as percentage of rupee values of item per unit time.

Carrying cost usually consists of three components:

(a) Cost of Capital: involves issues like Bank interest rate, forgone opportunity etc.

(b) Cost of storage: involves issues like rented ware house, tax and insurance etc.

(c) Cost of obsolescence, deterioration, and loss.

(4) **Stock out Cost (S):** it reflects the economic consequence of running out of stock. There are two cases possible in this situation

(a) Back order or substitution.

(b) Lost sales.

In both situations there is impact on profit and good will of the organization and may be loss of future sale to the customer.

One can see from the above cost structure that inventory management is a cross-functional problem. Marketing people may be interested in having as much stock as possible to minimize the stock out or lost sales. On the other hand the finance department may be interested more in minimizing the amount of inventory that needs to be financed. Operations may want a sufficient level of inventory to assure smooth scheduling and production control. Since these objectives may be at odds, it is important that the total cost minimization approach applied in inventory models should also account these constraints.

6.2 Inventories and Demand Uncertainty

The basic decision one needs to take for inventory management is **how much to order** and **when to order**. It is extremely difficult to formulate a single general inventory model which takes into account all variations (uncertainties) in real systems and even if such formulation is attempted it may not be analytically solvable. Therefore inventory models are developed with relaxations and assumptions and their sensitivity to real life situations is then analyzed.

6.2.1 Inventory control under deterministic demands:

In this group the simplest technique is classical EOQ Model which is based on following assumptions:

(a) Demand is known and uniform (D=constant).

(b) Replenishment of stock is instantaneous (Lead time 'L'=0).

(c) No shortages are allowed as instantaneous replenishment.

(d) Inventory carrying cost (H) and ordering cost/order (O) remain constant over time.

(e) Cost of item remains constant over time.

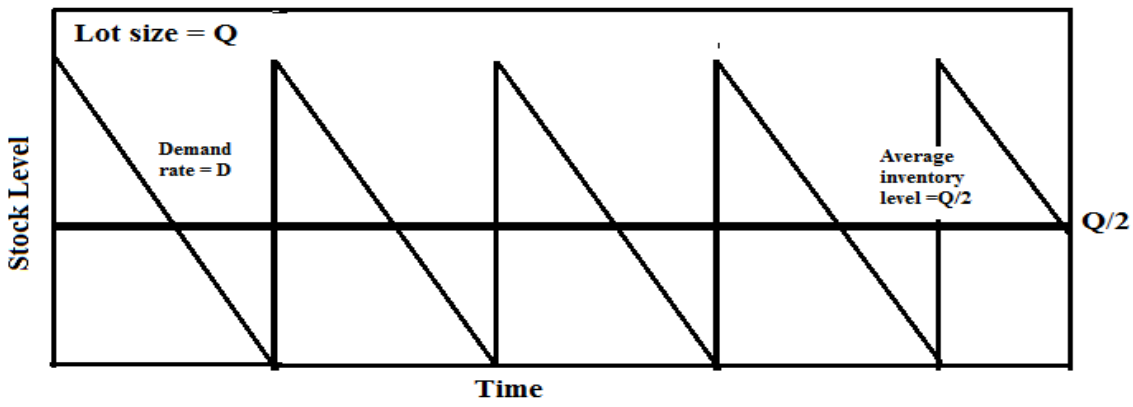

Figure 6.2.1: Classical EOQ Model

In choosing the lot size (Q), there is tradeoff between ordering frequency and inventory level. Small lots will lead to frequent reorders but a low average inventory level. If larger lots are ordered, the ordering frequency will decrease but more inventory will be carried. This tradeoff can be represented by mathematical equation as

Total inventory cost (TC) = cost of items + Total ordering cost per year +Total carrying cost per year

$$TC = CD + \frac{OD}{Q} + \frac{HQ}{2}$$

We neglect the first term in above expression for computation of minimum cost as demand and cost of items are assumed constant over the year. So we need to evaluate minimum for

$$TC = \frac{OD}{Q} + \frac{HQ}{2}$$

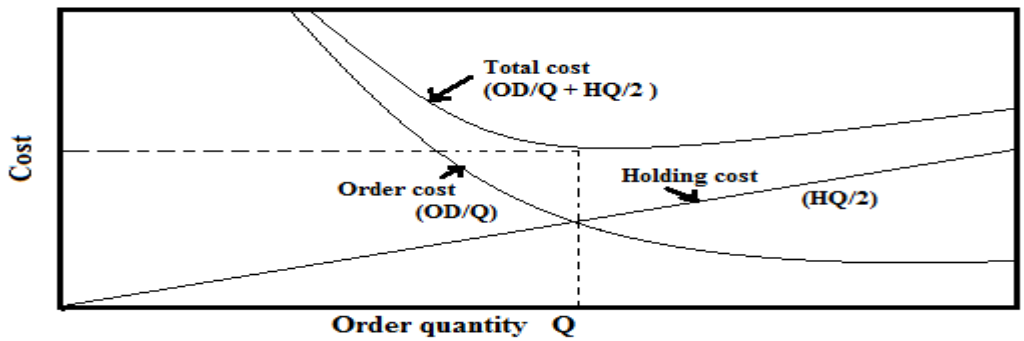

Figure 6.2.2: Tradeoff between ordering cost and carrying cost.

The value of 'Q' that minimizes cost can be found by taking the derivative of TC and setting it equal to zero and ensuring that second derivative is positive. Even one can find the minimum seeing from the graph as one function is linearly increasing and other inverse function of Q and intersect at minimum. We do by calculus:

$$TC' = -\frac{OD}{Q^2} + \frac{H}{2} = 0$$

$$\frac{OD}{Q^2} = \frac{H}{2}$$

$$Q^2 = 2\,OD/H$$

$$Q = \sqrt{\frac{2OD}{H}}$$

The above equation is classic Wilson economic order quantity, which minimizes the cost of operating inventory. One needs to take care that demand per unit time and carrying cost per unit time should be of same duration. We see from the curve that EOQ or minimum lies in quite a flat area and hence one can easily round off to integer value, if above formula gives fraction value, without affecting much the cost. EOQ is quite robust over a considerable range.

There are many extensions to the classical EOQ model, for example:

- **Re-order lead time** - allows a lead time between placing an order and receiving it - this introduces the problem of when to reorder (typically at some stock level called the *reorder level*).
- **Stock-outs** - we can allow *stock-outs* (often called *shortages*) i.e. no stock currently available to meet orders.
- **Finite Replenishment rate**- often an order is not received all at once, for example if the order comes from another part of the same factory then items may be received as they are produced.
- **Buffer (safety) stock** - some stock kept back to be used only when necessary to prevent stock outs.
- **Quantity Discount**- Supplier offers differential price rate for the quantity ordered.

Example 6.2.1: A lubricant manufacturing company faces almost constant rate annual demand for grade-S oil as 2,50,000 gallons. The setup cost is Rs.15,000 per batch production and the holding cost per gallon per year is Rs. 250. What is the optimum number of units to be produced per production run? What is the expected number of production runs per year? Assuming a 250 day working year, what is the expected time between these runs?

Solution:

i) Since the demand is certain or deterministic, we use EOQ model

$$Q = \sqrt{\frac{2OD}{H}}$$

$= \sqrt{\frac{2*15000*250,000}{250}}$

= 5,477.22 gallons (can take 5480 or 5500)

ii) Expected number of production run for grade-S oil = D/Q

=250,000/5500 = 45.45= 46

iii) Expected number of days between the runs = 250/45.45 = 5.5

6.2.2 Inventory control under uncertain demands

The main aim of the planning to minimize the uncertain aspect of demand planning and for this statistical inference analysis is done on the available relevant information or data. Statistics help us in organizing data in the form to understand and make inference for informed decision making. Before going into inventory model dealing uncertainty, let us first understand few parameters related to uncertainty.

The quantitative data can be analyzed by estimate of its central tendency (mean, mode, and median), its variation (range, quartile, variance and standard deviation) and the type of its shape (symmetric, skewed, etc). Plotting data in a frequency distribution shows the general shape of the distribution and gives a general sense of how the numbers are bunched and what statistic will be appropriate in the given situation. The statisticians try to fit standard mathematical distributions on the frequency plot to get more detailed analysis. The important statistics used in data analysis can be grouped into three as:

1. **Measures of central tendency.**

i. **Mode** - The mode of a distribution refers to the most frequent or common occurring value in the distribution. In the plot of the data, the mode is the point or value of X that corresponds to the highest point on the distribution.

ii. **Median** - The median is that value which divides the data set into halves such that half of the values are above the median and half are below it when the data are arranged in numerical order.

iii. **Mean** - The mean is the most common measure of central tendency and defined as the average of a distribution .The mean is the balance point in a distribution such that if one subtracts each value in the distribution from the mean and sum these deviation scores, the result will be zero.

2. **Measures of Spread** - They provide information about the degree to which individual values are clustered about or deviated from the central or average value in the data distribution.

i. **Range** – This is the simplest measure of variability and is defined as the difference between the highest and lowest value in a distribution.

ii. **Interquartile Range (IQR)** - Provides a measure of the spread of the middle 50% of the values of data. The IQR is defined as the 75th percentile - the 25th percentile. The advantage of IQR over range is that it eliminates the extreme values or outliers.

iii. **Variance** - The variance provides a measure of the average deviations of values from the mean and is computed by taking average of the squared deviations of data values about the mean. When the deviations are squared, the rank order and relative distance of scores in the distribution

remains unchanged and on the same hand we get rid of the negative values, which made the total deviation zero.

iv. **Standard deviation** - The standard deviation is defined as the square root of the variance. The advantage of standard deviation in comparison to variance is that it has the same units as the data and thus can be better inferred.

3. **Measures of Shape** - This statistics is generally applied to continuous data and is used to describe the shape of the data.

i. **Symmetric** – When the distribution has the same shape on both sides of the center or average. Example of symmetric distribution is normal distribution.

ii. **Skewness** – It refers to the degree of asymmetry in a distribution. The cause of skewed data distributions are extreme values, also known as outliers. A distribution is positively skewed when is has a tail extending out to the right (large numeric values). A negatively skewed distribution has an extended tail pointing to the left (smaller values) and reflects bunching of numbers in the upper part of the distribution with fewer scores at the lower end of the measurement scale. Example of positively skewed distribution is exponential distribution and of negative is β-distribution.

Table 6.2.1 :Computation of statistic

MEASURE	DATA SET :2, 2, 3, 5, 5,5,6,7, 8
The Mean (μ or $\bar{x}$) $\mu \text{ or } \bar{x} = \frac{\sum x_i}{n}$ $= \frac{\sum f_i x_i}{\sum f_i}$	Adding the numbers up gives: 2 + 2 + 3 +5+ 5 + 5 +6+ 7 + 8 = 43 So the mean(μ) is =43/9=4.77=4.8
The Median(m) m= $(n+1/2)^{th}$ term ,if n odd = average of $n/2^{th}$ and $(n/2+1)^{th}$ terms, If n even	The numbers in ascending order: 2 , 2 , 3 , 5, 5, 5 ,6 7 , 8 The median(m) is = middlemost value =5
The Mode (M) The mode is the value which appears the most often in the data.	The mode(M) is = 5
The Range(R) = highest value - lowest value	The range(R) is= 8 - 2 = 6
The Variance $\sigma^2 = \frac{\sum(x_i - \bar{x})^2}{n}$	The variance(σ^2) is ={$(2-4.8)^2$+$(2-4.8)^2$ +$(3-4.8)^2$ +$(5-4.8)^2$ +$(5-4.8)^2$ +$(5-4.8)^2$+$(6-4.8)^2$ +$(7-4.8)^2$+$(8-4.8)^2$}/9 = 3.95 = 4
The standard Deviation $\sigma = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n}}$	The standard deviation(σ) is = $\sqrt{4}$ = 2

Normal Distribution:

The normal distribution is most widely used distribution in statistical domain. The theoretical basis for its wide applicability is provided by central limit theorem. The central limit theorem claims that all sampling distribution of the mean become approximately normal regardless of the distribution of the original variable.

The probability density function of normal distribution is given as

$$f(x) = \frac{e^{-(x-\mu)^2/(2\sigma^2)}}{\sigma\sqrt{2\pi}}$$

where μ is the mean and σ is the standard deviation of the distribution and are called in statistical language as location parameter and the scale parameter. The following is the plot of the normal probability distribution function

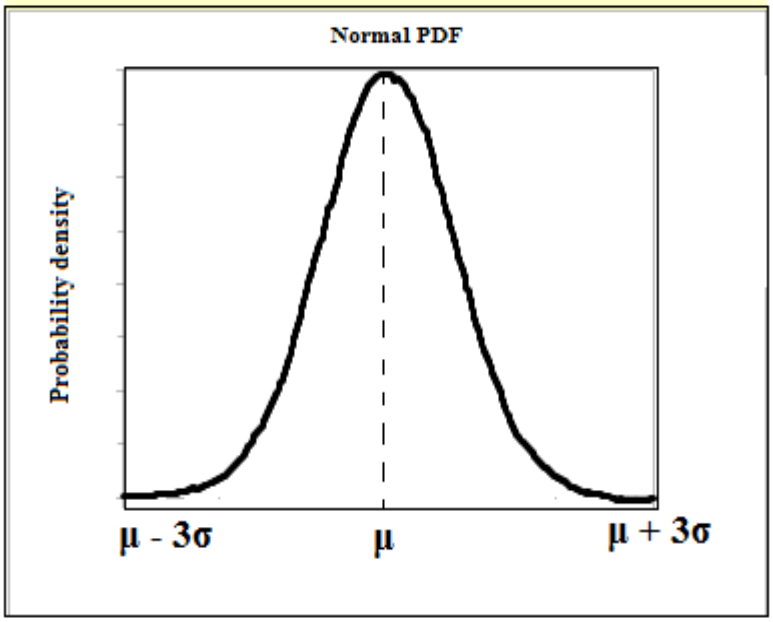

Figure 6.2.3: A normal distribution curve

We notice that normal distribution function is symmetric with same mean, mode, and median values = μ. The range contains all real values spanning from – ∞ to + ∞. The case where μ= 0 and σ= 1 is called the **standard normal distribution**. The equation for the standard normal distribution is

$$f(x) = \frac{e^{-x^2/2}}{\sqrt{2\pi}}$$

The general form of probability functions can be expressed in terms of the standard distribution; therefore a standard table for standard normal distribution table is developed and is used for finding the probability values for any type of normal distribution variable. The area under the probability

density function gives the probability of finding the value in that range. The left half of the area of normal distribution from point of symmetry or mean depicts 50% probability to have values within mean. Similarly right half denote area signifying probability of having value greater than μ. The 'z' value which can be read directly from standard normal table give corresponding representation of any normal probability distribution.

We have $z = \frac{(x-\mu)}{\sigma}$

z= 0 correspond to value of data=μ, and probability to have value less than or equal to μ will be 50%

z= 1 correspond to value of data=μ + σ, and probability to have value less than or equal to μ +σ will be 50%+34.13%

z= 2 correspond to value of data=μ + 2σ, and probability to have value less than or equal to μ+2σ will be 50%+47.72%

z= 3 correspond to value of data=μ + 3σ, and probability to have value less than or equal to μ+3σ will be 50%+49.82%.

Since normal distribution is symmetric we will find similar relation when we move left of the values of mean i.e. for

z= -1 correspond to value of data=μ − σ, and probability to have value less than or equal to μ -σ will be 50%-34.13%

z= -2 correspond to value of data=μ − 2σ, and probability to have value less than or equal to μ -2σ will be 50%-47.72%

z= -3 correspond to value of data=μ − 3σ, and probability to have value less than or equal to μ -3σ will be 50%-49.82%.

Calculation of safety stock in inventory management is done using z values corresponding to required probability of no-stockout, when the demand distribution is normal distributed. $Safety\ stock = z\sigma$

6.2.2(A) Continuous Review Inventory Model:

A continuous review inventory system, considers stochastic demand rate and manages inventory by monitoring the stock position after each transaction, or continuously. There is pre-determined target level(R) and instant the stock position touches that level, an order is placed of a fixed quantity (Q). Since the order quantity is fixed the time between orders will vary depending on the random nature of

demand. The quantity Q can be computed using EOQ formula taking demand as the average demand (E[D]) over the planning period.

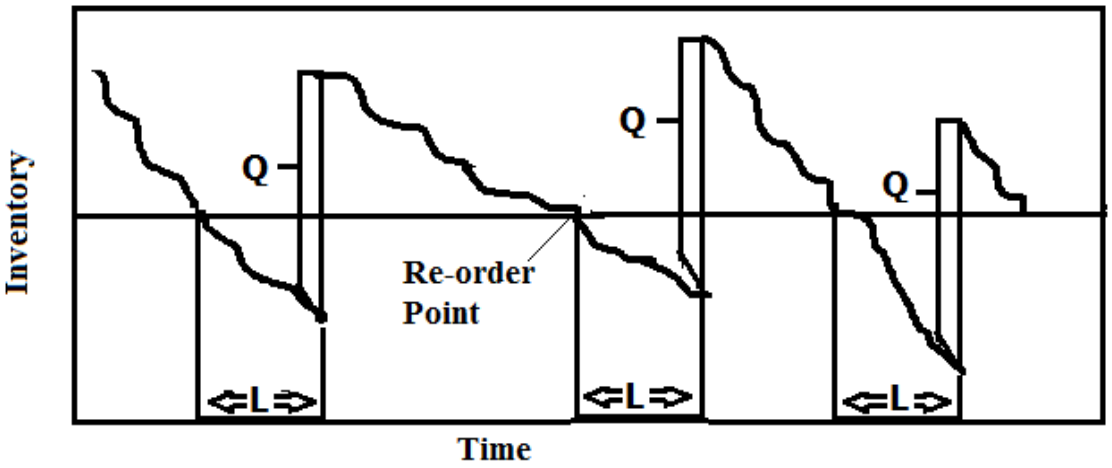

Figure 6.2.4: Continuous review inventory model

The value of R is determined using the service level criterion. Service level refers to percentage of customer demands satisfied from the available inventory. It can also be said as percentage of time the system has stock on hand. The concept of service level is explained by figure below assuming the random demand to be normally distributed.

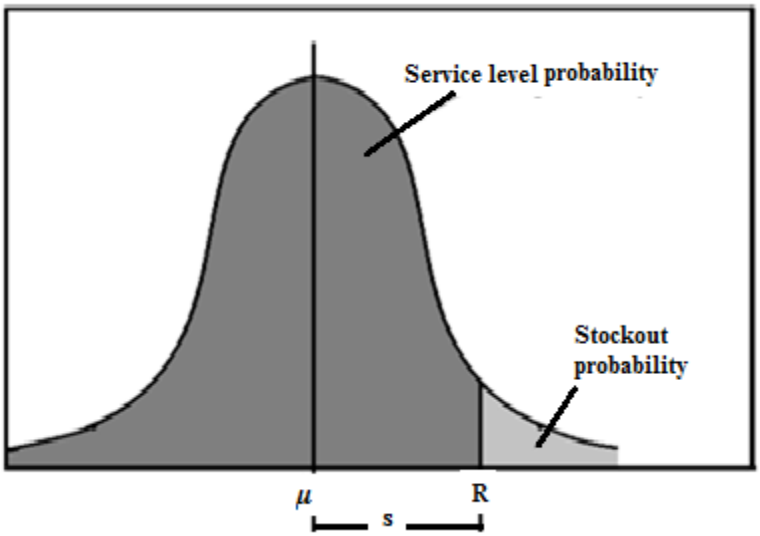

Figure6.2.5 : Probability distribution of demand over the lead time

The reorder point(R) is defined as follows:

$$R = \mu + s = \mu + z\sigma$$

where, μ= mean (average) demand over the lead time.

s=safety stock (or buffer stock)

z= safety factor

σ = standard deviation of demand over the lead time (=$\sqrt{L}\ \sigma_D$)

$\sigma_D =$ standard deviation of demand per unit time period.

$E[D] =$ average demand per unit time period.

By varying z, the number of standard deviation of lead time demand, we can set service level to desired value. For example for normally distributed demand for 95% desired service level the z value =1.65. For 50% service level z=0 or reorder point = mean demand.

Example 6.2.2: A store manager has to maintain a stock of a commodity facing uncertain demand. The demand for the item has following characteristics:

Average demand = 250 items per day

Lead time = 4 days for resupply from the vendor

Standard deviation of daily demand= 150 cases

Desired service level = 95%

O = Rs. 100 per order

C= Rs. 50 per item

I= 20% per year; H =0.2 *50 =Rs.10 per item per year.

Solution: Assuming that a continuous review system is used and the store is open six days a week, 50 weeks a year, or 300 days a year. Then average annual demand= 250(300) = 75,000 items per year.

The economic order quantity based on average demand is

$Q = \sqrt{\frac{2(100)(250*300)}{10}}$ =1224.7≈ 1225

The average demand over the lead time is 250 items a day for four days; therefore, μ=4(250) = 1000items

The standard deviation of lead time demand = $\sqrt{4}$ (150) = 300 units

The 95% service level requires a safety factor z = 1.65. Thus we have reorder point R as

$R = \mu + z\sigma = 1000 + 1.65 * 300 = 1495$

The Q system decision rule will be to place an order of 1225 items every time the stock position falls to 1495 items. On average there will be 61 orders placed per year or there will be 4.9 working days on average between orders. That is on an average there will be an order placed after every 5th working day.

6.2.2(B) Single period inventory problem

There are often situations in inventory management when the procurement lead time is very large and orders have to be placed well in advance of the demand period. The demand observed during the demand period (or consumption period) is uncertain and the ordering decision after observing the initial demand cannot change as the lead time is large. The ordering is done based on demand forecast. The risk in this situation is of two types. The demand can exceed the order quantity resulting in shortages and customer goodwill loss. Also, the demand can be less than the order quantity resulting in inventory in the system. Both shortages and inventories are costs (risks) and need to be minimized. Hence, the ordering should be done so as to minimize the expected inventory or shortage cost. Once the demand is realized, only one of the outcomes is possible: inventory or shortages.

We illustrate the decisions and issues in single ordering inventory problem through an example.

Example 6.2.3: The purchase manager of a power utility firm has to order bearings for the motors installed in cooling water plant. The demand for bearings is random and it depends on the maintenance schedule, replacement schedule, and breakdown of motors. The bearings are procured from a dedicated supplier and takes 3-4 months to arrive. Only one order is placed in a year. The cost of one bearing is Rs. 700. Any excess requirement of bearing is procured at a cost of Rs. 1000 per unit from a local supplier. Any unused bearing is sold in the market at Rs. 200. The likelihood of demand of bearing is as follows:

Table 6.2.2: Possible demands of bearing

Demand **x**	**Probability** **p(x)**	**Cumulative probability** **F(x)**
< 35	0.00	0.00
35	0.10	0.10
36	0.15	0.25
37	0.25	0.50
38	0.25	0.75
39	0.15	0.90
40	0.10	1.00

How many bearings should be ordered so as to minimize the expected risk (risk of inventory cost or shortage cost).

Solution: Let us define the relevant costs:

c: cost of procurement at regular price

r: cost of procurement at a premium from a local supplier

s: salvage value from returning unused bearing

C_u: *under-stocking cost* due to ordering one unit less = *r-c*

C_o: *overstocking cost* due to excess ordering of one unit = *c-s*

x: the number of bearings ordered (decision variable of the manager)

The optimal ordering quantity should satisfy the following condition:

$F(x) \geq C_u/(C_u + C_o)$

Critical ratio: $= C_u/(C_u + C_o)$ *=(r-c)/(r-s)*

Optimal solution: Order x such that F(x) is satisfied.

From the table above we see:

C_u = 1000 – 700 = 300

C_o = 700 – 200 = 500

Critical ratio = (1000-700)/ [(1000 – 700) + (700 – 200)] = 0.375. The first time F(x) satisfies the critical ratio is at 37 units. Hence, the optimal ordering quantity is 37 units.

6.3 Material Requirement Planning

The concept of computerized inventory control was introduced in 1970s. This system later becomes popular as Material requirements planning (MRP) system. The main objectives of MRP system were:

- Calculate demand for component items
- Keep track of components on when they are needed
- Generate work orders
- Generate purchase order after accounting for the lead time component items.

The three persons credited with the introduction of MRP system are Joseph Orlicky, George Plossl, Oliver Wright. At the time of introduction, MRP system brought computer and systematic planning to the manufacturing arena. Since the introduction, MRP system have undergone major changes and revision and the latest system is called as MRP-II; called as manufacturing resource planning; with a much broader scope than the original material planner.

MRP systems handle raw materials, components, and finished goods separately. In this process, the system planned purchased activities of raw materials and procured components, manufacturing activities of components and sub-assemblies, and delivery schedules of finished products. Thus in a way, MRP system are more of production scheduling systems than inventory schedules valid and up-to-date by maintaining latest and accurate information; MRP system assure the role of production control as well.

One of the major dilemmas is the decision of when to use MRP systems. Typically, MRP is useful for dependent and discrete demand items, complex products, batch production or assemble-to-order environments. By dependent demand, we imply that the demand that is calculated or derived from the independent items demand. Earlier order size analysis (EOQ, etc.) was based on independent demand scenario as the demand was dictated by market conditions which were independent of the operations. Examples of independent demand inventories are finished goods and spare-parts in a manufacturing company that are used to satisfy final customer demands. Dependent demand inventories, on the other hand are not subject to market conditions directly. They are dependent on demand of higher-level parts and components in the manufacturing system. This hierarchy of demand is governed by Master –production schedule which dictates what should be the end items or output of a production system in a given period. Examples of dependent demand include raw material and work in process inventories needed to meet the demand as per master production schedule.

Using MRP, the master production schedule is ‘exploded’ into purchase orders for raw materials and shop orders for scheduling the factory operations. The process of parts explosion involves determining all the parts and components needed to make a specified number of final items in the master schedule. This requires the individual lists of each product containing each of the parts needed to manufacture it, which is called Bill of Materials (BOM). The required parts may include assemblies, subassemblies, manufactured parts, and purchased parts. Parts explosion thus results in a complete list of parts that must be ordered (to vendor or production shop) and also the shop schedule required as per the master plan. Figure 6.3.1 given below shows the MRP system within a manufacturing unit.

In the process of parts explosion, it is necessary to consider inventories of parts that are already on hand or on order. Another important adjustment made during the parts explosion is for production and purchasing lead times. Starting with the master schedule, each manufactured or purchased part is offset (i.e. ordered earlier) by the amount of time it takes to get the part (the lead time). This procedure ensures that each component will be available in time to support the master schedule. If sufficient manufacturing and vendor capacity is available to meet the orders resulting from parts explosion, the MRP system will produce a valid plan for procurement and manufacturing actions. If sufficient capacity is not available, it will be necessary to re-plan the master production schedule to change the capacity.

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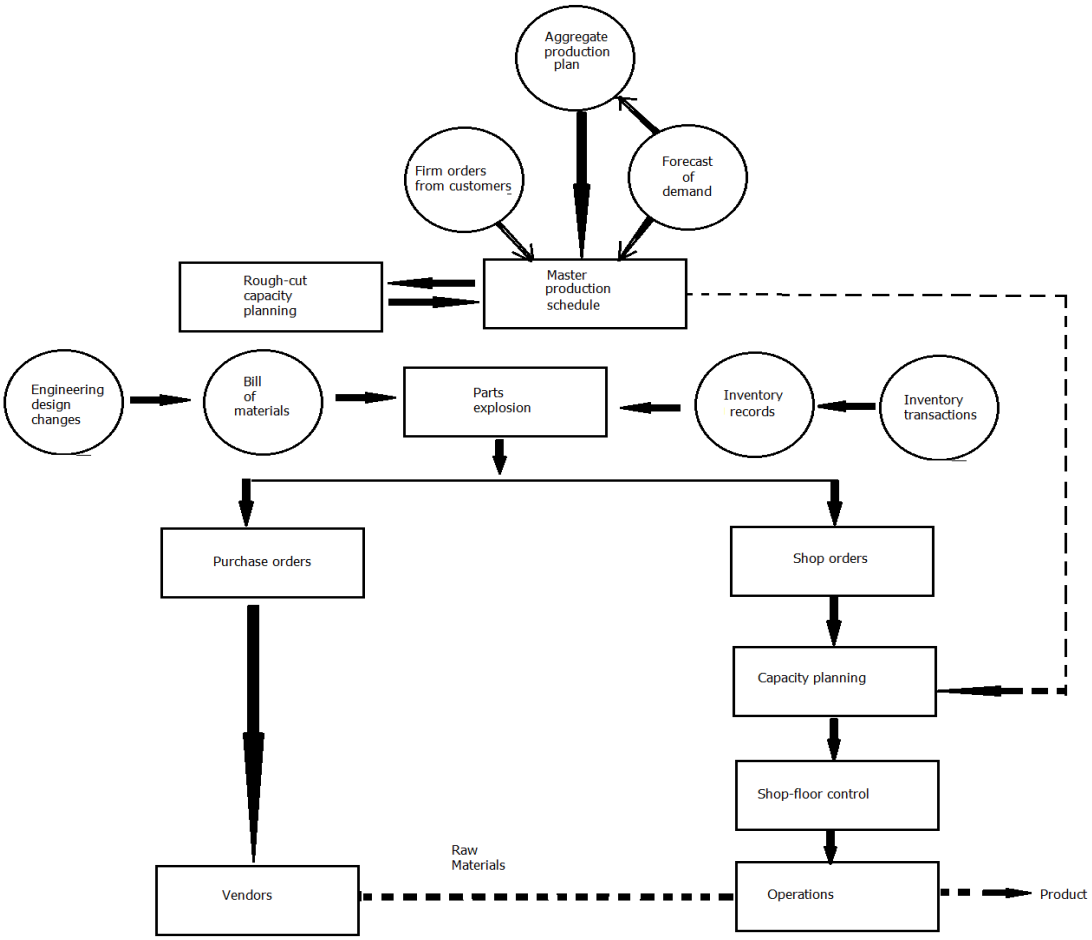


Figure 6.3.1: A closed loop MRP system(Schroeder.2000)

Comparison of MRP and Order-Point System:

The key distinction between MRP and order-point systems is that it is based on requirement philosophy whereas later is based on replenishment philosophy. Buffer stock or safety stock is present in both the situations to smoothen out the fluctuations, but there is much difference in implementation of both systems. Table given below highlights this difference

Table 6.3.1: Comparison of MRP and Order-Point System(Schroeder.2000)

Attribute	**MRP**	**Order Point**
Demand	Dependent	Independent
Order Philosophy	Requirements	Replenishment
Forecast	Based on master schedule	Based on past demand
Control concept	Control all items	ABC
Objectives	Meet manufacturing needs	Meet customer needs
Lot sizing	Discrete(as per requirement i.e. lot for lot policy)	EOQ(based on average demand)
Demand Pattern	Lumpy but predictable	Random
Types of inventory	Work in process and raw materials	Finished goods and spare parts

Example 6.3.1: Consider the chair to be manufactured, as shown in figure below. A finished chair consists of a top, two long legs, two short legs and six rails. The bill of material for this chair will comprise of the parts listed above. It is assumed that all parts of the chair are available with the supplier and thus can be purchased from outside. The only work that goes into the firm is assembling these parts. Suppose the plan to produce table as per demand is 200 for week 3, 200 for week 4 and 150 for week5. Also given there are already ready 50 chairs in stock and material available for another 50 chairs.

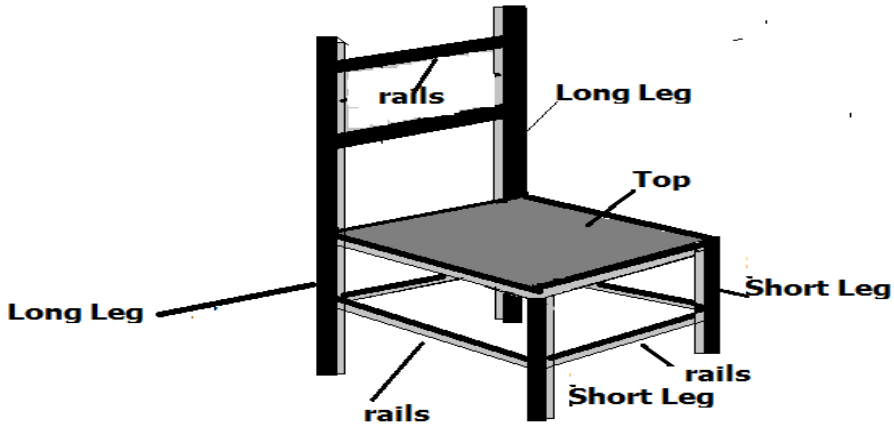


Figure 6.3.2 A chair manufacturing Example (MRP)

Solution: The master schedule for this chair contains the demand for finished tables as: 200 in week3, 200 in week 4, and 150 in week 5.The planned lead times for manufactured and purchased parts are as following;

To assemble chair from top, rails and finished legs: 1 week

To purchase rails; 1 week

To purchase short leg: 1 week

To purchase long leg: 1 week

Purchase top: 1 week.

It is now possible, using parts explosion, to construct a materials plan for the finished chairs and parts based on above information.

Table given below gives the MRP for the given problem.

Table 6.3.2 Material Recruirement Plannning(MRP) for the chair problem

Item	Week				
	1	**2**	**3**	**4**	**5**
Chairs					
Gross requirements	—	—	**200**	**200**	**150**
On-hand/scheduled receipts	**50**	—	—	—	—
Net requirements	—	—	**150**	**200**	**150**
Planned order releases	—	**150**	**200**	**150**	—
Tops					
Gross requirements	—	**150**	**200**	**150**	—
On-hand/scheduled receipts	**50**	**50**	—	—	—
Net requirements	—	**100**	**200**	**150**	—
Planned order releases	**100**	**200**	**150**	—	—
Legs long					
Gross requirements	—	**150 x 2=300**	**200x2=400**	**150 x2 =300**	—
On-hand/scheduled receipts	**100**	**100**	—	—	—
Net requirements	—	**200**	**400**	**300**	—
Planned order releases	**200**	**400**	**300**	—	—
Legs Short					
Gross requirements	—	**150 x 2=300**	**200x2=400**	**150 x2 =300**	—
On-hand/scheduled receipts	**100**	**100**	—	—	—
Net requirements	—	**200**	**400**	**300**	—
Planned order releases	**200**	**400**	**300**	—	—
Rails					
Gross requirements	—	**150 x 6=900**	**200x6=1200**	**150 x6 =900**	—
On-hand/scheduled receipts	**300**	**300**	—	—	—
Net requirements	—	**600**	**1200**	**900**	—
Planned order releases	**600**	**1200**	**900**	—	—

In the MRP table above the target quantities of chairs in the master schedule are put as gross requirements under chairs. Since we already have 50 chairs in stock, we subtract these available chairs from the gross requirement to arrive at net requirement, i.e150. Then the net requirement is offset by one week to arrive at planned order releases, as the planned lead time for chair assembly is one week.

Therefore, to meet gross requirements of the master schedule, shop orders must be released to assemble 150 chairs in week 2, 200 in week 3, and 150 in week 4.

From the planned order releases for chairs, we can calculate further the gross requirements for tops, long-legs, short-legs and rails situated at the next lower level in the BOM. Since one unit of top, two units of long-legs , 2 units of short-legs and 6 units of rails are needed for making a chair, the gross requirement is transferred as it is for the tops, 2 times for legs and 6 times for the rails. The on-hand inventory and scheduled receipts are subtracted from the gross requirement in the similar manner as was done at higher level to arrive at the net requirements. The net requirements are offset by the lead time (1 week here) to arrive at the planned order releases for tops, legs and rails. Notice in the table that there are already 50 tops on hand, hence only the purchase order of 150 tops must be released in first week as per the materials plan. Since there is a supply lead time of 1 week, these planned order releases of 150 tops will be received after 1 week, i.e. in week 2, when they will enter the assembly process to meet the gross requirement of chairs of week 3(as assembly lead time is 1 week).

A gross requirement at any level is the amount of material required to support planned orders at the next higher level. The gross to net calculation and the offset for lead time is then performed for each of the remaining three parts to arrive at order releases. This completes the part explosion of the given problem.

6.4 Store Management and Operation

Stores management is concerned with all the activities involved in storekeeping and inventory control to make the material availability efficiently and effectively. In this function it also encompasses the recruitment, selection, induction and the training of stores personnel, and much more.

Store is an area set aside into which all the items and materials required for production and/or for sale/distribution are received, where they are housed for safekeeping, and from which they will be issued as required. Stock items in the Store of an enterprise could include any or all of:-

- raw materials
- components (parts)
- spare parts
- partly finished work (sub-assemblies, work in progress)
- materials for maintenance
- consumables
- tools, jigs and gauges
- finished products (of the enterprise or purchased from others) ready for sale

The main functions of store are:

- Receive raw materials, components, tools, equipment's and other items and account for them.
- Provide adequate and proper storage and preservation to the various items.
- Meet the demands of the consuming departments by proper issues and account for the consumption.
- Minimize obsolescence, surplus and scrap through proper codification, preservation and handling.
- Highlight stock accumulation, discrepancies and abnormal consumption and effect control measures
- Ensure good housekeeping so that material handling, material preservation, stocking, receipt and issue can be done adequately.
- Assist in verification and provide supporting information for effective purchase action

The above list is illustrative not exhaustive but broadly we can divide the responsibilities of Stores Management on functional basis in three different groups as following:

1) Receipt and Dispatch Responsibilities

2) Custody & Warehousing including inspections

3) Materials Planning & Inventory Control

1) Receipt & Dispatch:

The store shall be responsible for:

i) Receipt of dispatch documents and keeping their records.

ii) Receipt of supplies from the vendors and other door deliveries.

iii) Collection of consignments from Railways/ Road Carriers.

iii) Taking delivery of consignment brought on door delivery basis.

iv) Arranging for open delivery if consignment found in outwardly damaged conditions or packages delivered short.

v) Receipts recording in 'Materials Inward Register and raising Unloading Reports.

vi) Handling and handing over materials to custody of user departments.

vii) Process freight payments to the carriers.

viii) Expediting deliveries of critically required materials.

ix) Securing marine insurance policies and arranging payment of premium to underwriters.

x) Furnishing monthly return of consignments received against the open policy of transit insurance and to ensure availability of sufficient premium amount for the goods in transit.

xi) Expedite settlement of claims on the carriers/underwriters/suppliers.

xii) Arranging dispatch of materials to out-station suppliers or other units of the Organization.

xiii) Any other work connected with receiving and dispatch work.

2) **Custody, Warehousing and Inspections:**

These responsibilities include:

i) Receipt of materials from Receiving & Dispatch Group along with the unloading reports, checking of materials with the U.Rs. Arrange inspection and check measurement by user departments, Generation of Stores Receipt Voucher, Billing, Binning and Ledger posting updating of computer master.

ii) Issue of materials to user departments, complete issue documentation, ledger posting of Issue Vouchers/ updating of computer master.

iii) Receive the surplus materials from user departments, binning, posting and maintaining records of Stores Return Note and their accounting.

iv) Issue of materials for inter-unit transfer, preparation, posting and accounting of Stores Transfer Notes.

v) To plan and arrange preservation, storage and material handling facilities.

vi) Facilitate physical stock verification and reconciliation of discrepancies, if any. Preparing and posting of Adjustment Vouchers so as to bring the ground balance in line with book balance, when discrepancies are noticed.

vii) Receive scrap materials and facilitate disposal action including handing over of such materials to prospective buyers.

viii) Identify obsolete/surplus items and facilitate disposal action in association with Material Planning & Inventory Control Section.

ix) Custody of rejected materials and pursuing with the Suppliers for replacement of rejections/ damages/shortages.

x) Preferring claims with the Carriers/ Under Writers for non-delivery of the consignments and for damages and shortages.

3) Material Planning & Inventory Control:

This includes:

i) Identifying regularly/commonly used items with by and large stabilized consumption pattern and declaring them as stock items and fixing their minimum, maximum, reorder level and re-ordering quantities.

ii) Circulating the details of items declared stock items from time to time so that Purchase Requisitions are not raised by any department other than Stores.

iii) Keeping a watch on movement of stock items and raising Purchase Requisitions as soon as re-order levels are reached.

iv) Analyzing lead-times for various categories of items and co-ordination with purchasing for timely availability of materials.

v) Review of stock holding level from time to time keeping in view the consumption pattern, lead-time and criticality of each item.

vi) Ensuring that stocks are available for stock items all the times so as to win the confidence of user departments. In case of stock out of an item, supplies against pending orders, if any, shall be expedited. If any delays are anticipated, arrangement for emergency/cash purchase of the item shall be made to overcome the situation.

vii) Review of Purchase Requisitions of non-stock items from the user departments.

viii) Identification of non-moving, surplus and obsolete items and recommend for their disposal action.

ix) Identifying, defining, and describing all items of stores, including drawing up of specifications and unit of measurement to meet requirements of cataloging and computerization.

x) Rational codification of all the stores items, preparation and distribution of code catalogues.

xi) MIS of Stores Management- generation of various reports for management information and review.

xii) Coordination with Electronic Data Processing (EDP) Department for successful implementation of Computerized Stores Accounting System and interfacing with Price Stores Ledger and Purchase Management.

xiii) Any other job connected with Materials Planning & Inventory Control. For example for pricing store division plays active role and its involvement also helps in valuation of store items appropriately.

6.4.2 Stores Organization[29]:

Usually the two kinds of organizations are adopted in relation to stores as shown in chart below.

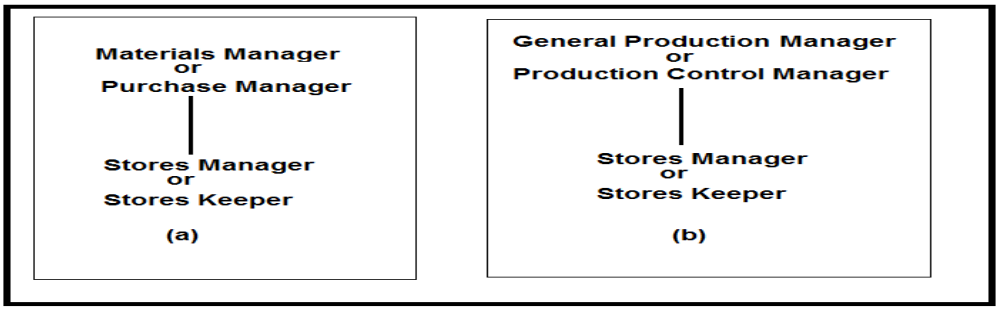


Figure 6.4.1: Stores organization structure

In type (a) organization the stores is considered to be a materials function more close to the receipt, and is clubbed with the purchasing and materials management department. This kind of arrangement is justified on the basis of following considerations:

(i) As the activity of stores are material oriented, it should report to a department whose primary interest lie in the materials and the related operations

(ii) From the total control point of view the receiving and the store activities should included with the rest of the materials activity. This facilitates the coordination among related materials activities from the stand-point of operations. Further, the interrelationships between stores, inventory control and purchase function will receive, proper attention in this type of organizational arrangement.

In type (b) organization the issue in the face of stores is considered to be more significant and thus it is clubbed with the production department. The arguments for such an organizational arrangement are as follows:

(i) In order to run the production operation smoothly the production management must have control over immediate material supply for stores. This will ensure the smooth delivery of materials to the production centers as and when required.

(ii) In order to avoid/discourage any kind of collusion and embezzlement of materials, the receiving and storing should be kept separate from the purchase department.

[29] IGNOU, "Management of Machines and Materials", Block6-Unit18

The objectives of the organizational decisions regarding stores cold be to store and manage the materials so that they are available in good conditions according to the need, to efficiently supply the materials according to production schedules, and to perform store functions at minimum cost.

Location and layout of stores:

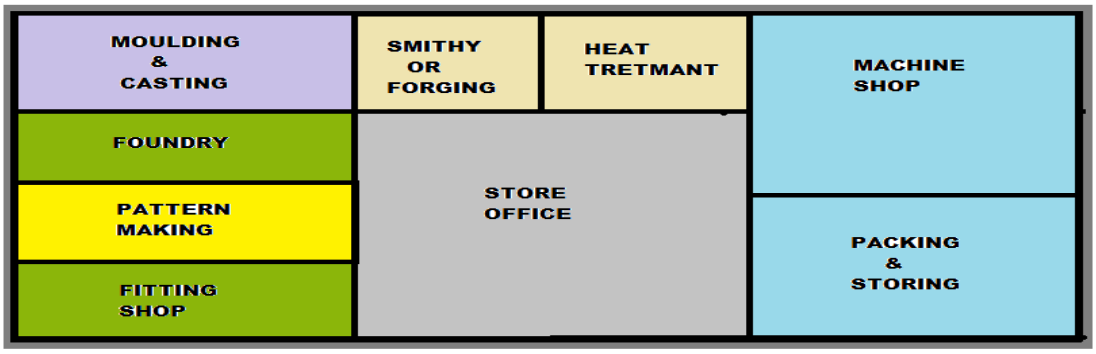
Generally, the storing facilities are provided in the form of a covered warehouse, sheds or even open yards. The size and the nature of storing facilities differ from company to company. The locations of the storage facility is important because it directly affects the material handling cost and the periodicity of the operating cycle, It is also considered in relation to the receiving point of the raw materials and the shipping point of the finished goods. The storage facilities should be located near the operating departments. However a reasonable distance must be maintained between the store and the plants.

There are certain items which must be stored separately e.g. items like explosives, inflammable materials, etc., should be segregated from main store. Gaseous item s like oxygen, argon, helium, acetylene, nitrogen, co_2, etc, should be stored under protective shed. Previous items, items requiring refrigerated storing or hot environment should be stored accordingly. Heavy machines and equipments should be located at such place where loading, unloading, mounting facilities are available.

The availability of total space and location of materials inside the store room should be taken into consideration while planning the layout of stores. Tine total space is decided on the basis of available floor area, containers, cabinets, racks, shelves, bins etc. While arranging the containers inside the stores room due consideration should be given to the materials handling facilities. Generally, Two – Way space is provided for the main path and one-way for side paths. The fast moving items should be stored in the nearby areas while the slow-moving items can be arranged in the remote interior areas. The arrangement of materials inside the storeroom also directly affects the material handling cost and the periodicity of the operating cycle.

Centralized and Decentralized stores:

The basic principle of store location is the minimization of handling, re-handling and internal transport, shortening of the journey distance and avoid back-tracking. In small industries it is desirable to centralize the materials so that they may be brought under the control of one store keeper. In this system the store room is located very near to the place of use. If there are number of manufacturing departments, the store-room should be situated such that it is near to all the departments as shown in figure



Centralised store

Figure 6.4.2: Centralized store example layout

This will reduce handling and enable to eliminate lot of manual operations. These types of stores are called centralized stores.

Advantages of Centralized stores:

(i) Large number of items can be purchased in one order, therefore, the firm can get quantity discount and there is a reduction in transportation cost.

(ii) Possibility of standardization of materials reducing the variety of items stored.

(iii) Less man power is required which reduces administrative cost.

(iv) Better security arrangements can be made to safeguard against pilferage and theft.

(v) Less storage space is required.

(vi) Optimum stores can be maintained.

(vii) Better layout of stores is possible.

(viii) Better supervision and control is possible.

Disadvantages of Centralized stores:

(i) There is an increase in material handling cost

(ii) There are chances of bottleneck and resultant delays.

(iii) More exposure to loss due to natural calamity like fire, rain, dust, etc.

(iv) Possibility of communication gap between the user of the item and its supplier.

Decentralized Store:

Decentralized stores are preferred in large factories, having different departments using different kinds of materials. In such case it is always beneficial to maintain different stores in different sections, for example, electrical store near electrical maintenance section, tools and equipments store near tool room, spare parts near maintenance section. Similarly, raw materials like sand, limestone, coke, iron ore and pig iron should be kept near the foundry shop.

Some items which are commonly required for all sections like soap, stationary, printed forms, cotton waste, lubricating oil, etc. should be kept at a convenient central place in central store. Decentralized store is shown in figure:

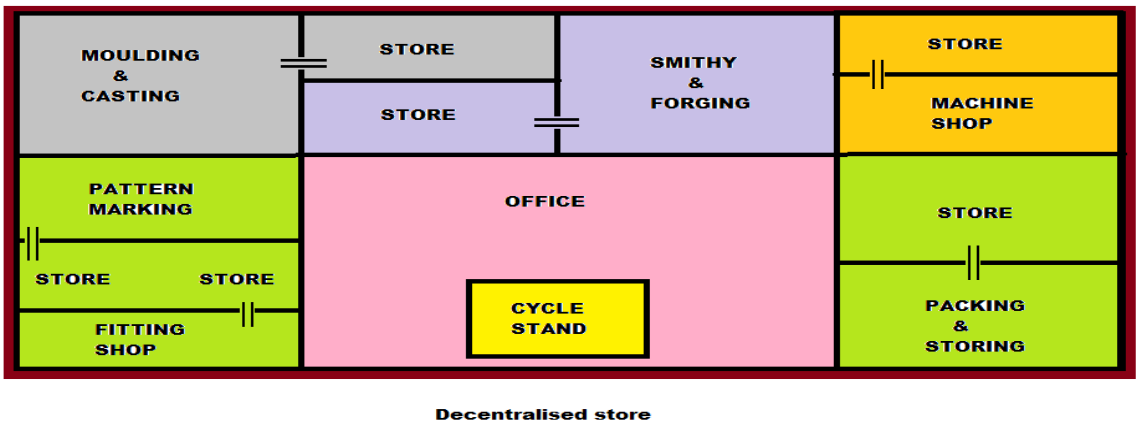


Figure 6.4.3: De-centralized store example layout

Advantages of Decentralized store:

(i) Reduced material handling and associated costs.

(ii) Less chance of bottlenecks and delays.

(iii) Less risk of loss by theft or fire.

(iv) Convenient for every department to draw materials.

6.5 Material Accounting, Flow of Cost and inventory valuation

Inventories are valued at year end and deducted from the cost of goods so as to ensure that only the cost of goods consumed or sold(COGS) during the accounting period is charged to the profit and loss account. One way to do this alternatively would be by identifying those goods which are consumed or sold and writing off such cost to the profit and loss account. The balance goods could be shown as assets at cost (stock) in the Balance Sheet.

The accounting method that a company decides to use to determine the costs of inventory can directly impact the balance sheet, income statement and statement of cash flow. There are three inventory-costing methods that are widely used by both public and private companies:

1. **First-In, First-Out (FIFO)**

This method assumes that the first unit making its way into inventory is the first sold. Consider for example a sheet metal component supplier produces on an average 5000 computer cabinets per week (approx. weight 100 kg, amount @Rs 50/- =Rs.5000/-of sheet metal), and does inventory assessment on the monthly basis. Suppose the cost of raw material, i.e. sheet metal rose to Rs.60/- and there is monthly purchase made for the months demand. Since he utilized the earlier inventory for this month demand therefore by FIFO approach the COGS is @Rs. 50/- per kg of sheet metal (recorded on the income statement) and the rate Rs.60/- would be allocated to ending inventory (appears on the balance sheet).

2. **Last-In, First-Out (LIFO)**

This method assumes that the last unit making its way into inventory is sold first. The older inventory, therefore, is assumed as left in stock at the end of the accounting period. For the 20000 cabinets supplied in the month, the same supplier would assign Rs.60/- per kg to COGS, while the remaining material in inventory would be used to calculate the value of inventory at the end of the period. Such practice helps in showing lesser profit on an annual basis, and is often tactics adopted by big players to avoid taxation for the time being.

3. **Average Cost**

This method takes the weighted average of all units available for sale during the accounting period and then uses that average cost to determine both the value of COGS and ending inventory. In our sheet metal supplier, assuming equal quantity bought each month the average cost for inventory would be (Rs50 +Rs.60/2) =Rs.55/-.

If inflation were nonexistent, then all three of the inventory valuation methods would produce the exact same results. But over the long term, prices tend to rise, and therefore the choice of accounting method play important role affecting valuation ratios.

If prices are rising, each of the accounting methods produce the following results:

- FIFO gives us a better indication of the value of ending inventory (on the balance sheet), but it also increases net income because inventory that might be several years old is used to value the cost of goods sold. Increasing net income sounds good, but it also has the potential to increase the amount of taxes that a company must pay.
- LIFO isn't a good indicator of ending inventory value because the leftover inventory might be extremely old and, perhaps, obsolete. This results in a valuation that is much lower than today's prices. LIFO results in lower net income because cost of goods sold is higher, and is often used as strategy to leverage tax.
- Average cost produces results that fall somewhere between FIFO and LIFO.

(Note: if prices are decreasing, then the complete opposite of the above is true.)

One thing to keep in mind is that companies are prevented from getting the best of both worlds. If a company uses LIFO valuation when it files taxes, which results in lower taxes when prices are increasing, it then must also use LIFO when it reports financial results to shareholders. This lowers net income and, ultimately, earnings per share.

Some issues related to Inventory Costing:

Typically, the cost of inventory would include not only its purchase price, but also various other costs such as transportation, duties, etc. However, to ensure that unrelated items are not added to the cost, the Finance &Accounting standard as laid by ICAI provides that only those costs that are incurred in bringing inventories to their present location and condition should be added. For example, selling and distribution costs are obviously not incurred, in the normal course, for bringing the inventories to their present location and hence are to be excluded. A controversial item is *interest on capital*. The argument for including interest in the cost of inventories is that where the production process is very long and capital is blocked for such period, it would be appropriate to add interest on such capital for the purpose of valuation. While this argument has some merit, interest is also seen to have remote connection with the production process. Permitting this may also enable companies find an additional technique of window dressing. The standard, therefore, frowns at this policy and provides that it should usually not be included.

An important change now is that the standard permits only two methods: First-in-First-out (FIFO) and weighted average cost. The controversial method of Last-in-First-out (LIFO) is now not permitted. The LIFO method reasoned that in days of high inflation, inventory prices are rising, and therefore it would be inappropriate to charge the lower cost of earlier purchases. Profits would be reflected fairly if the latest cost is charged. However, there were several arguments against also and, particularly the tax authorities generally disapproved this method. Only USA and Japan are the two countries still permitting LIFO, but very soon they will be phased out in demand of uniform global practices.

The use of standard cost method and retail method are also permitted if the value arrived by such methods approximate the actual cost.

The ICAI standard provides that inventories should be valued at the lower of cost or net realizable value. The method of determination of net realizable value has been provided for in great detail.

The standard recognizes the fact that specific identification method leaves scope for window dressing of accounts when the items are interchangeable. The entity could identify those items which have a higher (or lower) cost, as its suits it, to have the desired effect on the accounts. The accounting standard provides that where the items are interchangeable, the cost should be arrived at by the two recognized methods, as described above, only. The standard recognizes that items and components, which are not to be sold by the enterprises in that form, may have a lower realizable value. The standard accordingly provides that they may be valued at cost and not at their net realizable value if it is expected that the finished goods of which they would become part would realize at least the cost.

The standard also provides for valuation of by products and joint products as also of waste. When it is possible to identify and segregate the cost of the different joint or by products, this is permitted provided the allocation is done on a rational and consistent basis. However, whereby products or waste are immaterial in value, it is permitted that they can be valued at their net realizable value and this value in the deducted from the cost of the main product. The standard thus tackles the controversial area of inventory valuation, minimizes scopes for window dressing and provides for fewer standard methods of inventory valuation.

6.6 Security and Material Audits[30]

Any inventory of Raw materials, finished goods as well as Intermediate in process inventory has an economic value and is considered an asset in the books of the company. Accordingly any asset needs to be managed to ensure it is maintained properly and is stored in secure environment to avoid pilferage, loss or thefts etc.

[30] http://managementstudyguide.com/inventory-control.htm

Inventory control assumes significance on account of many factors.

First the inventory of raw materials as well as finished goods can run in thousands of SKU varieties. Secondly inventory can be in one location or spread over many locations. Thirdly inventory may be with the company or may be under the custody of a third party logistics provider. These factors necessitate inventory maintenance mechanisms to be devised to ensure inventory control.

Inventory control is also required as an operational process requirement. Inventory is has two different dimensions to it. On one level it is physical and involves physical transactions and movement of inventory. While on the other hand, inventory is recognizable by the book stock and the system stocks maintained. This necessitates inventory control mechanism to be implemented to ensure the book stocks and the physical stocks match at all times. Thirdly the inventory always moves through supply chain and goes through various transactions at various places. The number of transactions and handling that it goes through from the point of origin to the point of destination is numerous. Therefore it becomes essential to control inventory and have visibility through the pipeline including transit inventory.

Inventory control is exercised through inventory audits and cycle counts. An inventory audit essentially comprises of auditing the books stocks and transactions and matching physical stocks with the book stock.

Cycle counts: Cycle count refers to the process of counting inventory items available in physical locations. Depending upon the nature of inventory, number of transactions and the value of items, cycle count can be carried on periodically or perpetually.

1. **Daily Cycle Count:** Normally where the number of SKUs is very high coupled with high number of transactions and through put, daily cycle count is initiated, where in a certain percentage of locations or SKUs are counted on daily basis and physical stock is compared with system stock. By the end of the month all of the stocks would have been covered once in cycle count.

Inventory system throws up a count list based on an analysis of the movements of fast moving SKUs along with other attributes like value etc. In some of the system, inventory controllers can set up the attributes for each cycle count.

2. **Quarterly & Half Yearly Cycle Counts:** End of the sales quarter or end of half yearly sales, finished goods and spare parts are normally covered under inventory audit and a 100% cycle count is carried out.
3. **Wall to Wall Cycle Count:** End of financial year and closing of books entails doing wall to wall cycle count of all stocks lying in all locations and tallying with books of account. This is a mandatory audit requirement and until stock figures are reconciled, certified by auditors and published, New Year books of accounts cannot be started a fresh.

How the audit process works?

Except for daily cycle counts, all other cycle counts entail counting hundred percent of all the stocks by stopping all transactions during the counting period. System transactions are also frozen until the count is completed.

Inventory system throws up count list with SKU number, description and location number. The operator goes to the location, checks the SKU, counts the qty available and updates the list, which is then fed into the system. The system reconciles the physical quantity with system quantity and throws up discrepancy report, which is further worked upon to tally and adjust inventory.

6.7 Material Handling and Storage System[31]

Materials Handling may be regarded as the scientific method of analyzing of all handling and movement of materials. It should not be confused with mechanical handling, which is only one of the ways by which problem of material handling may be solved. It is the movement, storage, control and

[31] A.K. Datta, "Materials Management, Procedures, Text and Cases", Prentice- Hall of India, 1983

protection of materials, goods and products throughout the process of manufacturing, distribution, consumption and disposal. The focus is on the methods, mechanical equipment, systems and related controls used to achieve these functions. Handling merely adds to the cost of the e product without giving it any better value. Too much of handling of certain sensitive materials may even lead to wastage. In fact, in certain goods it may be estimated that the cost of handling from the source of raw materials to final distribution may be anything up to 70% of the total cost. The principle function of material handling should be aimed to eliminate unnecessary handling cost wherever possible and if storage cannot be done, to develop a method of improved handling scheme.

Better material handling is a valuable guide to waste elimination and cost reduction. The study of the following ratios may give a clear insight into its operating efficiency in a store. Usually there is a preliminary survey checklist which also gives a firsthand knowledge of material handling situation. Some important ratios:

(1) Material Handling Labour Ratio $= \frac{Personnel\ assigned\ to\ MH\ Duties}{Total\ operating\ work\ force}$

(2) Movement/Operating Ratio $= \frac{Total\ number\ of\ moves}{Total\ number\ of\ productive\ operations}$

(3) Direct Labour Handling Loss Ratio $= \frac{MH\ time\ lost\ by\ direct\ labour}{Total\ direct\ labour\ time}$

(4) Equipment Utilization Ratio $= \frac{Actual\ output}{Theoritical\ Capacity}$

After study of work movement and flow, analysis of work study data, space utilization, etc, the next step is to study what equipment should be installed. There are various groups such as:

(1) Conveyors:

(a) Gravity operated

(b) Hand operated

(i) Overhead

(ii) Monorails

(iii) Pulley Blocks, and

(iv) Light cranes

(2) Elevators

(a) Belt

(b) Chains, and

(c) Buckets

(3) Cranes

(a) Mobile, and

(b) Overhead travelling.

(4) Transporting and storing equipments

(a) Still-age, pallet hand trucks, platform trucks and Dollies, and

(b) Forklifts trucks and straddle trucks.

(5) Pneumatic fluidizing equipment: Tube types to convey pulverized materials such as cracking catalysts, cement, etc.

(6) Earth moving equipments

In modern handling methods forklift trucks have greater importance due to its better maneuverability and flexibility of operation. New attachment are regularly been designed so that practically anything can be handled thereby reducing considerable huge amount of handling costs. For example computer operated storage system and transport belts are common in computer industries.

Summarizing:

1. Elimination of all unnecessary handling and movements;
2. Planning of material handling for overall economy;
3. Reduction in movements of plants by relay out and keeping inventory of minimum;
4. Mechanization, wherever possible and use of simplest equipments
5. Standardization of handling equipments;
6. Seeing that equipments are fully used;

7. Aiming at an even flow of materials and balanced working of equipments;
8. Allowing for flexibility as a result of change in products, layout, etc;
9. Applying unit-load working for lower cost; and
10. Reviewing material handling constantly.

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