Master of Business Administration
(M.B.A.)

CP-204/MBA-204

PRODUCTION & OPERATIONS MANAGEMENT

Directorate of Distance Education
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Paper : Production & Operations Management **Code : CP-204**

Subject: Production and Operations Management

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LESSON: 1

Nature and scope of Production/Operations Management

Structure

1.0 OBJECTIVES

After going through this lesson, you will be able to:

1. **Define production and its role in the organization**
2. **Discuss historical origin of production/operation management**
3. **Explain different types of operating system**
4. **Describing the scope of production/operation management**

1.1 INTRODUCTION

Production/operations management is the process, which mingles and transforms various resources used in the production/operations subsystem of the organization into value added product/services in a controlled manner as per the policies of the organization. Therefore, it is that part of an organization, which is concerned with the transformation of a range of inputs into the required (products/services) having the requisite quality level.

The set of interrelated management activities, which are involved in manufacturing certain products, is called as **production management**. If the same concept is extended to services management, then the corresponding set of management activities is called as **operations management**.

1.2 ORIGIN OF PRODUCTION AND OPERATIONS MANAGEMENT

For over two centuries operations and production management has been recognized as an important factor in a country's economic growth. The traditional view of manufacturing management began in eighteenth century when **Adam Smith** recognized the economic benefits of specialization of labour. He recommended breaking of jobs down into subtasks and recognizes workers to specialized tasks in which they would become highly skilled and efficient. In the early twentieth century, F.W. Taylor implemented Smith's theories and developed scientific management. From then till 1930, many techniques were developed prevailing the traditional view. Brief information about the contributions to manufacturing management is shown in the Table 1.1.

TABLE 1.1 Evaluation Summary of Operations Management

Date	Contribution	Contributor
1776	Specialization of labour in manufacturing	Adam Smith
1799	Interchangeable parts, cost accounting	Eli Whitney and others
1832	Division of labour by skill; assignment of jobs by skill; basics of time study	Charles Babbage
1900	Scientific management time study and	Frederick W.

	work study developed; dividing planning and doing of work	Taylor
1900	Motion of study of jobs	Frank B. Gilbreth
1901	Scheduling techniques for employees, machines jobs in manufacturing	Henry L. Gantt
1915	Economic lot sizes for inventory control	F.W. Harris
1927	Human relations; the Hawthorne studies	Elton Mayo
1931	Statistical inference applied to product quality: quality control charts	W.A. Shewart
1935	Statistical sampling applied to quality control: inspection sampling plans	H.F. Dodge & H.G. Roming
1940	Operations research applications in World War II	P.M. Blacker and others
1946	Digital computer	John Mauchlly and J.P. Eckert
1947	Linear programming	G.B. Dantzig, Williams & others
1950	Mathematical programming, on-linear and stochastic processes	A. Charnes, W.W. Cooper
1951	Commercial digital computer: large-scale computations available.	Sperry Univac

1960	Organizational behaviour: continued study of people at work	Sperry Univac
1970	Integrating operations into overall strategy and policy, Computer applications to manufacturing, Scheduling and control, Material requirement planning (MRP)	W. Skinner J. Orlicky and G. Wright
1980	Quality and productivity applications from Japan: robotics, CAD-CAM	W.E. Deming and J. Juran

Source: Kumar and Suresh (2009). Operations Management, New Age International Publication.

Production management becomes the acceptable term from 1930s to 1950s. As F.W. Taylor's works become more widely known, managers developed techniques that focused on economic efficiency in manufacturing. Workers were studied in great detail to eliminate wasteful efforts and achieve greater efficiency. At the same time, psychologists, socialists' and other social scientists began to study people and human behaviour in the working environment. In addition, economists, mathematicians, and computer socialists contributed newer, more sophisticated analytical approaches.

With the 1970s emerge two distinct changes. The most obvious of these, reflected in the new name **operations**

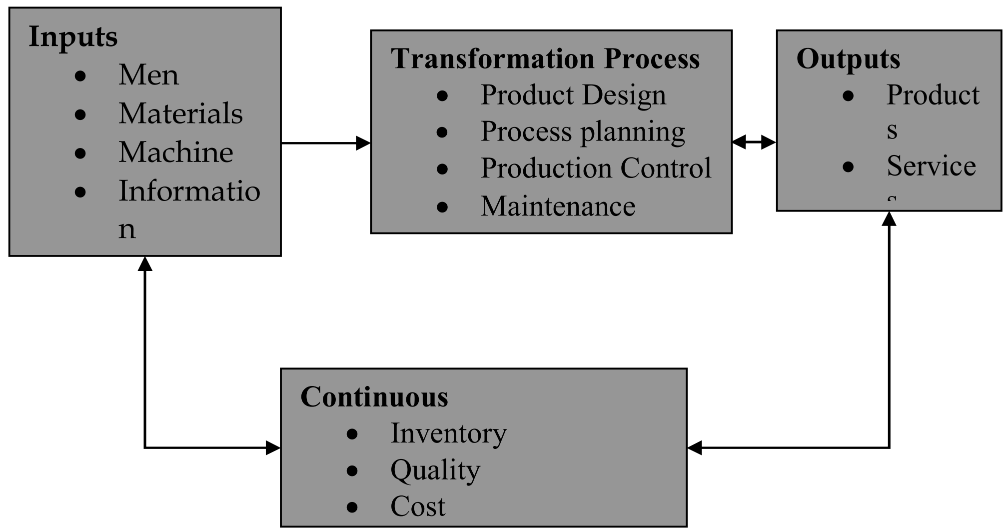
management was a shift in the service and manufacturing sectors of the economy. As service sector became more prominent, the change from 'production' to 'operations' emphasized the broadening of field to service organizations. The second, more suitable change was the beginning of an emphasis on synthesis, rather than just analysis, in management practices.

1.3 CONCEPT OF PRODUCTION

Production function is that part of an organization, which is concerned with the transformation of a range of inputs into the required outputs (products) having the requisite quality level.

Production is defined as "the step-by-step conversion of one form of material into another form through chemical or mechanical process to create or enhance the utility of the product to the user." Thus production is a value addition process. At each stage of processing, there will be value addition.

Edwood Buffa defines production as 'a process by which goods and services are created'. Some examples of production are: manufacturing custom-made products like, boilers with a specific capacity, constructing flats, some structural fabrication works for selected customers, etc., and manufacturing standardized products like, car, bus, motor cycle, radio, television, etc.



Environment

Feedback Information

Fig. 1.1 Schematic production system

1.4 PRODUCTION SYSTEM

The production system of an organization is that part, which produces products of an organization. It is that activity whereby resources, flowing within a defined system, are combined and transformed in a controlled manner to add value in accordance with the policies communicated by management. A simplified production system is shown above.

The production system has the following characteristics:

1. Production is an organized activity, so every production system has an objective.

2. The system transforms the various inputs to useful outputs.
3. It does not operate in isolation from the other organization system.
4. There exists a feedback about the activities, which is essential to control and improve system performance.

CLASSIFICATION OF PRODUCTION SYSTEM

Production systems can be classified as Job Shop, Batch, Mass and Continuous Production systems.

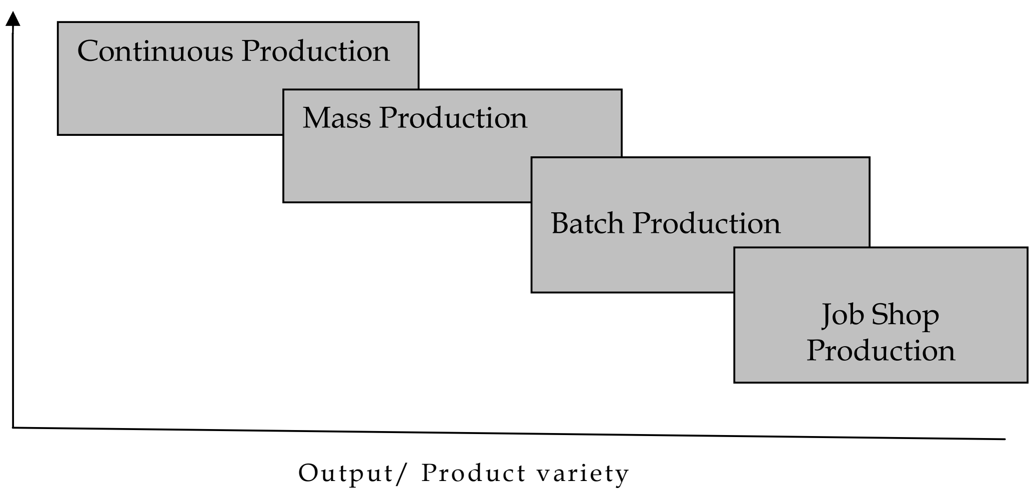


Fig. 1.2 Classification of production systems

Job Shop Production

Job shop production are characterized by manufacturing of one or few quantity of products designed and produced as per the specification of customers within prefixed time and cost. The distinguishing feature of this is low volume and high variety of products.

A job shop comprises of general purpose machines arranged into different departments. Each job demands unique technological requirements, demands processing on machines in a certain sequence.

Batch Production

Batch production is defined by American Production and Inventory Control Society (APICS) "as a form of manufacturing in which the job passes through the functional departments in lots or batches and each lot may have a different routing." It is characterized by the manufacture of limited number of products produced at regular intervals and stocked awaiting sales.

Mass Production

Manufacture of discrete parts or assemblies using a continuous process are called mass production. This production system is justified by very large volume of production. The machines are arranged in a line or product layout. Product and process standardization exists and all outputs follow the same path

Continuous Production

Production facilities are arranged as per the sequence of production operations from the first operations to the finished product. The items are made to flow through the sequence of operations through material handling devices such as conveyors, transfer devices, etc.

1.5 PRODUCTION MANAGEMENT

Production management is a process of planning, organizing, directing and controlling the activities of the production function. It combines and transforms various resources used in the production subsystem of the organization into value added product in a controlled manner as per the policies of the organization.

E. S. Buffa defines production management as, "**Production management** deals with decision making related to production processes so that the resulting goods or services are produced according to specifications, in the amount and by the schedule demanded and out of minimum cost."

1.5.1 OBJECTIVES OF PRODUCTION MANAGEMENT

The objective of the production management is 'to produce goods services of right quality and quantity at the right time and right manufacturing cost'.

1. Right Quality

The quality of product is established based upon the customers needs. The right quality is not necessarily best quality. It is determined by the cost of the product and the technical characteristics as suited to the specific requirements.

2. Right Quantity

The manufacturing organization should produce the products in right number. If they are produced in excess of demand the capital will block up in the form of inventory and if the quantity is produced in short of demand, leads to shortage of products.

3. Right Time

Timeliness of delivery is one of the important parameter to judge the effectiveness of production department. So, the production department has to make the optimal utilization of input resources to achieve its objective.

4. Right Manufacturing Cost

Manufacturing costs are established before the product is actually manufactured. Hence, all attempts should be made to produce the products at pre-established cost, so as to reduce the variation between actual and the standard (pre-established) cost.

1.6 OPERATING SYSTEM

Operating system converts inputs in order to provide outputs which are required by a customer. It converts physical resources into outputs, the function of which is to satisfy customer wants i.e., to provide some utility for the customer. In some of the organization the product is a physical good (hotels) while in others it is a service (hospitals). Bus and taxi services, tailors, hospital and builders are the examples of an operating system.

Everett E. Adam & Ronald J. Ebert define operating system as, "An operating system (function) of an organization is the part of an organization that produces the organization's physical goods and services."

Ray Wild defines operating system as, "An operating system is a configuration of resources combined for the provision of goods or services."

1.6.1 Concept of Operations

An operation is defined in terms of the mission it serves for the organization, technology it employs and the human and managerial processes it involves. Operations in an organization can be categorized into manufacturing operations and service operations. Manufacturing operations is a conversion process that includes manufacturing yields a tangible output: a product, whereas, a conversion process that includes service yields an intangible output: a deed, a performance, an effort.

1.6.2 Distinction between Manufacturing Operations and Service Operations

Following characteristics can be considered for distinguishing manufacturing operations with service operations:

1. Tangible/Intangible nature of output
2. Consumption of output
3. Nature of work (job)
4. Degree of customer contact
5. Customer participation in conversion
6. Measurement of performance.

Manufacturing is characterized by tangible outputs (products), outputs that customers consume overtime, jobs that use less labour and more equipment, little customer contact, no customer participation in the conversion process (in production), and sophisticated methods for measuring production activities and resource consumption as product are made.

Service is characterized by intangible outputs, outputs that customers consumes immediately, jobs that use more labour and less equipment, direct consumer contact, frequent customer participation in the conversion process, and elementary methods for measuring conversion activities and resource consumption. Some services are equipment based namely rail-road services, telephone services and some are people based namely tax consultant services, hair styling.

1.7 OPERATIONS MANAGEMENT

1.7.1 A Framework for Managing Operations

Managing operations can be enclosed in a frame of general management function as shown in Fig. 1.3. Operation managers are concerned with planning, organizing, and controlling the activities which affect human behaviour through models.

PLANNING: Activities that establishes a course of action and guide future decision-making is planning. The operations manager defines the objectives for the operations subsystem of the organization, and the policies, and procedures for achieving the objectives. This stage includes clarifying the role and focus of operations in the organization's overall strategy. It also involves product planning, facility designing and using the conversion process.

ORGANIZING: Activities that establishes a structure of tasks and authority. Operation managers establish a structure of roles and the flow of information within the operations subsystem. They determine the activities required to achieve the goals and assign authority and responsibility for carrying them out.

CONTROLLING: Activities that assure the actual performance in accordance with planned performance. To ensure that the plans for the operations subsystems are accomplished, the operations manager must exercise control by measuring actual outputs and comparing them to planned operations management. Controlling costs, quality, and schedules are the important functions here.

BEHAVIOUR: Operation managers are concerned with how their efforts to plan, organize, and control affect human behaviour. They also want to know how the behaviour of subordinates can affect management's planning, organizing, and controlling actions. Their interest lies in decision-making behaviour.

MODELS: As operation managers plan, organize, and control the conversion process, they encounter many problems and must make many decisions. They can simplify their difficulties using models like aggregate planning models for examining how best to use existing capacity in short-term, break even analysis to identify break even volumes, linear programming and computer simulation for capacity utilization, decision tree analysis for long-term capacity problem of facility expansion, simple median model for determining best locations of facilities etc.

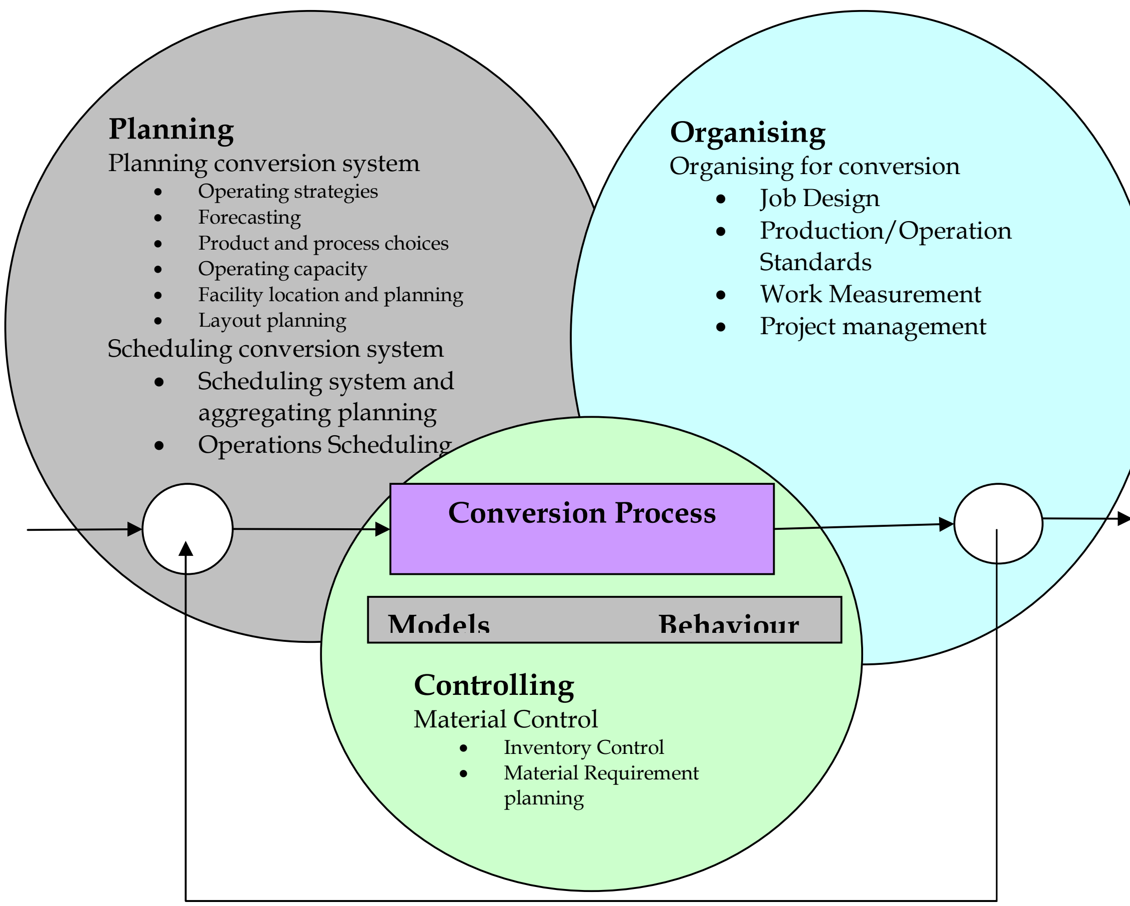


Fig. 1.3 General model for managing operations

Objectives of Operations Management

Objectives of operations management can be categorized into customer service and resource utilization.

CUSTOMER SERVICE

The first objective of operating systems is the customer service to the satisfaction of customer wants. Therefore, customer service is a key objective of operations management. The operating system must provide something to a specification which can satisfy the customer in terms of cost and timing. Thus, primary objective can be satisfied by providing the 'right thing at a right price at the right time'.

These aspects of customer service—specification, cost and timing—are described for four functions in Table 1.2. They are the principal sources of customer satisfaction and must, therefore, be the principal dimension of the customer service objective for operations managers.

TABLE 1.2 Aspects of customer service

Principal functions	Principal Customer wants	
	Primary considerations	**Other considerations**
Manufacture	Goods of a given, requested or acceptable specification.	Cost, i.e., purchase price or cost of obtaining goods. Timing, i.e., delivery delay from order or request to receipt of goods.
Transport	Management of a given, requested or acceptable specification.	Cost, i.e., cost of movements. Timing, i.e., 1. Duration or time to move. 2. Wait or delay from requesting to its commencement
Supply	Goods of a given, requested or acceptable specification.	Cost, i.e., purchase price or cost of obtaining goods. Timing, i.e., delivery delay from order or request to receipt of goods.
Service	Treatment of a given, requested or acceptable specification.	Cost, i.e., cost of movements. Timing, i.e.,

Generally an organization will aim reliably and consistently to achieve certain standards and operations manager will be influential in attempting to achieve these standards. Hence, this objective will influence the operations manager's decisions to achieve the required customer service.

RESOURCE UTILISATION

Another major objective of operating systems is to utilize resources for the satisfaction of customer wants effectively, i.e., customer service must be provided with the achievement of effective operations through efficient use of resources. Inefficient use of resources or inadequate customer service leads to commercial failure of an operating system.

Operations management is concerned essentially with the utilization of resources, i.e., obtaining maximum effect from resources or minimizing their loss, under utilization or waste. The extent of the utilization of the resources' potential might be expressed in terms of the proportion of available time used or occupied, space utilization, levels of activity, etc. Each measure indicates the extent to which the potential or capacity of such resources is utilized. This is referred as the objective of resource utilization.

Operations management is also concerned with the achievement of both satisfactory customer service and resource utilization. An improvement in one will often give rise to deterioration in the other. Often both cannot be maximized, and hence a satisfactory performance must be achieved on both objectives. All the activities of operations management must be tackled with these two objectives in mind, and many of the problems will be faced by operations managers because of this conflict. Hence, operations managers must attempt to balance these basic objectives.

Table 1.3 summarizes the twin objectives of operations management. The type of balance established both between and within these basic objectives will be influenced by market considerations, competitions, the strengths and weaknesses of the organization, etc. Hence, the operations managers should make a contribution when these objectives are set.

TABLE 1.3: The Twin Objectives of Operations Management

The customer service objective. To provide agreed/adequate levels of customer service (and hence customer satisfaction) by providing goods or services with the right specification, at the right cost	**The resource utilization objective.** To achieve adequate levels of resource utilisation (or productivity) e.g., to achieve agreed levels of utilization of materials, machines and labour.

1.8 SCOPE OF PRODUCTION AND OPERATIONS MANAGEMENT

Production and operations management concerns with the conversion of inputs into outputs, using physical resources, so as to provide the desired utilities to the customer, while meeting the other organizational objectives of effectiveness, efficiency and adoptability. It distinguishes itself from other functions such as personnel, marketing, finance, etc., by its primary concern for 'conversion by using physical resources.' Following are the activities which are listed under production and operations management functions:

1. Location of facilities
2. Plant layouts and material handling
3. Product design
4. Process design
5. Production and planning control
6. Quality control
7. Materials management
8. Maintenance management.

LOCATION OF FACILITIES

Location of facilities for operations is a long-term capacity decision which involves a long term commitment about the geographically static factors that affect a business organization. It is an important strategic level decision-making for an organization. It deals with the questions such as where our main operations should be based.

The selection of location is a key-decision as large investment is made in building plant and machinery. An improper location of plant may lead to waste of all the investments made in plant and machinery equipments. Hence, location of plant should be based on the company's expansion plan and policy, diversification plan for the products, changing sources of raw materials and many other factors. The purpose of the location study is to find the optimal location that will results in the greatest advantage to the organization.

PLANT LAYOUT AND MATERIAL HANDLING

Plant layout refers to the physical arrangement of facilities. It is the configuration of departments, work centers and equipment in the conversion process. The overall objective of the plant layout is to design a physical arrangement that meets the required output quality and quantity most economically.

According to **James Moore,** "Plant layout is a plan of an optimum arrangement of facilities including personnel, operating equipment, storage space, material handling equipments and all other supporting services along with the design of best structure to contain all these facilities".

'Material Handling' refers to the 'moving of materials from the store room to the machine and from one machine to the next during the process of manufacture. It is also defined as the art and science of moving, packing and storing of products in any form. It is a specialized activity for a modern manufacturing concern, with significant of the cost of production. This cost can be reduced by proper section, operation and maintenance of material handling devices. Material handling devices increases the output, improves quality, speeds up the deliveries and decreases the cost of production. Hence, material handling is a prime consideration in the designing new plant and several existing plants

PRODUCT DESIGN

Product design deals with conversion of ideas into reality. Every business organization has to design, develop and introduce new products as a survival and growth strategy. Developing the new products and launching them in the market is the biggest challenge faced by the organizations. The entire process of need identification to physical manufactures of product involves three functions: marketing, product development, and manufacturing. Product development translates the needs of customers given by marketing into technical specifications and designing the various features into the product to these specifications. Manufacturing has the responsibility of selecting the processes by which the product can be manufactured. Product design and development provides link between marketing, customer needs and expectations and the activities required to manufacture the product.

PROCESS DESIGN

Process design is a macroscopic decision-making of an overall process route for converting the raw material into finished goods. These decisions encompass the selection of a process, choice of technology, process flow analysis and layout of the facilities. Hence, the important decisions in process design are to analyze the workflow for converting raw material into finished product and to select the workstation for each included in the workflow.

PRODUCTION PLANNING AND CONTROL

Production planning and control can be defined as the process of planning the production in advance, setting the exact route of each item, fixing the starting and finishing dates for each item, to give production orders to shops and to follow up the progress of products according to orders.

The principle of production planning and control lies in the statement 'First Plan Your Work and then Work on Your Plan'. Main functions of production planning and control includes planning, routing, scheduling, dispatching and follow-up.

Planning is deciding in advance what to do, how to do it, when to do it and who is to do it. Planning bridges the gap from where we are, to where we want to go. It makes it possible for things to occur which would not otherwise happen.

Routing may be defined as the selection of path which each part of the product will follow, which being transformed from raw material to finished products. Routing determines the most advantageous path to be followed from department to department and machine to machine till raw material gets its final shape.

Scheduling determines the programme for the operations. Scheduling may be defined as the fixation of time and date for each operation' as well as it determines the sequence of operations to be followed.

Dispatching is concerned with the starting the processes. It gives necessary authority so as to start a particular work, which has already been planned under 'Routing' and 'Scheduling'. Therefore, dispatching is 'release of orders and instruction for the starting of production for any item in acceptance with the route sheet and schedule charts'.

The function of **follow-up** is to report daily the progress of work in each shop in a prescribed Performa and to investigate the causes of deviations from the planned performance.

QUALITY CONTROL

Quality Control (QC) may be defined as a system that is used to maintain a desired level of quality in a product or service. It is a systematic control of various factors that affect the quality of the product. Quality control aims at prevention of defects at the source, relies on effective feed back system and corrective action procedure.

Quality control can also be defined as 'that industrial management technique by means of which product of uniform acceptable quality is manufactured'. It is the entire collection of activities which ensures that the operation will produce the optimum quality products at minimum cost.

The main objectives of quality control are:

- To improve the companies income by making the production more acceptable to the customers i.e., by providing long life, greater usefulness, maintainability, etc.
- To reduce companies cost through reduction of losses due to defects.
- To achieve interchangeability of manufacture in large scale production.
- To produce optimal quality at reduced price.

- To ensure satisfaction of customers with productions or services or high quality level, to build customer goodwill, confidence and reputation of manufacturer.
- To make inspection prompt to ensure quality control. To check the variation during manufacturing.

MATERIALS MANAGEMENT

Materials management is that aspect of management function which is primarily concerned with the acquisition, control and use of materials needed and flow of goods and services connected with the production process having some predetermined objectives in view.

The main objectives of materials management are:

- To minimize material cost.
- To purchase, receive, transport and store materials efficiently and to reduce the related cost.
- To cut down costs through simplification, standardization, value analysis, import substitution, etc.
- To trace new sources of supply and to develop cordial relations with them in order to ensure continuous supply at reasonable rates.

- To reduce investment tied in the inventories for use in other productive purposes and to develop high inventory turnover ratios.

MAINTENANCE MANAGEMENT

In modern industry, equipment and machinery are a very important part of the total productive effort. Therefore, their idleness or downtime becomes very expensive. Hence, it is very important that the plant machinery should be properly maintained.

The main objectives of maintenance management are:

- To achieve minimum breakdown and to keep the plant in good working condition at the lowest possible cost.
- To keep the machines and other facilities in such a condition that permits them to be used at their optimal capacity without interruption.
- To ensure the availability of the machines, buildings and services required by other sections of the factory for the performance of their functions at optimal return on investment.

1.9 SUMMARY

The chapter depicts the meaning, nature, and scope of production/operation management. It also traces the origin of production/operation management as field of study. It also reviews the different types of production systems. It also outlines the objectives of production/operation management.

1.10 KEYWORDS

Production: Conversion of input-men, machine, materials, money, methods, and management into output through the transformation process.

Planning: Predefined future course of action.

Organizing: All activities that establish a structure of tasks and authorities.

Controlling: All course of action that ensures the actual performance is in accordance with established standards.

1.11 SELF ASSESSMENT QUESTIONS

1. Explain the different types of production systems.

2. Explain the framework of managing operations.

3. Explain the scope of production and operations management

4. Briefly explain the production system and its characteristics.

5. Distinguish between manufacturing operations and service operations.

1.12 FURTHER READINGS AND SOURCES

Buffa Elwood S., Operations Management, New Delhi: Wiley Eastern, 1986

Chase, Richard B., and Eric L. Prentis "Operation Management: A Field Rediscovered" Journal of Management, 13(2), Oct. 1987, pp 351-366.

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Subject: Production and Operations Management

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Course: MBA Course Code: CP-204

LESSON: 2

Facilities Location/Plant Layout

Structure

2.0 OBJECTIVES

After going through this lesson, you will be able to:

1. **Define facilities Location Defined**
2. **Understand Significance of Facilities Location**
3. **Put thought on Issues in Plant location**
4. **Analyze the Locational factors**
5. **Understand the Methods of facilities Locations**

2.1 INTRODUCTION

Facilities location deals with the questions such as "where our main operations should be based? Should it be Punjab, Utter Pradesh, Maharashtra, Himachal Pardesh, or Haryana? If Haryana is a close second to Delhi, should the operational facilities be located at Faridabad which is in Haryana but is proximate to Delhi? The success of location decision both affects and is affected by organising and control activities. Since the operation manger fixes many costs with the location decision, both efficiency and effectiveness of the conversion process are dependent upon location. This lesson deals with various aspects of plant location and layout. It analyzing the aspects of plant location and the appropriate plant layout can help an organization achieve economic efficiencies in business operations.

2.2 FACILITIES LOCATION DEFINED

Every organization is faced with the problem of deciding the best site for location of his plant or factory.

What is plant location?

Plant location refers to the choice of region and the selection of a particular site for setting up a business or factory.

But the choice is made only after considering cost and benefits of different alternative sites. It is a strategic decision that cannot be changed once taken. If at all changed only at considerable loss, the location should be selected as per its own requirements and circumstances. Each individual plant is a case in itself. Operation manager should try to make an attempt for optimum or ideal location.

What is an ideal location?

An ideal location is one where the cost of the product is kept to minimum, with a large market share, the least risk and the maximum social gain. It is the place of maximum net advantage or which gives lowest unit cost of production and distribution. For achieving this objective, organization can make use of locational analysis for this purpose.

2.3 SIGNIFICANCE OF FACILITIES LOCATION

From the discussion above, we have already learnt that location of a plant is an important organizational decision because it influences the cost of production and distribution to a great extent. In some cases, you will find that location may contribute to even 10% of cost of manufacturing and marketing. Therefore, an appropriate location is essential to the efficient and economical working of a plant. A firm may fail due to bad location or its growth and efficiency may be restricted.

2.4 ISSUES IN FACILITY LOCATION

The problem of facility location is faced by both new and existing businesses, and its solution is critical to a company's eventual success. When the site selection process is initiated, the pool of potential locations for a manufacturing or services facilities is, literally, global, or domestic is considered. In the following discussion we identify some of the important factors that influence manufacturing and services facilities location.

Proximity to Customers: For example, Japan's NatSteel Electronics has built its two largest plants in Mexico and Hungary to be closer to major markets in the United States and Europe—whose buyers want their goods delivered yesterday. Such proximity also helps ensure that customer needs are incorporated into products being developed and built.

Business Climate: A favorable business climate can include the presence of similar-sized businesses, the presence of companies in the same industry, and, in the case of international locations, and the presence of other foreign companies. Pro-business government legislation and local government intervention to facilitate businesses locating in an area via subsidies, tax abatements, and other support are also factors.

Total Costs: The objective is to select a site with the lowest total cost. This includes regional costs, inbound distribution costs, and outbound distribution costs. Land, construction, labor, taxes, and energy costs make up the regional costs. In addition, there are hidden costs that are difficult to measure. These involve (1) excessive moving of preproduction material between locations before final delivery to the customers and (2) loss of customer responsiveness arising from locating away from the main customer base.

Infrastructure: Adequate road, rail, air, and sea transportation are vital. Energy and telecommunications requirements also must be met. In addition, the local government's willingness to invest in upgrading infrastructure to the levels required may be an incentive to select a specific location.

Quality of Labor: The educational and skill levels of the labor pool must match the company's needs. Even more important are the willingness and ability to learn.

Suppliers: A high-quality and competitive supplier base makes a given location suit- able. The proximity of important suppliers' plants also supports lean production methods.

Free Trade Zones: A foreign trade zone or a **free trade zone** is typically a closed facility (under the supervision of the customs department) into which foreign goods can be brought without being subject to the normal customs requirements. There are about 170 such free trade zones in the United States today. Such specialized locations also exist in other countries. Manufacturers in free trade zones can use imported components in the final product and delay payment of customs duties until the product is shipped into the host country.

Political Risk: The fast-changing geopolitical scenes in numerous nations present exciting, challenging opportunities. But the extended phase of transformation that many countries are undergoing makes the decision to locate in those areas extremely difficult. Political risks in both the country of location and the host country influence location decisions.

Government Barriers: Barriers to enter and locate in many countries are being removed today through legislation. Yet many non-legislative and cultural barriers should be considered in location planning.

Trading Blocs: The world of **trading blocs** gained a new member with the ratification of the North American Free Trade Agreement (NAFTA). Such agreements influence location decisions, both within and outside trading bloc countries. Firms typically locate, or relocate, within a bloc to take advantage of new market opportunities or lower total costs afforded by the trading agreement. Other companies (those outside the trading bloc countries) decide on locations within the bloc so as not to be disqualified from competing in the new market. Examples include the location of various Japanese auto manufacturing plants in Europe before 1992 as well as recent moves by many communications and financial ser- vices companies into Mexico in a post-NAFTA environment.

Environmental Regulation: The environmental regulations that impact a certain industry in a given location should be included in the location decision. Besides measurable cost implications, these regulations influence the relationship with the local community.

Host Community: The host community's interest in having the plant in its midst is a necessary part of the evaluation process. Local educational facilities and the broader issue of quality of life are also important.

Competitive Advantage: An important decision for multinational companies is the nation in which to locate the home base for each distinct business. Porter suggests that a company can have different home bases for distinct businesses or segments. Competitive advantage is created at a home base where strategy is set, the core product and process technology are created, and a critical mass of production takes place. So a company should move its home base to a country that stimulates innovation and provides the best environment for global competitiveness. This concept can also be applied to domestic companies seeking to gain sustainable competitive advantage. It partly explains the southeastern states' recent emergence as the preferred corporate destination within the United States (that is, their business climate fosters innovation and low-cost production).

Other Facilities: The location of other plants or distribution centers of the same company may influence a new facility's location in the network. Issues of product mix and capacity are strongly interconnected to the location decision in this context.

Local Considerations:

a) Natural or climatic conditions.

b) Availability and nearness to the sources of raw material.

c) Transport costs-in obtaining raw material and also distribution or marketing finished products to the ultimate users.

d) Access to market: small businesses in retail or wholesale or services should be located within the vicinity of densely populated areas.

e) Availability of Infrastructural facilities such as developed industrial sheds or sites, link roads, nearness to railway stations, airports or sea ports, availability of electricity, water, public utilities, civil amenities and means of communication are important, especially for small scale businesses.

f) Availability of skilled and non-skilled labour and technically qualified and trained managers.

g) Banking and financial institutions are located nearby.

h) Locations with links: to develop industrial areas or business centers result in savings and cost reductions in transport overheads, miscellaneous expenses.

i) Strategic considerations of safety and security should be given due importance.

j) Government influences: Both positive and negative incentives to motivate firms to choose a particular location are made available. Positive includes cheap overhead facilities like electricity, banking transport, tax relief, subsidies and liberalization. Negative incentives are in form of restrictions for setting up industries in urban areas for reasons of pollution control and decentralization of industries.

2.5 LOCATIONAL ANALYSIS

Locational analysis is a dynamic process where firm analyses and compares the appropriateness or otherwise of alternative sites with the aim of selecting the best site for a given enterprise. It consists the following:

(a) Demographic Analysis: It involves study of population in the area in terms of total population (in no.), age composition, per capita income, educational level, occupational structure etc.

(b) Trade Area Analysis: It is an analysis of the geographic area that provides continued clientele to the firm. He would also see the feasibility of accessing the trade area from alternative sites.

(c) Competitive Analysis: It helps to judge the nature, location, size and quality of competition in a given trade area.

(d) Traffic analysis: To have a rough idea about the number of potential customers passing by the proposed site during the working hours of the shop, the traffic analysis aims at judging the alternative sites in terms of pedestrian and vehicular traffic passing a site.

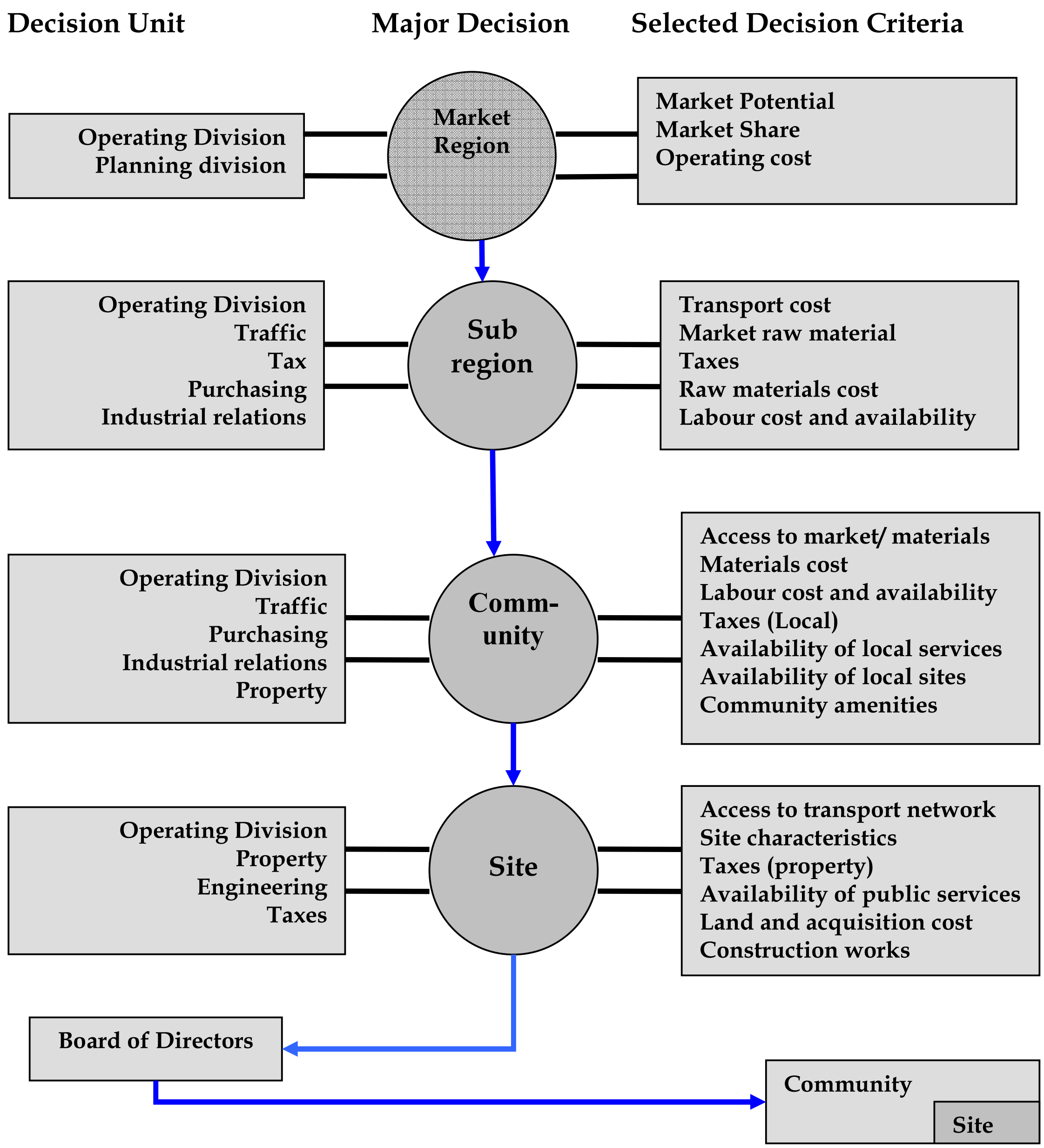
(e) Site economics: Alternative sites are evaluated in terms of establishment costs and operational costs under this. Costs of establishment is basically cost incurred for permanent physical facilities but operational costs are incurred for running business on day to day basis, they are also called as running costs.

2.6 PLANT LOCATION METHODS

Figure 2.1 summarizes the set of decisions that a company must make in choosing a plant location. Although the figure implies a step-by-step process, virtually all activities listed take place simultaneously.

As suggested by the preceding discussion, political decisions may occasionally override systematic analysis.

Evaluation of alternative regions, sub-regions, and communities is commonly termed *macro analysis.* Evaluation of specific sites in the selected community is termed *micro analysis.* Techniques used to support macro analyses include factor-rating systems, linear programming, and centroid method. A detailed cost analysis would accompany each of these methods, and they must, of course, be related to business strategy.



Source: T. M. Carroll And R. D. Dean, "A Bayesian Approach To Plant-Location Decisions," Decision Sciences 11, No. 1(January 1980), P. 87. Copyright © 1980 Decision Sciences. Reprinted By Permission of Decision Sciences Institute, Located At Georgia State University, Atlanta, Ga.

Figure-2.1

2.6.1 FACTOR RATING SYSTEMS

Factor-rating systems are perhaps the most widely used of the general location techniques because they provide a mechanism to combine diverse factors in an easy-to-understand format.

By way of example, a refinery assigned the following range of point values to major factors affecting a set of possible sites

	Range
Fuel in region	0 to 300
Power availability and reliability	0 to 200
Labour climate	0 to 100
Living conditions	0 to 100
Transportation	0 to 50
Water supply	0 to 10
Climate	0 to 50
Supplier	0 to 60
Tax policy and laws	0 to 20

Each site was then rated against each factor, and a point value was selected from its as signed range. The sums of assigned points for each site were then compared. The site with the most points was selected.

A major problem with simple point-rating schemes is that they do not account for the wide range of costs that may occur within each factor. For example, there may be only a few hundred rupees difference between the best and worst locations on one factor and several thousands of rupees difference between the best and the worst on another. The first factor may have the most points available to it but provide little help in making the location decision; the second may have few points available but potentially show a real difference in the value of locations. To deal with this problem, it has been suggested that points possible for each factor be derived using a weighting scale based on standard deviations of costs rather than simply total cost amounts. In this way, relative costs can be considered.

2.6.2 TRANSPORTAT ION METHOD OF LINEAR PROGRAMMING

The transportation method is a special linear programming method. It gets its name from its application to problems involving transporting products from several sources to several destinations. The two common objectives of such problems are either

(1) Minimize the cost of shipping n units to m destinations or

(2) Maximize the profit of shipping n units to m destinations

EXAMPLE 2.1 Indian Pharmaceutical Co.

Suppose the Indian Pharmaceutical Company has four factories supplying the warehouses of four major customers and its management wants to determine the minimum cost shipping schedule for its monthly output to these customers. Factory supply, warehouse demands, and shipping costs per case for these drugs are shown in table 2.1.

Table 2.1 (a)

Factory	Supply	Warehouse	Demand
Delhi	15	**Bangalore**	10
Rohtak	6	**Mumbai**	12
Hisar	14	**Kochi**	15
Kurukshetra	11	**Shilong**	9

Table 2.1 (b)

Shipping Cost per Case (in Rupees)

From	To Bangalore	To Mumbai	To Kochi	To Shilong
Delhi	25	35	36	60
Rohtak	55	30	25	25
Hisar	40	50	80	90

To / From	Bangalore	Mumbai	Kochi	Shilong	Supply
Delhi	25	35	**15** 36	60	**15**
Rohtak	55	30	25	**6** 25	**6**

Hisar	2 40	12 50	80	90	**14**
Kurukshetra	8 30	40	66	3 75	**11**
Demand	**10**	**12**	**15**	**9**	**46/46**

Kurukshetra 30 40 66 75

Table 2.2 Solution Indian Pharmaceutical Company

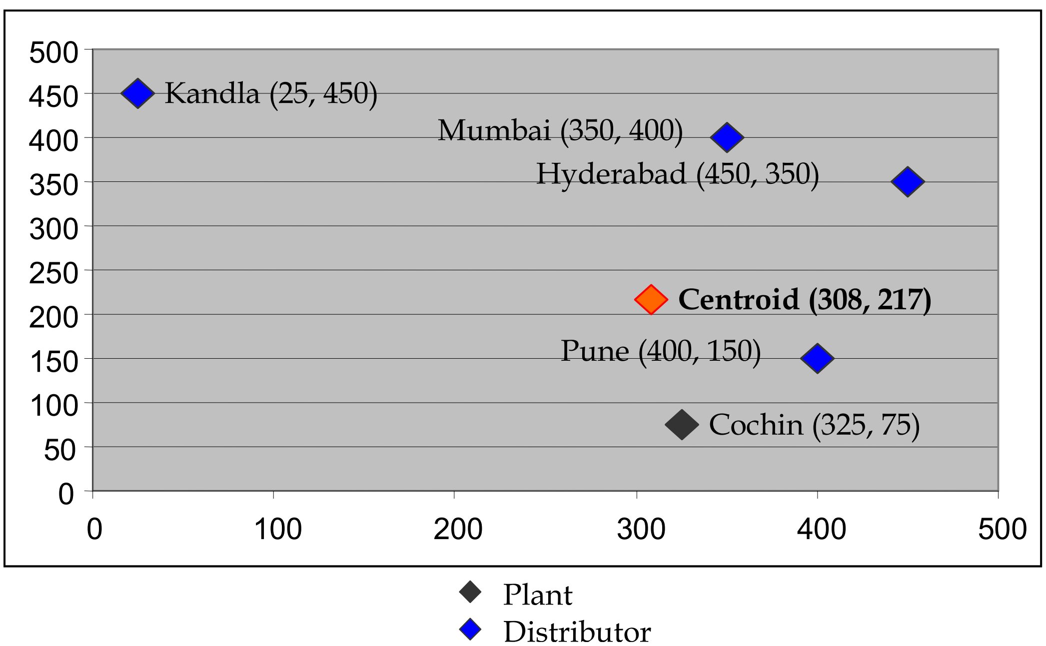
The transportation matrix for this example appears in table 2.1 (a) and table 2.1 (b), where supply availability at each factory and the warehouse demands are shown table 2.1 (a). The shipping costs are shown table 2.1 (b). For example, the cost to ship one unit from the Delhi factory to the customer warehouse in Bangalore is Rs. 25. The solution of given problem is depicted in table 2.2, which shows the total minimum transportation cost *vis-a vis* different sources and destinations.

The transportation method can be used to solve many different types of problems if it is applied innovatively. For example, it can be used to test the cost impact of different candidate locations on the entire production–distribution network. To do this we might add a new row that contains the unit shipping cost from a factory in a new location, say, Jaipur, to the existing set of customer warehouses, along with the total amount it could supply. We could then solve this particular matrix for minimum total cost. Next we would replace the factory located in Jaipur in the same row of the matrix with a factory at a different location, Chandigarh, and again solve for minimum total cost. Assuming the factories in Jaipur and Chandigarh would be identical in other important respects; the location resulting in the lowest total cost for the network would be selected.

2.6.3 CENTROID METHOD

The **centroid method** is a technique for locating single facilities that considers the existing facilities, the distances between them, and the volumes of goods to be shipped. The technique is often used to locate intermediate or distribution warehouses. In its simplest form, this method assumes that inbound and outbound transportation costs are equal, and it does not include special shipping costs for less than full loads.

Exhibit 2.1 Grid Map for Centroid Example



Another major application of the centroid method today is the location of communication towers in urban areas. Examples include radio, TV, and cell phone towers. In this application the goal is to find sites that are near clusters of customers, thus ensuring clear radio signals. The centroid method begins by placing the existing locations on a coordinate grid system. The choice of coordinate systems is entirely arbitrary. The purpose is to establish relative distances between locations. Using longitude and latitude coordinates might be helpful in international decisions. Exhibit 2.1 shows an example of a grid layout.

The centroid is found by calculating the *X* and *Y* coordinates that result in the minimal transportation cost. We use the formulas

$$C_x = \frac{\Sigma d_{ix} v_i}{\Sigma V_i}$$

$$C_y = \frac{\Sigma d_{iy} v_i}{\Sigma V_i}$$

C_x = *X* coordinate of the centroid

C_y = *Y* coordinate of the centroid

d_{ix} = *X* coordinate of the *i*th location

d_{iy} = *Y* coordinate of the *i*th location

V_i = Volume of goods moved to or from the *i*th location

EXAMPLE 2.2

Hindustan Refining Company

The Hindustan Refining Company needs to locate an intermediate holding facility between its refining plant in Cochin and its major distributors. Exhibit 2.1 shows the coordinate map. The amount of gasoline shipped to or from the plant and distributors appears in Table 2.3.

In this example, for the Cochin location (the first location), d_{1x} = 325, d_{1y} = 75, and V_1 = 1,500

Table 2.3

LOCATION	GALLONS OF GASOLINE PER MONTH (000,000)
Cochin	1,500
Pune	250
Hyderabad	450
Mumbai	350
Kandla	450

SOLUTION

Using the information in Exhibits 2.1 and table 2.3, we can calculate the coordinates of the centroid

$$C_x = \frac{(325\times1500)+(400\times250)+(450\times450)+(350\times350)+(25\times450)}{1500+250+450+350+450}$$
$$= \frac{923{,}750}{3{,}000} = 307.9$$
$$C_y = \frac{(75\times1500)+(150\times250)+(350\times450)+(400\times350)+(450\times450)}{150+250+450+350+450}$$
$$= \frac{650{,}000}{3{,}000} = 216.7$$

This gives management the *X* and *Y* coordinates of approximately 308 and 217, respectively, and provides an initial starting point to search for a new site. By examining the location of the calculated centroid on the grid map, we can see that it might be more cost-efficient to ship directly between the Cochin plant and the Pune distributor than to ship via a warehouse near the centroid. Before a location decision is made, management would probably recalculate the centroid, changing the data to reflect this (that is, decrease the gallons shipped from Cochin by the amount Pune needs and remove Pune from the formula)

2.6.4 LOAD DISTANCE TECHNIQUE

A variation of the center-of-gravity method for determining the coordinates of a facility location is the load-distance technique. In this method, a single set of location coordinates is not identified. Instead, various locations are evaluated using a load-distance value that is a measure of weight and distance. For a single potential location, a load-distance value is computed as follows:

$$LD = \sum_{i=1}^{n} I_i d_i$$

Where

LD_i = the load-distance value

Ii = the load expressed as a weight, number of trips, or units being shipped from the proposed site and location

d_j = the distance between the proposed site and location i

The distance d in this formula can be the travel distance, if that value is known or can be determined from a map. It can also be computed using the following formula for the straight line distance between two points, which is also the hypotenuse of a right triangle:

$$d_i = \sqrt{(xi - x)2 + (yi - y)2}$$

Where

(x, y) = coordinates of proposed site

(x_i, y_i) = coordinates of existing facility

The load-distance technique is applied by computing a load distance value for each potential facility location. The implication is that the location with the lowest value would result in the minimum transportation cost and thus would be preferable.

2.6.5 LOCATIONAL BREAK-EVEN ANALYSIS

Locational break-even analysis is based on cost-volume analysis to make economic comparison of location alternatives. By identifying fixed and variable cost and graphing them for each location, we can determine which one provides the lowest cost. Location break-even analyses can be done mathematically or graphically. The graphic approach has the advantage of providing the range of volume over which each location is preferable.

The three steps to locational break-even analysis are:

1.Determine the fixed and variable cost for each location.

2.Plot the costs for each location, with costs on the vertical axis of the graph and annual volume on the horizontal axis.

3.Select the location that has the lowest total cost for the expected production volume.

2.7 BEHAVIOURAL IMPACTS IN FACILITY LOCATION

Our previous discussions of models focused on the cost consequences. But costs are not the whole story and models can't account for aspects of a problem that are not quantifiable. New locations require that organisations establish relationships with new environments and employees and adding or deleting facilities requires adjustments in the overall management system. The organisation structure and modes of making operating decisions must be modified to accommodate the change. These hidden "system costs" are usually excluded from quantitative models and yet they are very real aspects of the location decision.

Cultural Differences

The decision to locate a new facility usually means that employees will be hired from within the new locale. It also means that the organisation must establish appropriate community relations to "fit into" the locale as a good neighbor and citizen. The organisation must recognise the differences in the way people in various ethnic, urban, suburban and rural communities react to new businesses. Managerial style and organizational structure must adapt to the norms and customs of local subcultures. Employees' acceptance of authority may vary with subcultures, as do their life goals, beliefs about the role of work, career aspirations and perceptions of opportunity. These cultural variations in attitude impact on-the-job behaviour and talent.

At the international level are even greater cultural differences. Compare, for example, the Japanese work tradition with that of Western industrial society. Japanese workers are often guaranteed lifetime employment. Management decisions usually are group rather than individual decisions. Employee compensation is determined by length of service, number of dependents and numerous factors apart from the employee's productivity. Obviously operations managers in Japan face a very different set of managerial problems from their US counterparts. Wage determination, employee turnover, hiring and promotion practices are not at all the same.

The European social system as another example, has resulted in a more "managerial elite" in their organisations than in the US because of education, training and socialisation, including a lifelong exposure to a relatively rigid class system, lower subordinates are not prepared to accept participative managerial styles. This has resulted in more authoritarian/centralised organisations than participative/decentralized.

Locating a new facility in a new culture is not simply a matter of duplicating a highly refined manufacturing process. Merely transferring tools and equipment is not adequate. Managerial techniques and skills, in a proper mix, must be borrowed from the culture and so must the cultural assumptions that are needed to make them work. Clearly, the economic, political and cultural makeup of a society has far-reaching effects on the technological and economic success of multinational location decisions.

Job Satisfaction

In recent years managers have been very concerned about employee job satisfaction because it affects how well the organisation operates. Although no consistent overall relationship between job satisfaction and productivity seems to exist, other consistent relationships have been found. As compared with employees with low job satisfaction, those expressing high job satisfaction exhibit the following characteristics:

1 Fewer labour turnovers

2 Less absenteeism

3 Less tardiness

4 Fewer grievances

These four factors can substantially affect both costs and disruptions of operations. But how is job satisfaction related to facility location? There is some evidence that satisfaction is related to community characteristics such as community prosperity, small town versus large metropolitan locations and the degree of unionisation. Accordingly, a company with facilities in multiple locations can expect variations in employee satisfaction due to variation in attitudes and value systems across locations.

Consumer Considerations

For many organisations, location planning must emphasise consumer behaviour and proximity to customers. If primary product is a service to the public, the customer convenience may be the prime consideration. Theatres, banks, supermarkets and restaurants heavily emphasise customer convenience when choosing a location. In fact, location convenience itself is often considered to be the service. For these reasons the location decision may be regarded as a responsibility of marketing staff instead of production/operations staff, especially as it affects revenues rather than costs.

2.8 SOLVED EXAMPLES

EXAMPLE 2.3

From the following data select the most advantageous location for setting a plant for manufacturing Television sets:

		Bhopal	Mandideep	Vidisha
i)	Total initial capital expenditure	400,000	400,000	400,000
ii)	Total expected sales/year	500,000	600,000	500,000
iii)	Distribution expenses	80,000	80,000	150,000
iv)	Raw material expenses	140,000	160,000	180,000
v)	Power and water supply expenses	80,000	60,000	40,000
vi)	Wages and salaries	40,000	50,000	40,000

vii)	Other expenses	50,000	80,000	60,000
viii)	Community attitude	indifferent	wants	Indifferent
ix)	Employee housing facilities	poor	excellent	good

SOLUTION

Site Bhopal Mandideep

Vidisha

Total expenses 390,000 430,000

470,000

(Add iii, iv, v, vi. vii)

Rate of return %(ROR) $= \dfrac{Total\ Sale - Total\ expenses}{Total\ investment} \times 100$

ROR of Bhopal = (500,000-390,000)/400,000 x 100 = 27.5%

ROR of Mandideep = (600,000-430,000)/40, 0000 x 100 = 42.5%

ROR of Vidisha = (500,000-470,000)/400,000 x 100 = 7.5%

From economic consideration point of view site of Mandideep is most advantageous. Moreover, intangible factors of community want business and housing facilities are excellent and also favour the site of Mandideep.

EXAMPLE 2.4

The Indian Seamless Tube Company Ltd. which has distribution plants in Gujarat and Andhra is considering adding a third assembly and distribution plant either in Ahmedabad, Bangalore or Cochin.

The company has collected the following economic and other relevant data:

Factor	Cochin	Ahmedabad	Bangalore
Transportation cost/week	Rs 780	Rs 640	Rs 560
Labour cost/week	Rs 1200	Rs 1020	Rs 1180
Selected criteria scores			
(Based on a scale of 0-100 points)			
Finishing material supplied	35	85	70
Maintenance facilities	60	25	30
Community attitude	50	85	70

Company Management has pre-established weights for various factors. They include a standard of 1.00 for each Rs 10 per week of economic advantage. Other weights that are applicable are 1.5 on finishing material supply, 0.8 on maintenance facilities and 2.0 on community attitude. Maintenance also has a minimum acceptable score of 30. Develop a quantitative factor comparison for the three locations.

SOLUTION

1. The relevant factors are

    a) Relative economic advantage

    b) Finishing material supply

    c) Maintenance facility

    d) Community, attitude

2. Evaluation scales are all 0-100 points.

3. Factor weights for (a), (b), (c) and (d) per Rs 10 weekly advantage are 1.0, 1.5, 0.8 and 2 respectively.

4. Weighted scores = E (score) (weight)

First we must determine the relative economic advantage score:

	Cochin	Ahmedabad	Bangalore
Cost/week (transportation + labour)	1980	1660	1740
Relative economic (highest cost/week)	0	320	240
Economic advantages score in Rs 10 units	0	32	24

Factor	Cochin	Ahmedabad	Bangalore
Economic	Ox1.0 = 0	32x 1.0 = 32.0	24x 1.0 = 24
Material supply	35x 1.5 = 52.5	85x 1.5 = 127.5	70x1.5 = 105
Maintenance	60xO.8 = 48.0	25xO.8 = 20.0	30xO.8 = 24
Community	50x2.0 = 100.0	65x2.0 = 130.0	70x2.0 = 140

The Bangalore and Ahmedebad sites do not meet the maintenance minimum criteria of 30. Though Cochin has the least total points and would be recommended on the basis of this limited analysis (even though Bangalore and Ahmedebad have a lower cost structure). If maintenance criterion is lowered to 20 points than, Ahmedebad is perhaps the best choice.

EXAMPLE 2.5

A manufacturer of farm equipment is considering three locations (A, Band C) for a new plant. Cost per year at the sites are Rs 2,40,000, Rs 2,70,000 and Rs 2,52,000 respectively. Whereas variable cost are Rs 100 per unit, Rs 90 per unit and Rs 95 per unit respectively. If the plant is designed to have an effective system capacity of2500 units per year and is expected to operate at 80 per cent efficiency what is the most economic location on the basis of actual output.

SOLUTION

Actual output = System efficiency x System capacity

= 80/100 x 2500 = 2000 units/year

Cost/site = (Fixed cost + Variable cost) = Actual output

A = (2, 40,000 + (100) x 2,000) = 4, 40,000

B = (2, 70,000 + (90) x 2,000) = 4, 50,000

C = (2, 52,000+ (95) x 2,000) = 4, 42,000

The most economical location is A.

EXAMPLE 2.6

	A	B	C	D
Labour (per unit)	0.75	1.10	0.80	0.90
Plant construction cost (Million Rs.)	4.60	3.90	4.00	4.80
Materials and Equipment (per unit)	0.43	0.60	0.40	0.55

Electricity (per year)	30,000	26,000	30,000	28,000
Water (per year)	7,000	6,000	7,000	7,000
Transportation (per unit)	0.20	0.10	0.10	0.05
Taxes (per year)	33,000	28,000	63,000	35,000

A firm is considering 4 alternative locations for a new plant. It has attempted to study all costs at the various locations and finds that the production costs of the following items vary from one location to another. 'The firm will finance the new plant from bonds bearing 10% interest. Determine the most suitable location (economically) for output volumes in the range of 50,000 to 1, 30,000 units per year.

Cost	A	B	C	D
Fixed cost (per year)				
10% of investment	460,000	390,000	400,000	480,000
Electricity	30,000	26,000	30,000	28,000
Water	7,000	6,000	7,000	7,000
Taxes33,000	28,000	63,000	35,000	
Total	530,000	450,000	500,000	550,000

Cost A	B	C	D	
Variable cost (per unit) Labour	0.75	1.1 °	0.80	0.90
Material and Equipment	0.43	0.60	0,410	0.55
Transportation	0.02	0.10	0.10	0.05

Total Variable Cost/Unit	1.20	1.80	1.30	1. 50
Total Fixed	530,000	450,000	500,000	550,000
and Variable Costs	1.20/unit	1.80/unit	1.30/unit	l.50/unit

The points for a plant location Break-even Analysis chart are as follows. As zero units of output use fixed cost values. At 100,000 units of output:

A = (530,000)	+	100,000 x 1.20	=	650,000
B = (450,000)	+	100,000 x 1.80	=	630,000
C = (550,000)	+	100,000 x 1.30	=	680,000
D = (550,000)	+	100,000 x 1.50	=	700,000

So, it is evident that for a minimum cost use site B, for a volume of 50,000 to 100,000 units use site C and for a volume of 100,000 to 130,000 units.

2.9 SUMMARY

In this lesson you have observed that the enterprises has to make decisions regarding plant location, which refers to the selection of a particular site for setting up a production facilities. But before making such a choice, enterprise has to go through the detailed locational analysis considering various factors, which influence his decision. It is a long-term strategic decision, which cannot be changed once taken. An optimum location can reduce the cost of production and distribution to a great extent. Thus great care and appropriate planning is required to select the most appropriate location.

An efficient plant layout is one that aims at achieving various objectives like efficient utilization of available floor space, minimizes cost, allows flexibility of operation, provides for employees convenience, improves productivity etc. The entrepreneurs must possess the expertise to lay down a proper layout for new or existing plants. It differs from one plant to another. Designing of layout is different in all above three categories e.g. manufacturing unit may follow one of Product, Process, and fixed position or combined layout, as the case may be. Traders might go either for self- service or full service or special layouts whereas service establishments such as motels, hotels, and restaurants must give due attention to customer convenience, quality of service, efficiency in delivering the service etc. While deciding for layout for factory or unit or store, enterprise has to consider the factors like the nature of the product, production process, size of factory building, human needs etc.

Plant layout is applicable to all types of industries or plants. At the end, the layout should be conducive to health and safety of employees. It should ensure free and efficient flow of men and materials. Future expansion and diversification may also be considered while planning factory layout.

2.10 KEY WORDS

Business Environment – Implies aggregate of all forces, factors and institutions, which are external to and beyond the control of business organizations and their management

Continuous Process - A process, which involves mass production of, standardized product repetitively.

Diversification – A process of entering into a field of business, which is new in terms of the market or technology or both

Expansion – Consists of increasing the sales revenue, profits and market share of existing product line or service

Handling cost - Cost of carrying material or storage cost.

Intermittent process – Is a process in which raw materials are converted into components or parts for stock. But they are combined according to customer orders.

Manufacturing – General term for the process of producing or assembling goods by hands or machines for sale to others.

Overhead cost – Operating costs of a business enterprise, which cannot be directly traced to a particular unit of product

Production capacity- Ability to produce in terms of units

2.11 SELF ASSESSMENT EXERCISE

1. Describe the factors that should be taken into account in deciding the location of facilities?

2. What is the importance of location in business?

3. The governing principle is that a plant should be so located as to permit the production of the product at the lowest cost per unit." comment.

4. What do you mean by locational analysis?

5. Explain the meaning and significance of plant location .How will you decide the location of a mini steel plant in India?

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Course: MBA Course Code: CP-204

LESSON: 3

Layout Planning and Analysis

Structure

3.0 OBJECTIVES

After going through this lesson, you will be able to:

1. **Define of plant layout**
2. **Understand Significance and essentials of facility layout**
3. **Explain different types of layouts**
4. **Understanding the capacity planning**
5. **Describe use and role of computers in design of layouts**

3.1 INTRODUCTION

The efficiency of production depends on how well the various machines; production facilities and employee's amenities are located in a plant. Only the properly laid out plant can ensure the smooth and rapid movement of material, from the raw material stage to the end product stage. Plant layout encompasses new layout as well as improvement in the existing layout.

It may be defined as a technique of locating machines, processes and plant services within the factory so as to achieve the right quantity and quality of output at the lowest possible cost of manufacturing. It involves a judicious arrangement of production facilities so that workflow is direct.

3.2 DEFINITION OF PLANT LAYOUT

A plant layout can be defined as follows:

Plant layout refers to the arrangement of physical facilities such as machinery, equipment, furniture etc. with in the factory building in such a manner so as to have quickest flow of material at the lowest cost and with the least amount of handling in processing the product from the receipt of material to the shipment of the finished product.

According to Riggs, "the overall objective of plant layout is to design a physical arrangement that most economically meets the required output – quantity and quality."

According to J. L. Zundi, "Plant layout ideally involves allocation of space and arrangement of equipment in such a manner that overall operating costs are minimized.

3.3 IMPORTANCE OF PLANT LAYOUT

Plant layout is an important decision as it represents long-term commitment. An ideal plant layout should provide the optimum relationship among output, floor area and manufacturing process. It facilitates the production process, minimizes material handling, time and cost, and allows flexibility of operations, easy production flow, makes economic use of the building, promotes effective utilization of manpower, and provides for employee's convenience, safety, comfort at work, maximum exposure to natural light and ventilation. It is also important because it affects the flow of material and processes, labour efficiency, supervision and control, use of space and expansion possibilities etc.

3.4 REQUISITES FOR PLANT LAYOUT

An efficient plant layout is one that can be instrumental in achieving the following objectives:

a) Proper and efficient utilization of available floor space

b) To ensure that work proceeds from one point to another point without any delay

c) Provide enough production capacity.

d) Reduce material handling costs

e) Reduce hazards to personnel

f) Utilize labour efficiently

g) Increase employee morale

h) Reduce accidents

i) Provide for volume and product flexibility

j) Provide ease of supervision and control

k) Provide for employee safety and health

l) Allow ease of maintenance

m) Allow high machine or equipment utilization

n) Improve productivity

3.5 TYPES OF LAYOUT

As discussed so far the plant layout facilitates the arrangement of machines, equipment and other physical facilities in a planned manner within the factory premises. An organization must possess an expertise to lay down a proper layout for new or existing plants. It differs from plant to plant, from location to location and from industry to industry. But the basic principles governing plant layout are more or less same.

As far as small business is concerned, it requires a smaller area or space and can be located in any kind of building as long as the space is available and it is convenient. Plant layout for Small Scale business is closely linked with the factory building and built up area.

From the point of view of plant layout, we can classify business or unit into three categories:

1. Manufacturing units
2. Traders
3. Service Establishments

3.5.1 Manufacturing units

In case of manufacturing unit, plant layout may be of four types:

(a) Product or line layout

(b) Process or functional layout

(c) Fixed position or location layout

(d) Combined or group layout

3.5.1.1 Product or line layout

Under this, machines and equipments are arranged in one line depending upon the sequence of operations required for the product. The materials move form one workstation to another sequentially without any backtracking or deviation. Under this, machines are grouped in one sequence. Therefore materials are fed into the first machine and finished goods travel automatically from machine to machine, the output of one machine becoming input of the next, e.g. in a paper mill, bamboos are fed into the machine at one end and paper comes out at the other end. The raw material moves very fast from one workstation to other stations with a minimum work in progress storage and material handling.

The grouping of machines should be done keeping in mind the following general principles.

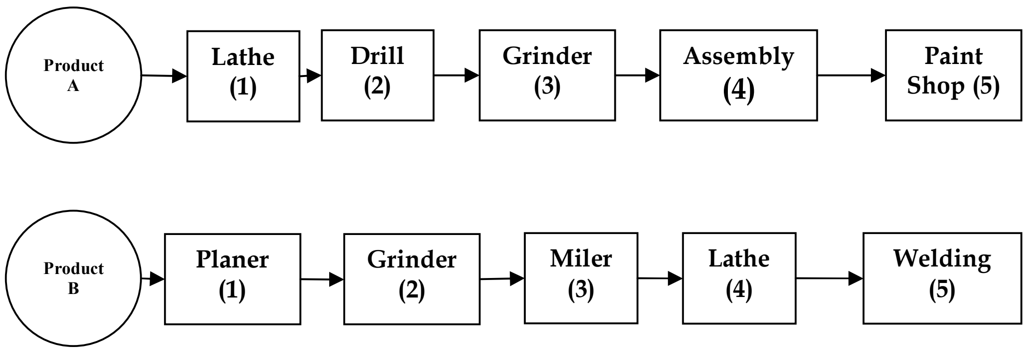
a) All the machine tools or other items of equipments must be placed at the point demanded by the sequence of operations

b) There should be no points where one line crossed another line.

c) Materials may be fed where they are required for assembly but not necessarily at one point.

d) All the operations including assembly, testing, packing must be included in the line

A line layout for two products is given below.



Advantages: Product layout provides the following benefits:

a) Low cost of material handling, due to straight and short route and absence of backtracking

b) Smooth and uninterrupted operations

c) Continuous flow of work

d) Lesser investment in inventory and work in progress

e) Optimum use of floor space

f) Shorter processing time or quicker output

g) Less congestion of work in the process

h) Simple and effective inspection of work and simplified production control

i) Lower cost of manufacturing per unit

Disadvantages: Product layout suffers from following drawbacks:

a) High initial capital investment in special purpose machine

b) Heavy overhead charges

c) Breakdown of one machine will hamper the whole production process

d) Lesser flexibility as specially laid out for particular product.

Suitability: Product layout is useful under following conditions:

a) Mass production of standardized products

b) Simple and repetitive manufacturing process

c) Operation time for different process is more or less equal

d) Reasonably stable demand for the product

e) Continuous supply of materials

Therefore, the manufacturing units involving continuous manufacturing process, producing few standardized products continuously on the

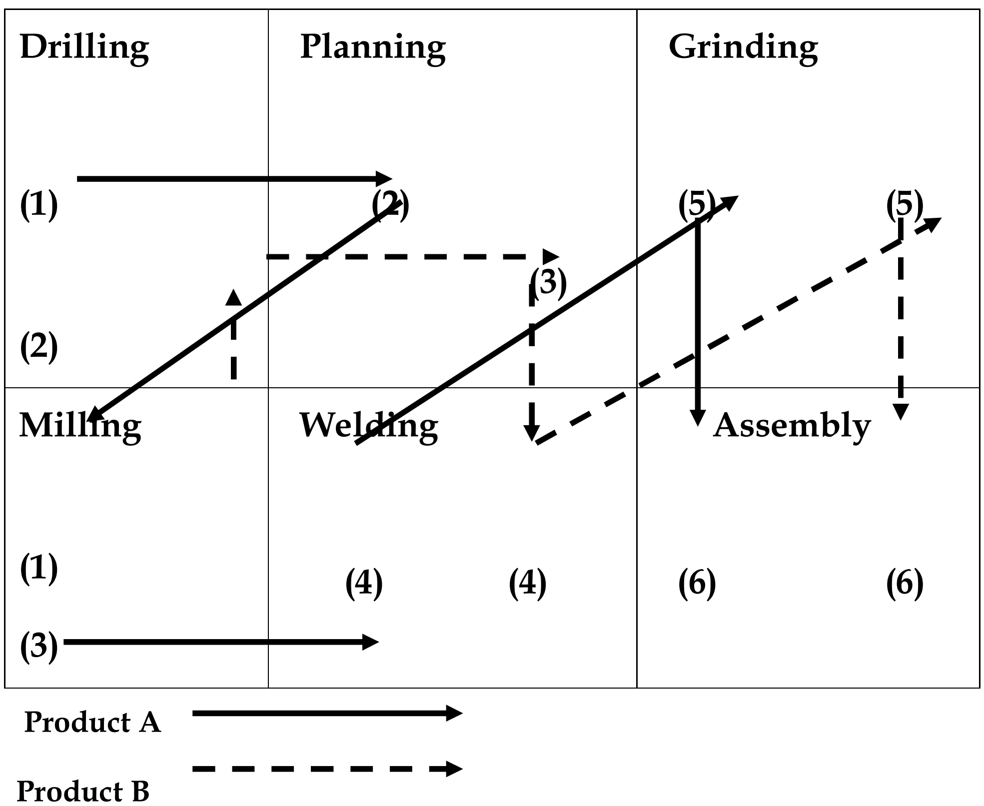
firm's own specifications and in anticipation of sales would prefer product layout e.g. chemicals, sugar, paper, rubber, refineries, cement, automobiles, food processing and electronics etc.

3.5.1.2 Process layout:

In this type of layout machines of a similar type are arranged together at one place. e. g. Machines performing drilling operations are arranged in the drilling department, machines performing casting operations be grouped in the casting department. Therefore the machines are installed in the plants, which follow the process layout.

Hence, such layouts typically have drilling department, milling department, welding department, heating department and painting department etc. The process or functional layout is followed from historical period. It evolved from the handicraft method of production. The work has to be allocated to each department in such a way that machines are chosen to do as many different job as possible i.e. the emphasis is on general purpose machine.

The work, which has to be done, is allocated to the machines according to loading schedules with the object of ensuring that each machine is fully loaded. Process layout is shown in the following diagram.



Process layout showing movement of two products

The grouping of machines according to the process has to be done keeping in mind the following principles

a) The distance between departments should be as short as possible for avoiding long distance movement of materials

b) The departments should be in sequence of operations

c) The arrangement should be convenient for inspection and supervision

Advantages: Process layout provides the following benefits

a) Lower initial capital investment in machines and equipments. There is high degree of machine utilization, as a machine is not blocked for a single product

b) The overhead costs are relatively low

c) Change in output design and volume can be more easily adapted to the output of variety of products

d) Breakdown of one machine does not result in complete work stoppage

e) Supervision can be more effective and specialized

f) There is a greater flexibility of scope for expansion.

Disadvantages: Process layout suffers from following drawbacks

a) Material handling costs are high due to backtracking

b) More skilled labour is required resulting in higher cost.

c) Time gap or lag in production is higher

d) Work in progress inventory is high needing greater storage space

e) More frequent inspection is needed which results in costly supervision

Suitability: Process layout is adopted when

a) Products are not standardized

b) Quantity produced is small

c) There are frequent changes in design and style of product

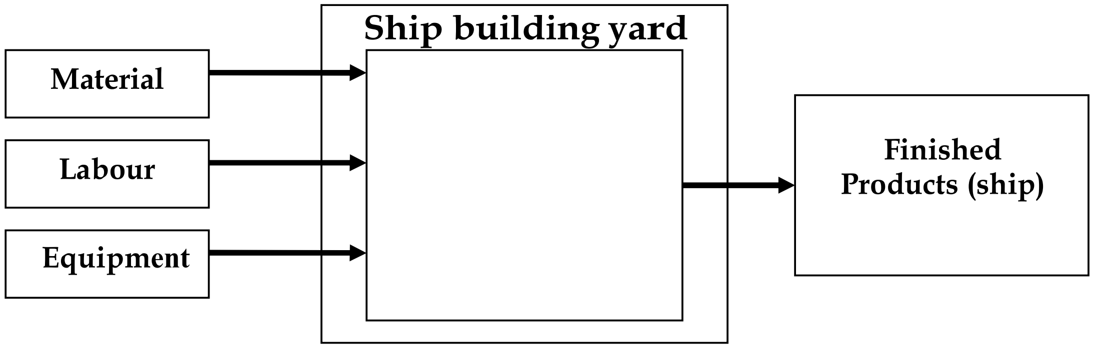
d) Job shop type of work is done

e) Machines are very expensive

Thus, process layout or functional layout is suitable for job order production involving non-repetitive processes and customer specifications and non- standardized products, e.g. tailoring, light and heavy engineering products, made to order furniture industries, jewelry.

3.5.1.3 Fixed Position or Location Layout

In this type of layout, the major product being produced is fixed at one location. Equipment, labor and components are moved to that location. All facilities are brought and arranged around one work center. This type of layout is not relevant for small scale entrepreneur. The following figure shows a fixed position layout regarding shipbuilding.



Advantages: Fixed position layout provides the following benefits

a) It saves time and cost involved on the movement of work from one workstation to another.

b) The layout is flexible as change in job design and operation sequence can be easily incorporated.

c) It is more economical when several orders in different stages of progress are being executed simultaneously.

d) Adjustments can be made to meet shortage of materials or absence of workers by changing the sequence of operations.

Disadvantages: Fixed position layout has the following drawbacks

a) Production period being very long, capital investment is very heavy

b) Very large space is required for storage of material and equipment near the product.

c) As several operations are often carried out simultaneously, there is possibility of confusion and conflicts among different workgroups.

Suitability: The fixed position layout is followed in following conditions

a) Manufacture of bulky and heavy products such as locomotives, ships, boilers, generators, wagon building, aircraft manufacturing, etc.

b) Construction of building, flyovers, dams.

c) Hospital, the medicines, doctors and nurses are taken to the patient (product).

3.5.1.4 Combined layout

Certain manufacturing units may require all three processes namely intermittent process (job shops), the continuous process (mass production shops) and the representative combined process (i.e. miscellaneous shops).

In most of industries, only a product layout or process layout or fixed location layout does not exist. Thus, in manufacturing concerns where several products are produced in repeated numbers with no likelihood of continuous production, combined layout is followed. Generally, a combination of the product and process layout or other combination are found, in practice, e.g. for industries involving the fabrication of parts and assembly, fabrication tends to employ the process layout, while the assembly areas often employ the product layout. In soap, manufacturing plant, the machinery manufacturing soap is arranged on the product line principle, but ancillary services such as heating, the manufacturing of glycerin, the power house, the water treatment plant etc. are arranged on a functional basis.

3.5.2 Traders

When two outlets carry almost same merchandise, customers usually buy in the one that is more appealing to them. Thus, customers are attracted and kept by good layout i.e. good lighting, attractive colors, good ventilation, air conditioning, modern design and arrangement and even music. All of these things mean customer convenience, customer appeal and greater business volume.

The customer is always impressed by service, efficiency and quality. Hence, the layout is essential for handling merchandise, which is arranged as per the space available and the type and magnitude of goods to be sold keeping in mind the convenience of customers.

There are three kinds of layouts in retail operations today.

1. Self service or modified self service layout
2. Full service layout
3. Special layouts

The self-service layouts, cuts down on sales clerk's time and allow customers to select merchandise for themselves. Customers should be led through the store in a way that will expose them to as much display area as possible, e.g. grocery stores or department stores. In those stores, necessities or convenience goods should be placed at the rear of the store. The use of color and lighting is very important to direct attention to interior displays and to make the most of the stores layout.

All operations are not self-service. Certain enterprises sell to fewer numbers of customers or higher priced product, e.g. Apparel, office machines, sporting goods, fashion items, hardware, good quality shoes, jewelry, luggage and accessories, furniture and appliances are all examples of products that require time and personal attention to be sold. These full service layouts provide area and equipment necessary in such cases.

Some layouts depend strictly on the type of special store to be set up, e.g. TV repair shop, soft ice cream store, and drive-in soft drink stores are all examples of business requiring special design. Thus, good retail layout should be the one, which saves rent, time and labour.

3.5.3 Services centers and establishment

Services establishments such as motels, hotels, restaurants, must give due attention to client convenience, quality of service, efficiency in delivering services and pleasing office ambience. In today's environment, the clients look for ease in approaching different departments of a service organization and hence the layout should be designed in a fashion, which allows clients quick and convenient access to the facilities offered by a service establishment.

3.6 FACTORS INFLUENCING LAYOUT

While deciding his factory or unit or establishment or store, a small-scale businessman should keep the following factors in mind:

1. **Factory building:** The nature and size of the building determines the floor space available for layout. While designing the special requirements, e.g. air conditioning, dust control, humidity control etc. must be kept in mind.

2. **Nature of product:** product layout is suitable for uniform products whereas process layout is more appropriate for custom-made products.

3. **Production process:** In assembly line industries, product layout is better. In job order or intermittent manufacturing on the other hand, process layout is desirable.

4. **Type of machinery:** General purpose machines are often arranged as per process layout while special purpose machines are arranged according to product layout.

5. **Repairs and maintenance:** machines should be so arranged that adequate space is available between them for movement of equipment and people required for repairing the machines.

6. **Human needs:** Adequate arrangement should be made for cloakroom, washroom, lockers, drinking water, toilets and other employee facilities, proper provision should be made for disposal of effluents, if any.

7. **Plant environment:** Heat, light, noise, ventilation and other aspects should be duly considered, e.g. Paint shops and plating section should be located in another hall so that dangerous fumes can be removed through proper ventilation etc. Adequate safety arrangement should also be made.

Thus, the layout should be conducive to health and safety of employees. It should ensure free and efficient flow of men and materials. Future expansion and diversification may also be considered while planning factory layout.

3.7 CAPACITY PLANNING

Capacity may be defined as the maximum or limited capability of a production unit to produce in a specific period. This is expressed in terms of output per unit of time. If stated period of time is one month, the capacity is said to be the limiting capability of the producing unit in one month, e.g., 10,000 per units per month. This capacity is the capability of the producing unit under given (or specified) condition, e.g., one shift working/two shifts working or three shifts working or one shift + 4 hours OT working, two shifts + 4 hours O.T. working and so on. Thus, the capacity is related to the intensity of the facilities used.

Measures of Capacity

Different types of organizations use different measures of capacity, e.g. steel plant uses tons of steel produced, beer plant uses cases of beer produced and auto plant uses number of autos produced.

Type of Capacity

Designed Capacity: Designed capacity is the theoretical maximum capacity that producing units can produce under ideal conditions. This is based on the designed parameters by R & D.

Effective Capacity: Effective capacity is per cent utility of the designed capacity.

$$\text{Effective Capacity} = \frac{\text{Achievable Capacity x 100}}{\text{Designed capacity}}$$

Rate Capacity: Rated capacity is the actual capacity achievable under stated conditions.

Rate capacity = Achievable Capacity x Efficiency

= (Designed Capacity x Utilisation) x Efficiency

Examples: The steel melting shop arc furnace is designed for a production of 50 t Capacity/heat. The average efficiency is found to be 90% and the utilization of the furnace in week of 168 hours, i.e. 7 days working. If the average heat time is four hours/heat, find the rated capacity of the steel melting shop.

Rated Capacity = (168 – 4) X .90 X 50

= 1890 tons per week

Need for Capacity Planning

Whenever the existing demand changes or addition of new product(s) has to be made, then re-assessment of capacity at various stages of production, depending upon the processed details, is called for and steps are taken to take care of the desired capacity demands.

Thus Capacity Planning Design includes:

(1) Re-assessment of existing capacity;

(2) Effective of change in demand, i.e. effect of addition, deletion of products and their impact on existing capacity;

(3) Identifying ways of meeting desired capacity through

   a. Better utilizations,

   b. Higher efficiency,

   c. Overtime.

   d. Adding s shifts or two;

   e. Adding new machinery, adding another production unit and so on.

Capacity Requirement Planning

As the master schedule is develop, rough-cut capacity planning is used to check capacity requirements against capacity availability. But rough-cut capacity planning does not take into account lead time off setting, or the amount ahead of time component parts must be made to meet the master schedule for the end items. MRP forms the basis for detailed capacity calculations.

The output of the MRP system indicates what component items will have to be produced and when, and this output can therefore be converted into the capacities required to produce these items. The explosion of the MRP results in details on machine load, or workload projections. The MRP then compares this with available departmental and work center capacities to answer such question as relating to overtime work, inter-departmental transfer of work/people, sub-contracting of work, starting new shifts, hiring more manpower, etc.

This exercise by using the routing sheet, which indicates the sequence of machines or work centers a part must go through during processing and the labour standards, makes it possible to determine capacity requirements at each operation.

The total capacity requirements placed on a work centre during a given time period are called the load. The output of Capacity Requirements Planning (CRP) is usually in the form of load report, or load profile, which is a graphical representation of the load on each work centre by time period. This report provides visibility into future and is based on valid order priorities. Hence, it facilitates capacity requirement planning by providing essential inputs for the capacity requirement planning system to function effectively.

- It was developed as a new tool that tried to correct this situation by at least identifying under-utilization and overload conditions at a machine or work cell.
- CRP was a useful reporting tool, but it didn't provide the ability to fully model production and all its constraints.

Goldratt, around the same time, introduced a new paradigm in managing operations. He moved away from 'managing' constraints that create operational problems to 'removing constraints' and consequently the associated problems. This is the Theory of Constraints (TOC).

3.8 APPLICABILITY OF PLANT LAYOUT

Plant layout is applicable to all types of industries or plants. Certain plants require special arrangements which, when incorporated make the layout look distinct from the types already discussed above. Applicability of plant layout in manufacturing and service industries is discussed below.

In case of the manufacturing of detergent powder, a multi-storey building is specially constructed to house the boiler. Materials are stored and poured into the boiler at different stages on different floors. Other facilities are also provided around the boiler at different stations.

Another applicability of this layout is the manufacture of talcum powder. Here machinery is arranged vertically i.e. from top to bottom. Thus, material is poured into the first machine at the top and powder comes out at the bottom of the machinery located on the ground floor.

Yet another applicability of this layout is the newspaper plant, where the time element is of supreme importance, the accomplishment being gapped in seconds. Here plant layout must be simple and direct so as to eliminate distance, delay and confusion. There must be a perfect coordination of all departments and machinery or equipments, as materials must never fail.

Plant layout is also applicable to five star hotels as well. Here lodging, bar, restaurant, kitchen, stores, swimming pool, laundry, shaving saloons, shopping arcades, conference hall, parking areas etc. should all find an appropriate place in the layout. Here importance must be given to cleanliness, elegant appearance, convenience and compact looks, which attract customers.

Similarly plant layout is applicable to a cinema hall, where emphasis is on comfort, and convenience of the cinemagoers. The projector, screen, sound box, fire fighting equipment, ambience etc. should be of utmost importance.

A plant layout applies besides the grouping of machinery, to an arrangement for other facilities as well. Such facilities include receiving and dispatching points, inspection facilities, employee facilities, storage etc.

Generally, the receiving and the dispatching departments should be at either end of the plant. The storeroom should be located close to the production, receiving and dispatching centers in order to minimize handling costs. The inspection should be right next to other dispatch department as inspections are done finally, before dispatch.

The maintenance department consisting of lighting, safety devices, fire protection, collection and disposal of garbage, scrap etc. should be located in a place which is easily accessible to all the other departments in the plant. The other employee facilities like toilet facilities, drinking water facilities, first aid room, cafeteria etc. can be a little away from other departments but should be within easy reach of the employees.

Hence, there are the other industries or plants to which plant layout is applicable.

3.9 ROLE OF COMPUTERS IN DESIGN OF LAYOUTS

The manual graphical approach has limitations as its effectiveness depends upon the individual's ability and insight. To overcome this limitation, particularly when the departments increase, a number of computerized techniques have been developed as follows: (1) CRAFT (Computerized Relative Allocation of Facilitate Technique), (2) ALDEP (Automated Layout Design Planning) and (3) CORELAP (Computerized Relationship Layout Planning).

(1) CRAFT: The procedure of CRAFT is similar to graphical method.

Inputs required for it are:

(A) Load summary;

(B) Interdepartmental movement unit cost;

(C) Initial layout is given along with the problem;

(D) Distance between different locations;

(E) The floor area requirement of different departments; and

(F) The non-availability of certain departments.

How the Programme Works?

(a) It computes the geographical distances, the inter-departmental distance and the material handling costs for the given layout.

(b) With the initial layout and load summary given, CRAFT, interchanges a pair of departments which have: (i) either a common border or, (ii) the same area requirement. This is done by interchanging the 'Centrois' location of the departments rather than an actual physical change.

(c) Having done this (interchanging of centrois), it calculates the total costs for the modified layout for all possible pair-wise interchanges and the least cost interchange is than accepted.

(d) This interchange is now done physically, i.e., by physically interchanging the area.

(e) The layout at (d) now becomes the given layout.

(f) All the above steps of processing are repeated till the last layout is obtained.

(g) However, it may be noted that the last layout solution obtained through CRAFT is not necessarily the optimal solution.

(h) The programme prints the block diagram of the layout with the last cost along with other information such as departments involved in exchange, total cost and the cost reduction effected. The programme can also print block diagrams at each stage, e.g., second best, third best and so on.

(2) ALDEP (Automated Layout Design Planning): The layout is basically an expression of the various relationships between different operations or work areas, e.g., the two departments having close relationship with each other may be required to keep adjacent to each other, e.g., for each of supervision, minimum distance need for common lighting, etc. Similarly, the two departments may not be required to keep adjacent to each other as in the case of surgical and gynecology departments. The relationship diagrams require recognition of' closeness' and are expressed on an ordinary scale of:

A, E, I, O, U, X

Where

A	=	Absolutely essential
E	=	Essential,
I	=	Important,
O	=	Ordinarily,
U	=	Unimportant, and
X	=	Not desirable.

The 'ALDEP' technique converts the ordinary scale to quantitative scores by assigning values as given below:

A = 4, E = 3, I= 2, O = 1, U = 0, X =-1

Input information to ALDEP

(1) Size and number of each department to be located,

(2) Description of the building dimensions, and

(3) Preference table with nearness diagram and values for the letters.

These pair-wise interdepartmental closeness ratings are used to develop a suitable layout which satisfies the maximum number of relationships.

The output consists of layout matrix with departments, with maximum preference scale selected every time. Departments are exchanged two at a time and the preference score evaluated. ALDEP can take up to 63 departments and can lay out a multi-story building up to three floors.

(3) CORELAP (Computerized Relationship Layout Planning): The features of CORELAP technique in many ways are similar to ALDEP. The input information includes building-wise length ratio and departmental area restrictions. Various steps involved in CORELAP technique are:

1. Calculation of TCR (Total Closeness Rating)

$$= \sum_{j=1}^{n} R_{ij}$$

Where,

Rij is the rating of the relationship between the department 'i' and 'j' & n' is the total number of departments.

2. The programme selects the department having maximum TCR value, say, department 'one' (1).
3. Then the programme selects from the Nearness diagram, whether any department has the relationship' A' with

department (1), if so, place this department adjacent to department (1), if not go to next value, i.e., E, if not go to I, if not go to O. Even if 0 is not there, then go for the next TCR value, say department two (2).

4. Next, the programme checks whether any department with value' A' is left, if so, place it adjacent to the above departments and this step is continued till all departments are placed in the layout.

Example: Given the following nearest diagram, arrange the work station into a suitable 3 x 2 grid:

(A) Visual Check or Intuitive Approach:

a → Department 1 & 2

Department 3 & 4

Department 2 & 5

Department 3 & 6

: 1: 2: 5:

: 4: 3: 6:

2 x 3 grids

(1) Place 2 in between 1 & 5 (a relationship).

(2) Place 3 in between 4 & 6 (a relationship).

(3) Let us check

(a) 1 and 4 have relationship ~E' (Ok),

(b) 2-and 3 have relationship 'E' (Ok),

(c) 5 and 6 is not Ok and they have '0' relationship,

(d) Interchanging 4 and 6 does not help, and

(e) Interchanging 1 & 5 also does not help.

Hence, the layout appears to be good to a great extent.

(B) CORELAP Method:

A = 4, E = 3, I = 2, O = 1, U = 0, X = -1

Compute value of TCR for all departments:

For work centre (1):

TCR = A + I + E + I + U

= 4 + 2 + 3 + 2 + 0

= 11

For work centre (2):

TCR = A + E + X + A + I

= 4 + 3 + (-1) + 4 + 2

= 12

For work centre (3):

TCR = 1 + E + A + 0 + A

= 2 + 3 + 4 + 1 + 4

= 14

For work centre (4):

TCR	=	E + X + A + U + E
	=	3 + (-1) + 4 + 0 + 3
	=	9

For work centre (5):

TCR	=	I + A + 0 + U + 0
	=	2 + 4 + 1 + 0 + 1
	=	8

For work centre (6):

TCR	=	U + I + A + E + 0
	=	0 + 2 + 4 + 3 + 1
	=	10

(1) As per procedure, the height TCR = TCR = 14 is for work centre (3). Hence select this work station.

(2) If work centre (3) has relationship 'A' with work centres (4) & (6), then place these work centres adjacent to work centre (3).

4	3	6
5	2	1

Further work centre (3) has relationship 'E' with work centre (2) next higher TCR, whereas work centre (2) has relationship 'A' with work centre (5) but 'X' with work centre (4). So place 2 at 22 position (second row, second column) & (5) on left of it, because work centre (2) has relationship 'X' with work centre (4).

CHECK

(1) Position' A' is Ok for all

(2) Position 'E' is Ok for (2) & (3) but not for

(1) & (6)

(4) & (6)

(1) & (4)

(3) Position 'I' is Ok for (2) & (6)

(1) & (3)

(1) & (5)

(4) Position 'X' is Ok for (2) & (4) (little bit).

However, the layout appears to be a good one, but the layout is not necessarily an optimal layout.

Student Activity 3

1. Develop a basic framework for designing a plant layout. You may make any assumptions in this regard and use any software available freely on the internet.
2. Compare and contrast the CRAFT, ALDEP, CORELAP techniques of plant layout design.

3.10 SUMMARY

This unit establishes that design of an operations layout is a strategic issue. It provides an integrated approach by analyzing the basic production systems and moves on to explain the different kinds of layouts. A study into the factors influencing plant layout and the guiding fundamentals to a successful layout is also dealt with layout Engineering as separate topic lends an overview into the technicalities of their area. Also, the increasing role of computers and the enhanced information access as a mode of layout planning have also been provided.

The layout is basically an expression of the various relationships between different operations or work areas, e.g., the two departments having close relationship with each other may be required to keep adjacent to each other, e.g., for each of supervision, minimum distance need for common lighting, etc. Similarly, the two departments may not be required to keep adjacent to each other as in the case of surgical and gynecology departments.

The cycles of layout development follow a sequence of four phases. The first phase is to determine where the layout shall be, where the facilities to be laid out are to be located. The second phase is to plan an overall layout for the new production area. Then, detailed layout plan and finally the installation. Since the overall layout may influence the choice of location, the layout engineer should not decide definitely on his location until he has reached a decision on a theoretical arrangement of the area. Likewise, he should not definitely consider his overall plan as firm until he has checked at least roughly into the next phase the detailed layout of each department. This means there should be an overlapping from one phase to the next.

In gathering the data, be sure to cover anticipated as well as current or past conditions; long-range forecasts, new-product plans, seasonal variations, trends in the industry; increased service-parts requirements. After a layout is carefully engineered and installed, it is difficult to crowd in forgotten of additional features unless excess space is deliberately planned. Many companies employ combination method (i.e., the combination of product or line and process or functional). Examples of layout of fabrication and processing line method for assembly and for some particular components and process layout for painting or finishing and packaging for shipment. The objective, of course, is to minimize the cost of production per unit of output.

The combination method of layout is feasible when a number of products require about the same sequence of functional operations but none enjoys sufficient volume to justify individual production line. The principle of this method lies in the arrangement of functional departments across the building at right angle to the flow of product and in the required sequence of operations. Particular sections of each department are assigned different lines of products, but the sections can be adjusted as volumes change to accommodate larger or smaller orders.

3.11 KEY WORDS

The various key words, which arise in this Lesson, are:

Continuous process - A process, which involves mass production of, standardized product repetitively.

Intermittent process –Is a process in which raw materials are converted into components or parts for stock. But they are combined according to customer orders.

Manufacturing – General term for the process of producing or assembling goods by hands or machines for sale to others.

Overhead cost – Operating costs of a business enterprise, which cannot be directly traced to a particular unit of product

3.12 SELF ASSESSMENT QUESTIONS

1. Define the plant layout.
2. What are the various factors influencing the layout of steel plant in India?
3. What are the principles for planning the layout of a new factory?
4. Explain process layout. State its advantages and disadvantages in brief.
5. Distinguish between product layout and process layout and Explain the suitability of fixed position layout
6. Write about any two types of plant layout
7. What is plant layout? Discuss the objectives and advantages of a good layout.

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Course: MBA Course Code: CP-204

LESSON: 4 **MATERIAL HANDLING**

Structure

4.0 OBJECTIVES

After going through this lesson, you will be able to:

- **Understand the significance of materials handling.**
- **Analysis the principles for materials handling.**
- **Understand the cost aspect of materials handling**
- **Analysis the factors for selection of materials handling system and equipments.**

4.1 MEANING

Material handling is one of the important activities in stores & production engineering.

Material handling involves the movement of materials from one place to the another for the purpose of processing the job done by material handling equipment include – moving, dropping, positioning, holding, releasing etc. Material handling activities are done with the help of various accessories like hand truck, pulley blocks, chutes, roller conveyors etc. In short, material handling includes all types' vertical or horizontal movement of raw materials from the store-room to the shipping section.

Definition

"Material handling is the art and science involving the movement, packing and storing of substances in any form."

"American Material Handling Society"

4.2 IMPORTANCE OF MATERIAL HANDLING

Material handling function enjoys a pivotal role in production. Material handling operations offer enough scope for minimizations of handling cost. And if there were poor handling operations there will be delay in results. So, the importance of material handling like in the fact that the cost & time of materials can be reduced to greater extent by adopting a sound material handling procedure.

Material handling system is important because of the following factors:-

a) More work with less wastage & spoilage will be there in the industry.
b) Economic utilisation of material effects the organisation & economy and will bring better results by efficient material operation.
c) Productivity capacity of labour will be increased as there will be reduction in the fatigue of workers due to improved material handling system.
d) Plant capacity will be utilized fully.
e) Material handling makes possible the factory working easy.

Material handling is one area which can increase productivity almost overnight. The field of material handing remains still to be fully explored. It can be said that competition is beginning force for material handling technology.

4.3 FACTOR CONSIDERATIONS IN MATERIAL HANDLING SYSTEMS

While making a decision on materials handling methods & equipment, the important consideration are:-

1. How much is the load to be moved?
2. The frequency with which the load is to be moved from one place to another.
3. The existing or proposed layout of the stores & production areas.
4. The already existing material handling equipment.
5. Examination of economic aspects of material handling equipments i.e. price, operating cost etc.
6. Examination of technical aspect i.e. speeds, volume carrying capacity etc.
7. Accessing the various accessories that might be required such as pallete, drums etc.

Before purchasing new equipment it should be evaluated on the basis of above mentioned factors otherwise it can't produce savings in labour cost, spare-cost and time cost as would be expected.

4.4 TYPES OF MATERIAL HANDLING EQUIPMENTS

a) **Hand Truck** – This is a manually operated truck to carry small quantities of solid materials. Another version of these hand trucks is the pallet truck where instead these trucks are of use in handling pallets on which oil countries, small barrels or other items can be kept and transported.

b) **Cranes & hoists** – They lift and move the loads of varying size. The lifting capacity is subject to limitation. They are operated hydraulically, pneumatically or electrically.

c) **Chutes: -** Chutes are the handling equipment which handles the material between fixed points. They move the light material and small jobs which can slide down under the gravity.

d) **Pallets:** - Pallets have been standardised and ISO (International Organization for Sanitation) specifications are available for different verities of pallets. Pallet are of different types –

    i) Two – way pallet
    ii) Four way pallet
    iii) Single – decked pallet
    iv) Double – decked pallet
    v) Wing pallet.

e) **Conveyors** – Conveyors perform the movement of uniform loads between fixed points. The materials are fed to the conveyor from some other source at the point of starting. They are carried by the conveyor to the point of destination. They are most suited where the flow of materials is continuous. The important types of conveyors are:-

    → Belt conveyors
    → Roller conveyors
    → Bucket conveyors

f) **Trucks, Tractors and Trailers –** The trucks are used to move the heavy material over varying paths. They are either hand-driven or power-driven. Generally, two wheeler, three wheeler or four or more wheeler trucks are used to carry and to move the heavy loads.

g) **Pulley Blocks** – These are used many a time to lift heavy weights occasionally. Pulleys are quite common as a make – shift devise in construction places where heavy pieces of equipment have to be fixed at a height.

4.5 PRINCIPLES OF MATERIALS HANDLING

The important principles of material handling are as follow:

i. **Planning Principle: All handling activities should be planned:** Handling activities should be planned and not left to chance, or to the vagaries of performance likely to result if operating personnel are left on their own to devise methods of handling. Handling may account for 25 to 80 percent of all productive activity. Management most certainly deserves to have this sizable portion of total activity planned and not left to chance.

ii. **Systems Principle:** Plan a system integrating as may handle activities as possible and coordinating the full scope of operations (receiving, storage, production, inspection, packaging, warehousing, shipping and transportation).

iii. **Materials** – Flow Principle: Plan an operation sequence and equipment arrangement to optimise materials flow. Materials handling and plant layout are intimately interrelated. The material-flow pattern is actually the backbone of most production facilities and one of the first steps in planning a materials handling system is the design of the materials-flow pattern. This may be largely determined by operation sequence, which in turn will determine the pattern of equipment arrangement.

iv. **Simplification Principle:** Reduce, combine, or eliminate unnecessary movements and/or equipment. Simplification is one of the by-words of efficiency, motion economy and many other aspects of industrial operation. It should like-wise be a goal in materials handling. As used there it implies primarily the reduction or elimination of moves as well as the elimination or reduction of equipment that is not being properly utilised.

v. **Gravity Principle:** Utilize gravity to move materials whenever practicable. This is certainly a very obvious principle but one that is all frequently over-looked because of its simplicity. Many materials can be made efficiently by the proper application of the law of gravity.

vi. **Space Utilisation Principle:** Make optimum utilisation of building cube. Factory and warehouse space are expensive. Therefore, wasted space is wasted money. Inherent in this principle is that square feet and cubic feet as 'clear" height will permit items to be stacked. In this way, a square foot can be "Used" many times over – with 15, 20, 30, 40 foot stacking of materials.

vii. **Unit Size Principle:** Increase quantity, size, weight of load handled: In general, the larger the load, the lower the cost per unit handled. Wherever practical, individual items should be gathered and made up into unit loads. We have discussed in the next unit the load concept, since it is one of the keystones of modern, efficient materials handling.

viii. **Safety Principle:** Provides for safe handling methods and equipment: All handling activities in operation or being planned should be safe, since an objective materials handling is to improve working conditions by providing safer work situations. A high proportion of all industrial accidents is in the materials handling aspect of the production activity.

ix. **Equipment Selection Principle:** In selecting handling equipment, consider all the aspects of the materials to be handled, the MOVE(S) to be made, the METHOD(S) to be utilised. This principle is primarily a reminder to be extremely careful in selecting and specifying handling equipment by being sure that all phases of the problems are thoroughly analysed.

x. **Mechanisation/Automation Principle:** Use mechanised or automated handling equipment when practicable. Used judiciously, mechanized or automated handling devices and equipment can be of extreme value in increasing materials handling efficiency. However, handling operations should not be mechanised for the sake of mechanisation alongs, nor should they be over-mechanised in terms of the function to be performed.

xi. **Standardisation Principle:** Standardize methods as well as types and sizes of handling equipment. In almost any field of endeavor it is wise to standardise the "one best way" after it has been determined. This is not, however, meant to imply that methods, equipment, etc., should be "frozen" and adhered to indefinitely. A search for better methods should always be under way. Standardisation does not mean only one type or make of equipment to be used. It should be interpreted to mean the fewest practical number of types, makes, models, sizes, etc.

xii. **Flexibility Principle:** Use methods and equipment that can perform a variety of tasks and applications. Equipment that can perform a wide range of handling tasks and which has a variety of uses and applications can often more fully utilised than a single-purpose one.

xiii. **Dead-weight Principle:** Reduce the ratio of mobile equipment dead-weight to pay load. Excess weight of mobile equipment not only costs money, but may require additional power and be slower to operate. It is, therefore, unwise to invest in a heavier weight piece of equipment than is required by the task to be performed.

xiv. **Motion Principle:** Equipment designed to transport materials should be kept in motion. This principle implies that mobile equipment should be kept moving, that is performing the function for which it was designed. It should be tied up for unduly/long periods of time for loading and unloading.

xv. **Idle-Time Principle:** Reduce idle or unproductive time of both handling equipment and manpower. Idle time is undesirable in nearly any industrial or commercial activity and especially so in the use of materials handling equipment or manpower. Equipment and manpower are "making money" when fully utilised. Therefore, every effort should be made to plan methods and schedule equipment to permit full use of both resources.

xvi. **Maintenance Principle:** Plan for preventive maintenance and scheduled repair of all handling equipment. The suggestions for application of the previous principles have implied the importance of preventive maintenance and scheduled repairs to the effectiveness of materials handling activities. Probably very few phases of the materials handling programme can contribute more to overall plant efficiency than a well-organised maintenance and repair function.

xvii. **Obsolescence Principle:** Replace obsolete handling methods and equipment when more efficient methods or equipment will improve operations. As with any other type of physical equipment, materials handling devices are subject to obsolescence, as well as depreciation. And, in a similar sense, so are handling methods. New ideas, techniques, methods and equipment are reported everyday and one should be continuously alert to be sure he is aware of the latest developments. Physical depreciation is not difficult to observe and to take consideration in an analysis but obsolescence is a less obvious characteristic. Many old, or even "ancient" pieces of equipment "still work" and even at relatively low costs for maintenance and repairs. However, new equipment may be faster, higher capacity, more efficient, etc. and result in a lower cost per unit handled even though it does require a capital investment.

xviii. **Control Principle:** Use material handling equipment to improve production control, inventory control and order handling. Since materials handling equipment is used to move materials through the plant and the production process, its use can have a great effect on the control of the items being moved. In many cases, handling equipments provides a direct mechanical path for the movement and thereby facilitates the control of the material.

xix. **Capacity Principle:** Use handling equipment to help achieve full production capacity. In many ways, this principle is a summation of all the preceding ones, in that a major objective of materials handling is to increase production capacity. Nearly every one of the foregoing principles will contribute in some way to higher production levels. However, the emphasis here is on those facts of operation and other principles that are directed specifically towards increasing or making full use of production capacity.

xx. **Performance Principle:** Determine efficiency of handling performance in terms of expense per unit handled. As pointed out above, there are many objectives of materials handling. However, an effective handling method may achieve one or several of these objectives. The primary criterion for measuring the efficiency of a handling technique is costs. Although efficiency could be measured in terms of total cost (and sometimes is) or equipment performance (as judged against selected criteria), the most effective means of measurement is in terms of rupees per unit handled. This is usually the ultimate measure from the point of view of management. It should be pointed out that there are cases where maximum economy is not the overall goal. Some materials handling devices may be installed to provide higher production rates, safer working conditions, or reduced physical effort. Time or effort saved may be the primary criteria and the cost of handling may be of little or no interest.

4.6 ADVANTAGES OF MATERIAL HANDING SYSTEM

Following are the advantages of efficient material handling system-

1. A good material handling system minimizes the movement of material, moves them continuously and at maximum rate which is advantages as under:-
    - i) Shorter operating cycle
    - ii) Reduction in handling cost.
2. It eliminates unproductive handling of materials like back tracking, re-handling etc.
3. It reduces ideal machine capacity thus ensuring better turnover of investment.
4. It reduces the ideal time of labour. Workers are required to pace with the production process supported by good handling system. Moreover, they are freed from the physical work of moving and positioning materials.

5. It eliminates the factory hazards and thus increases the safety of the operator.
6. The quality of the materials is maintained through minimum human touches, eliminations of breakage etc.
7. The factory area is used most effectively, unproductive overhead and floor areas are used most productively.
8. It avails of greater economy in store-room and facilitates materials issues.
9. It helps in maintaining effective production control.
10. It helps in providing better customer services due to
    - i) Reduced operating cost.
    - ii) Better quality of product, and
    - iii) Timely production.

4.7 ECONOMICS OF MATERIAL HANDLING

The American Society of Mechanical Engineers (ASME) had developed certain formulas for estimating the economics that are possible with the application of certain equipments to a material handling problems. The following factors in the handling costs are taken into account by letters:

- i. A = Percentage allowance on investment
- ii. B = Percentage allowance for insurance, taxes etc.
- iii. C = Percentage allowance for maintenance
- iv. D = Percentage allowance for depreciation and obsolesces
- v. E = Yearly cost of power supplies and other items in dollars
- vi. S = Yearly saving in direct labour cost in dollars
- vii. T = Yearly saving in fixes charges, operating charges or burden in dollars.

viii. U = Yearly savings or earning through increased production in dollars.

ix. X = Percentage of year during which equipment is used

x. I = Initial cost of equipment.

Formulae: The relations between these factors are expressed in the following formulae:

i. Maximum justifiable investment in dollars (i.e., Z)

$$Z = \frac{(S+T+U-E)X}{A+B+C+D}$$

ii. Yearly cost of maintaining the equipment (i.e., Y)

$$Y = I(A+B+C+D)$$

iii. Yearly profit from the operation of the equipments, above simple interest (i.e., V)

$$V = [(S+T+U-E)X]-Y$$

iv. The estimated rate of profit (i.e., P)

$$P = \frac{V}{I} + A$$

v. Number of years required for amortization of investment out of earning (i.e., H)

$$H = \frac{100}{P+D}$$

4.8 SUMMARY

Material handling involves the movement of materials from one place to the another for the purpose of processing the job done by material handling equipment include – moving, dropping, positioning, holding, releasing etc. Material handling function enjoys a pivotal role in production. Material handling operations offer enough scope for minimizations of handling cost. And if there were poor handling operations there will be delay in results. So, the importance of material handling like in the fact that the cost & time of materials can be reduced to greater extent by adopting a sound material handling procedure. Some materials handling devices may be installed to provide higher production rates, safer working conditions, or reduced physical effort. Time or effort saved may be the primary criteria and the cost of handling may be of little or no interest.

4.9 KEY WORDS

Material handling is the art and science involving the movement, packing and storing of substances in any form.

Hand Truck is a manually operated truck to carry small quantities of solid materials. Another version of these hand trucks is the pallet truck where instead these trucks are of use in handling pallets on which oil countries, small barrels or other items can be kept and transported

Chutes are the handling equipment which handles the material between fixed points. They move the light material and small jobs which can slide down under the gravity.

Conveyors perform the movement of uniform loads between fixed points. The materials are fed to the conveyor from some other source at the point of start. They are carried by the conveyor to the point of destination.

4.10 SELF ASSESSMENT EXERCISE

1. "Material handling is a necessary evil" Elaborate.
2. What is the relevance and importance of material handling in industry?
3. Give a detailed note on different type of material handling equipment.
4. Write an essay on the principles of materials handling

4.11 FURTHER READINGS AND SOURCES

- Arnold, J. R. Tony, Introduction to Material management, 4th Edition Upper Saddle River NJ: Prentice Hall, 2001
- Meyer, Fred E., and Mathew P. Stephens, Manufacturing Feasibilities Design and Materials Handling, 2nd edition Englewood Cliffs, NJ: Prentice Hall, 2001
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Subject: Production and Operations Management

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Course: MBA Course Code: CP-204

LESSON :5

Production Planning and controlling

Structure

5.13 KEYWORDS

5.14 SELF ASSESSMENT EXERCISE

5.15 FURTHER READINGS AND SOURCES

5.0 OBJECTIVES

After going through this lesson, you will be able to:

1. **Enumerate meaning, importance and steps for production planning and control**
2. **Understand the different types and of manufacturing process**
3. **Different types of production systems**
4. **Understand aggregate planning**

5.1 INTRODUCTION

After taking decisions about the type of business, its location, layout etc. the enterprise steps into the shoe of production manager and attempts to apply managerial principles to the production function in an enterprise.

Production is a process whereby raw material is converted into semi finished products and thereby adds to the value of utility of products, which can be measured as the difference between the value of inputs and value of outputs.

Production function encompasses the activities of procurement, allocation and utilization of resources. The main objective of production function is to produce the goods and services demanded by the customers in the most efficient and economical way.

Therefore efficient management of the production function is of utmost importance in order to achieve this objective.

5.2 PRODUCTION PLANNING AND CONTROL MEANING

Production planning is an essential prerequisite to production control. It involves management decision on the resources that the firm will require for its manufacturing operations and the selection of theses resource to produce the desired goods at appropriate time and at the least possible cost.

Once the enterprise has taken the decisions regarding the product design and production processes and system, its next task is to take steps for production planning and control, as this function is essentially required for efficient and economical production. One of the major problems of small scale enterprises is that of low productivity. Small scale industries can utilize natural resources, which are otherwise lying.

Planned production is an important feature of an enterprise. The production managers possessing the ability to look ahead, organize and coordinate and having plenty of driving force and capacity to lead and ability to supervise and coordinate work and simulates his associates by means of a programme of human relation and organization of employees, he would be able to get the best out of his industrial unit.

According to Alford and Beatty, production planning is defined as, “the techniques of foreseeing or picturing ahead, every step in along series of separate operations, each step to be taken in the right place, of the right degree and at the right time, and each operation to be done at maximum efficiency".

Gorden and Carson observe production; planning and control involve generally the organization and planning of manufacturing process. Especially it consists of the planning of routing, scheduling, dispatching inspection, and coordination, control of materials, methods, machines, tools and operating times. The ultimate objective is the organization of the supply and movement of materials and labour, machines utilization and related activities, in order to bring about the desired manufacturing results in terms of quality, quantity, time and place.

Production planning without production control is like a bank without a bank manager, planning initiates action while control is an adjusting process, providing corrective measures for planned development. Production control regulates and stimulates the orderly how of materials in the manufacturing process from the beginning to the end.

5.3 IMPORTANCE OF PRODUCTION PLANNING AND CONTROL

Production planning and control can facilitate the enterprise in the following ways

a) Optimum Utilization of Capacity:

With the help of Production Planning and Control (PPC) the enterprise can schedule its tasks and production runs and thereby ensure that its productive capacity does not remain idle and there is no undue queuing up of tasks via proper allocation of tasks to the production facilities. No order goes unattended and no machine remains idle.

b) Inventory control

Proper PPC will help the enterprise to resort to just- in- time systems and thereby reduce the overall inventory. It will enable to ensure that the right supplies are available at the right time.

c) Economy in production time

PPC will help the enterprise to reduce the cycle time and increase the turnover via proper scheduling.

d) Ensure quality

A good PPC will provide for adherence to the quality standards so that quality of output is ensured.

To sum up we may say that PPC is of immense value to the enterprise in capacity utilization and inventory control. More importantly it improves its response time and quality. As such effective PPC contributes to time, quality and cost parameters of enterprise success.

5.4 PRODUCT DESIGN

Product design is a strategic decision as the image and profit earning capacity of a firm depends largely on product design. Once the product to be produced is decided by the enterprise the next step is to prepare its design. Product design consists of form and function. The form designing includes decisions regarding its shape, size, color and appearance of the product. The functional design involves the working conditions of the product. Once a product is designed, it prevails for a long time therefore various factors are to be considered before designing it. These factors are listed below: -

a) Standardization
b) Reliability
c) Maintainability
d) Servicing
e) Reproducibility
f) Sustainability
g) Product simplification
h) Quality Commensuration with cost
i) Product value
j) Consumer quality
k) Needs and tastes of consumers.

Above all, the product design should be dictated by the market demand. It is an important decision and therefore the enterprise should pay due effort, time, energy and attention in order to get the best results.

5.5 DESIGN OF PRODUCTION SYSTEM

Production system is the framework within which the production activities of an enterprise take place. Manufacturing process is the conversion process through which inputs are converted into outputs. An appropriate designing of production system ensures the coordination of various production operations. There is no single pattern of production system which is universally applicable to all types of production system varies from one enterprise to another.

5.5.1 TYPES OF PRODUCTION SYSTEM

Broadly one can think of three types of production systems which are mentioned here under: -

a) Continuous production
b) Job or unit production
c) Intermittent production

(a) Continuous production: - It refers to the production of standardized products with a standard set of process and operation sequence in anticipation of demand. It is also known as mass flow production or assembly line production. This system ensures less work in process inventory and high product quality but involves large investment in machinery and equipment. The system is suitable in plants involving large volume and small variety of output e.g. oil refineries, cement manufacturing etc.

(b) Job or Unit production: - It involves production as per customer's specification. Each batch or order consists of a small lot of identical products and is different from other batches. The system requires comparatively smaller investment in machines and equipment. It is flexible and can be adapted to changes in product design and order size without much inconvenience. This system is most suitable where heterogeneous products are produced against specific orders.

(c) Intermittent Production: Under this system the goods are produced partly for inventory and partly for customer's orders. E.g. Components are made for inventory but they are combined differently for different customers. . Automobile plants, printing presses, electrical goods plant are examples of this type of manufacturing.

5.6 MANUFACTURING PROCESS

The nature of the process of production required by these three different types of production system are distinct and require different conditions for their working. Selection of manufacturing process is also a strategic decision as changes in the same are costly. Therefore the manufacturing process is selected at the stage of planning a business venture. It should meet the basic two objectives i.e. to meet the specification of the final product and to be cost effective.

5.6.1 TYPES OF MANUFACTURING PROCESS

The manufacturing process is classified into four types.

I. Job production
II. Batch production
III. Mass or flow production
IV. Process Production

I. Job Production: - Herein one or few units of the products are produced as per the requirement and specification of the customer. Production is to meet the delivery schedule and costs are fixed prior to the contract.

II. Batch Production: - In this, limited quantities of each of the different types of products are manufactured on same set of machines. Different products are produced separately one after the other.

III. Mass or flow production: - Under this, the production run is conducted on a set of machines arranged according to the sequence of operations. A huge quantity of same product is manufactured at a time and is stocked for sale. Different product will require different manufacturing lines. Since one line can produce only one type of product, this process is also called as line flow.

IV. Process Production:- Under this, the production run is conducted for an indefinite period.

5.6.2 FACTORS AFFECTING THE CHOICE OF MANUFACTURING PROCESS

Following factors need to be considered before making a choice of manufacturing process.

1. Effect of volume/variety: This is one of the major considerations in selection of manufacturing process. When the volume is low and variety is high, intermittent process is most suitable and with increase in volume and reduction in variety, continuous process become suitable. The following figure indicates the choice of process as a function of repetitiveness. Degree of repetitiveness is determined by dividing volume of goods by variety.

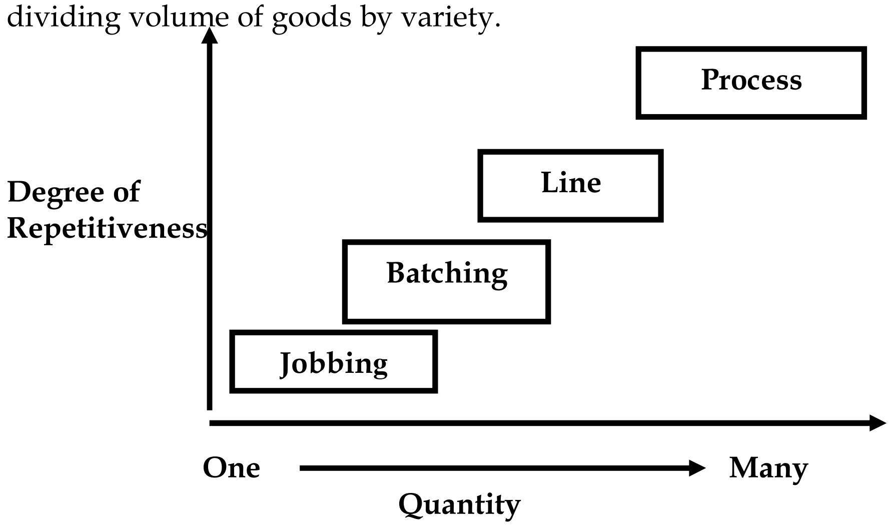


Figure 5.1: Types of Production Processes

2. **Capacity of the plant:** Projected sales volume is the key factor to make a choice between batch and line process. In case of line process, fixed costs are substantially higher than variable costs. The reverse is true for batch process thus at low volume it would be cheaper to install and maintain a batch process and line process becomes economical at higher volumes.

3. **Lead time: -** The continuous process normally yields faster deliveries as compared to batch process. Therefore lead-time and level of competition certainly influence the choice of production process.

4. **Flexibility and Efficiency:** - The manufacturing process needs to be flexible enough to adapt contemplated changes and volume of production should be large

5. **Enough to lower costs.**

Hence it is very important for entrepreneur to consider all above mentioned factors before taking a decision regarding the type of manufacturing process to be adopted as for as SSI are concerned. They usually adopt batch processes due to low investment.

5.7 STEPS OF PRODUCTION PLANNING AND CONTROL

Production Planning and Control (PPC) is a process that comprises the performance of some critical functions on either side, viz., planning as well as control. See figure 5.2.

5.8 PRODUCTION PLANNING

Production planning may be defined as the technique of foreseeing every step in a long series of separate operations, each step to be taken at the right time and in the right place and each operation to be performed in maximum efficiency. It helps entrepreneur to work out the quantity of material, manpower, machine and money requires for producing predetermined level of output in given period of time.

Routing

Under this, the operations, their path and sequence are established. To perform these operations the proper class of machines and personnel required are also worked out. The main aim of routing is to determine the best and cheapest sequence of operations and to ensure that this sequence is strictly followed. Routing procedure involves following different activities.

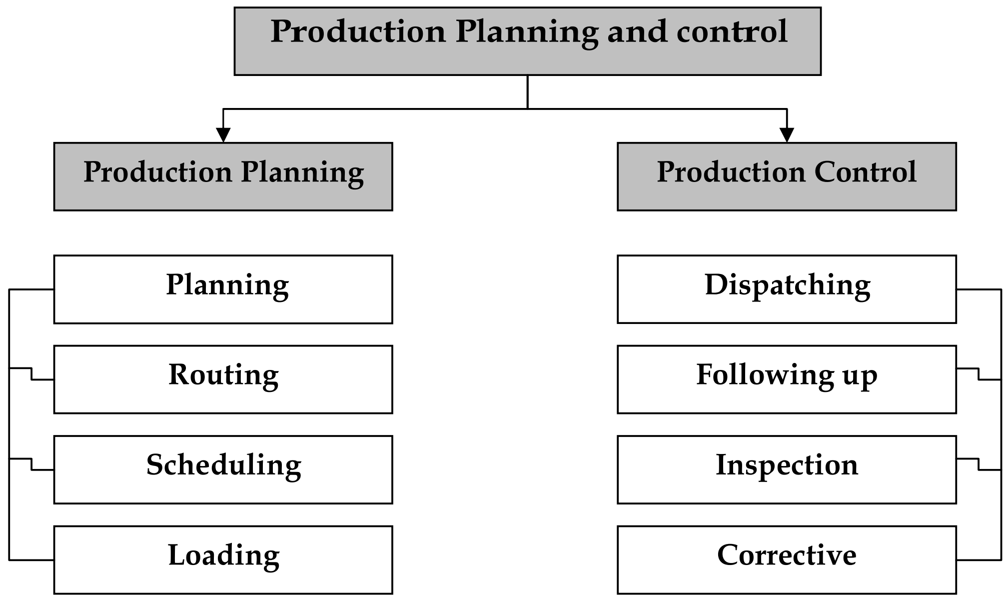


Figure 5.2: PPC Process

1. An analysis of the article to determine what to make and what to buy.
2. To determine the quality and type of material
3. Determining the manufacturing operations and their sequence.
4. A determination of lot sizes
5. Determination of scrap factors
6. An analysis of cost of the article
7. Organization of production control forms.

Scheduling

It means working out of time that should be required to perform each operation and also the time necessary to perform the entire series as routed, making allowances for all factors concerned. It mainly concerns with time element and priorities of a job. The pattern of scheduling differs from one job to another which is explained as below:

Production schedule: The main aim is to schedule that amount of work which can easily be handled by plant and equipment without interference. Its not independent decision as it takes into account following factors.

1. Physical plant facilities of the type required to process the material being scheduled.
2. Personnel who possess the desired skills and experience to operate the equipment and perform the type of work involved.
3. Necessary materials and purchased parts.

Master Schedule: Scheduling usually starts with preparation of master schedule which is weekly or monthly break-down of the production requirement for each product for a definite time period, by having this as a running record of total production requirements the entrepreneur is in better position to shift the production from one product to another as per the changed production requirements. This forms a base for all subsequent scheduling acclivities. A master schedule is followed by operator schedule which fixes total time required to do a piece of work with a given machine or which shows the time required to do each detailed operation of a given job with a given machine or process.

Manufacturing schedule: It is prepared on the basis of type of manufacturing process involved. It is very useful where single or few products are manufactured repeatedly at regular intervals. Thus it would show the required quality of each product and sequence in which the same to be operated

Scheduling of Job Order Manufacturing: Scheduling has acquires greater importance in job order manufacturing. This will enable the speedy execution of job at each center point.

Loading

The next step is the execution of the schedule plan as per the route chalked out it includes the assignment of the work to the operators at their machines or work places. So loading determines who will do the work as routing determines where and scheduling determines when it shall be done. Gantt Charts are most commonly used in small industries in order to determine the existing load and also to foresee how fast a job can be done. The usefulness of their technique lies in the fact that they compare what has been done and what ought to have been done.

5.9 PRODUCTION CONTROL

Production control is the process of planning production in advance of operations, establishing the extract route of each individual item part or assembly, setting, starting and finishing for each important item, assembly or the finishing production and releasing the necessary orders as well as initiating the necessary follow-up to have the smooth function of the enterprise. The production control is of complicated nature in small industries. The production planning and control department can function at its best in small scale unit only when the work manager, the purchase manager, the personnel manager and the financial controller assist in planning production activities.

The production controller directly reports to the works manager but in small scale unit, all the three functions namely material control, planning and control are often performed by the entrepreneur himself. Production control starts with dispatching and ends up with corrective actions.

Dispatching

Dispatching involves issue of production orders for starting the operations. Necessary authority and conformation is given for:

1. Movement of materials to different workstations.
2. Movement of tools and fixtures necessary for each operation.
3. Beginning of work on each operation.
4. Recording of time and cost involved in each operation.
5. Movement of work from one operation to another in accordance with the route sheet.
6. Inspecting or supervision of work.

Dispatching is an important step as it translates production plans into production.

Follow up

Every production programme involves determination of the progress of work, removing bottlenecks in the flow of work and ensuring that the productive operations are taking place in accordance with the plans. It spots delays or deviations from the production plans. It helps to reveal detects in routing and scheduling, misunderstanding of orders and instruction, under loading or overloading of work etc. All problems or deviations are investigated and remedial measures are undertaken to ensure the completion of work by the planned date.

Inspection

This is mainly to ensure the quality of goods. It can be required as effective agency of production control.

Corrective measures

Corrective action may involve any of those activities of adjusting the route, rescheduling of work, changing the workloads, repairs and maintenance of machinery or equipment, control over inventories of the cause of deviation is the poor performance of the employees. Certain personnel decisions like training, transfer, demotion etc. may have to be taken. Alternate methods may be suggested to handle peak loads.

5.10 AGGREGATE PLANNING DEFINED

Aggregate Planning may be defined as 'Intermediate Planning' which is normally done for a period of up to one year's time. The word 'Aggregate' symbolizes that the planning is done at the broadest level. The details of the individual product requirements and the detailed scheduling of various resources (men/machines) and other facilities is normally not done and left to the individual at lower level to carry out the same.

Various Steps Involved

1. The first step involved is the forecast of resource for a reasonable period (normally up to a year's time).
2. The state of the system at the end of last period.
3. Once these two factors are decided, the decision for the upcoming period about the size of the workforce and production rate can be known.

4. Also, the decision made may call for having or laying of personnel thereby expanding or contracting the effective capacity of the productive system.
5. Special techniques available for Aggregate Planning are:
    a. Graphical Method
    b. Linear Decision Rule (LDR)

Objectives of Aggregate Planning

1) To make use of the available facilities and resources to ensure their optimum use.
2) Aggregate Planning increases the range of alterations for capacity use through various techniques viz., hiring of additive manpower or laying out of personnel thereby fixing the size of the workforce and the production rate.
3) Inventories for work-in-progress and finished goods is made during the loan demand so as to use the same to meet the peak demand.
4) More time is devoted to produce more from the same machinery capacity through properly employing the sequencing and scheduling techniques.
5) The following variables are studied under the Aggregate Planning:
    a) Production Rate
    b) Labour Employment
    c) Inventories
    d) Sub-contracting (if permissible)

If the production rate and labour employment are fixed, the Inventories & Sub Contracting can be derived therefore. However, Aggregate Planning is not long-term planning.

Conversion of an Aggregate Plan into a Master Schedule

Month	**Apr.**	**May**	**June.**	**July.**	**Aug.**	**Sept.**
UNITS REQD.	4000	3000	5000	5000	6000	3000
Month	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**
UNITS REQD	3000	4000	5000	6000	5000	4000

MASTER SCHEDULE

Month Rating	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sept.**
6A	2000	2000	3000	3000	4000	2000
16A	1200	500	1000	1000	1000	-
20A	-	200	-	500	-	-
25A	-	-	500	-	500	500
32A	500	-	500	200	200	200
40A	200	-	-	200	200	200
63A	100	-	500	100	100	100
	4000	2700	5500	5000	6000	3000

Month Rating	**Apr.**	**May**	**Jun.**	**July.**	**Aug.**	**Sept.**
6A	2000	3000	4000	4000	3000	3000
16A	500	500	-	500	500	500
20A	500	-	500	500	500	-
25A	-	500	500	500	500	500
32A	-	-	-	200	200	-

40A	-	-	-	200	200	-
63A	-	-	-	100	100	-
	3000	4000	5000	6000	5000	4000

Various Strategies Involved in Aggregate Planning

The objective of the various strategies of Aggregate Planning is to smooth out the peaks and voltages of the demand during the Planning horizon. This is achieved through actions briefed below:

1. Without changing production output rate.
2. Varying production output rate.
3. Appropriate Inventory Level.
4. Subcontracting.
5. Capacity Utilisation.

(1) Without Changing Production Level

- **i.** During periods of low demand, the increase of sales of goods can be done through special discount schemes/cutting prices etc.
- **ii.** During periods of high demand, the method of back logging orders can be adopted but depends upon the willingness of the customer if he could wait for that much time. However, backlogging of orders is not without danger of loosing goodwill.

(2) Change in Production Level

The change in production level is done to the extent possible to contain the fluctuation in demand. This is achieved as follows:

a. When demand is on the increasing side, the output rate can be changed by hiring workers temporarily. Wherever, it is possible to increase production through change in workforce or by keeping workers on over-time (OT) or through some special Incentive Schemes' by altering the capacity through increase of a few equipments/machinery or sometimes by changing the planned plant shut downs.
b. When demand is decreasing, changing the output rate by logging off Casual/Temporary Workers/by paying full salary to employees but reducing output rate for a short period - Without demoralising/ demotivating the workforce or by reducing capacity by switching off part machinery whenever possible.

(3) By Appropriate Inventory Level

Inventory of furnished goods is increased during periods of low demand and the same can be used to meet high demand/seasonal demand in other periods. Manufacturing firms can use this strategy very well.

(4) Sub Contracting

Sub contracting means meeting demand through acquiring part of goods from other manufacturers/producers rather than making in-house. House benefits must be weighed against cost and quantity.

(5) Capacity Utilisation

Capacity utilization is very common to service industries, organisations or companies which cannot store products or services. They must arrange to meet peak load through sharing capacity utilizations. Example: Telephone Companies, Electric Power Companies & Computer Time Sharing Companies.

Solved Examples on Aggregate Planning

Prob. 1: The forecasted demand of an item, influenced by seasonal factors is given below:

April	200	Oct	260
May	81	Nov	176
June	270	Dec	84
July	560	Jan	108
Aug	805	Feb	190
Sept	100	March	450

The Number of working days in the financial years is given below:

April	20	Oct	20
May	27	Nov	22
June	27	Dec	28
July	28	Jan	27
Aug	23	Feb	19
Sept	25	March	25

Show the daily requirement and cumulative demand and determine the production rate to meet the average demand.

Sol. The production requirements are tabulated hereunder:-

Month	Forecasted Demand	No. of Production Days Available	Demand per day (2/3)	Cumulative Production days	Cumulative Demand (units)

1	2	3	4	5	6
April	200	20	10	20	200
May	81	27	3	47	281
June	270	27	10	74	551
July	560	28	20	102	1111
Aug	805	23	35	125	1916
Sept	100	25	4	150	2016
Oct	260	20	13	170	2276
Nov	176	22	8	192	2452
Dec	84	28	3	220	2536
Jan	108	27	4	247	2644
Feb	190	19	10	266	2834
March	450	25	18	291	3284
	3284	291			

$$\text{Average Demand} = \frac{\text{Total Demand}}{\text{Total Production Days}}$$

$$= 3284/291$$

$$= 11.28 = 11 \text{ units (day)}$$

Varying Workforce Level to Meet Demand

Prob. 2: A company employs 20 persons at an average salary of Rs 2000 per month. Each unit of production requires 4 standard hours to produce. Hiring cost is estimated Rs.1500 per month man, layoff cost are estimated at Rs 1000 per man per month given below, the forecasted demand, find the total cost.

MONTH	DEMAND (Units)	WORKING
April	1000	25
May	2340	26
June	864	24
July	1674	27
Aug.	1408	22
Sept.	1512	18

So

MONTH	**April**	**May**	**June**	**July**	**Aug**	**Sept.**
1. MEN REQD	$\frac{1000x4}{25x8}$ =20	$\frac{2340x4}{26x8}$ =45	$\frac{864x4}{24x8}$ =18	$\frac{1674\times4}{27x8}$ =31	$\frac{1408x4}{22x8}$ =32	$\frac{1512x4}{18x8}$ =42
2. REGULAR LABOUR SALARY(Rs)	2000x20 =40,000	2000x45 =90,000	2000x18 =36,000	2000x31 =62,000	2000x32 =64,000	2000x42 =84,000
3. HIRING COST (Rs)	NIL	25x1500 =37,500	Nil	11x1500 16500	12x1500 =18,000	22x1500 =33,000
4.LAY-OFF (Rs) REQD	NIL		2 x 1000 =2000			
TOTAL (Rs)	40,000	1,27,500	38,000	78,500	82,000	1,17,000

Total Cost = Rs =4,83,000

Keeping Workforce Fixed

Prob. 3: If in the above example, the number of men employed is 30, the inventory Carrying cost is Rs 6/unit/month and the shortage cost is Rs 100/unit/month. Then find the total cost under this plan. Compare the two plans, which plan would you recommend and why?

Sol.

	MONTH	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**
1	MEN REQD	30	30	30	30	30	30
2	REGULAR LABOUR SALARY (Rs)	2000x30 =60,000	2000x30 =60,000	2000x30 =60,000	2000x30 =60,000	2000x30 =60,000	'2000x30 =60,000
3	INVENTORY (Units)	1500 -1000 =500	500 +1560 -2340 =-280	-280 +1440 -864 =296	296 +1620 -1674 =242	242 +1320 -1408 =154	154 1080 -1512 =-278
4	INVENTORY CARRYING COST (Rs)	500x6 =3000		296x6 =1576	242x6 =1452	154x6 =924	
5	SHORTAGE COST (Rs)		278xl00 =27,800				
	TOTAL (Rs)	63,000	88,000	61,576	61,452	60,924	87,800

Total Cost = Rs **422,752**

Comparison of strategy I vs. strategy II

The second strategy is more economical. Moreover, it is very advantageous particularly from the following angles:

(i) Manpower is fixed and no hiring and firing.

(ii This keeps manpower motivated; consequently there is no demoralizing effect.

(iii) Extra inventory in most of the months is good to meet extra demand.

(iv) However, shortage to the extent possible should be avoided even if men have to be kept on Incentive/O.T./more men on extra duty have to be engaged.

Student Activity 2

1. Arrange the following steps of aggregate planning process in the correct order as presented to you earlier:

a) Analyze the system at the end of the last period

b) Special techniques for aggregate planning are used

c) Decide the production rate

d) Expand or contract workforce strength

e) Forecast for the upcoming year

2. In your opinion, is outsourcing also a strategy under aggregate planning? Give a business example in support of your answer.

3. Given the following data, compute the cost of operations for a plant.

Month	Demand	Working days
January	1000	26
February	1812	22
March	1306	25
April	1999	25

A working day comprises 7.5 working days. Each unit requires 3.5 working hours and workers are allowed half hour break from the total working hours everyday. Hiring cost is Rs 1000 per man per month while the layoff costs are approximately Rs 800 per man per month. Assume decimal points to be whole numbers.

Would the total cost be lower if the plant manager followed a fixed manpower strength policy? Assume s/he employs 20 workers throughout the months. Calculate the total cost of operation in such case.

5.11 PLANT CAPACITY

Capacity may be defined as the maximum or limiting capability of a production unit to produce in a specific period. This is expressed in terms of output per unit of time. If stated period of time is one month, the capacity is said to be the limiting capability of the producing unit in one month, e.g., 10,000 units per month. This capacity is the capability of the producing unit under given (or specified) conditions, e.g., one shift working/two shifts working or three shifts working or one shift + 4 hours OT working two shifts + 4 hours O.T. working and so on. Thus, the capacity is related to the intensity of the facilities used.

Measures of Capacity

Different types of organisations use different measures of capacity, e.g. steel plant uses tons of steel produced, beer plant uses cases of beer produced and auto plant uses number of autos produced.

Types of Capacity

Designed Capacity: Designed capacity is the theoretical maximum capacity that producing unit can produce under ideal conditions. This is based on the designed parameters by R & D.

Effective Capacity: Effective capacity is per cent utility of the designed capacity.

$$\frac{\text{Achievable Capacity}}{\text{Designed capacity}} \times 100$$

***Rate Capacity**:* Rated capacity is the actual capacity achievable under stated conditions.

Rate capacity = Achievable Capacity x Efficiency

= (Designed Capacity x Utilisation) x Efficiency

Examples: The steel melting shop arc furnace is designed for a production of 50 t Capacity/heat. The average efficiency is found to be 90% and the utilization of the furnace in a week of 168 hours, i.e. 7 days working. If the average heat time is four Hours/heat, find the rated capacity of the steel melting shop.

Rated Capacity = (168/4) x .90 x 50

= 1890 tons per week

Need for Capacity Planning

Whenever the existing demand changes or addition of new product(s) has to be made, then re-assessment of capacity at various stages of production, depending upon the processed details, is called for and steps are taken to take care of the desired capacity demands.

Thus Capacity Planning Design includes:

1. Re-assessment of existing capacity;
2. Effect of change in demand, i.e., effect of addition, deletion of products and their impact on existing capacity;
3. Identifying ways of meeting desired capacity through
   a. Better utilizations,
   b. Higher efficiency,
   c. Overtime,
   d. Adding a shift or two,
   e. Adding new machinery, adding another production unit and so on.

Solved Problem on Investment and Capacity Consideration

The demand of a certain product indicates that it will increase @ 2,000 units per year uniformly for four years. Two machines P and Q are available with production capacities of 4,000 and 8,000 units per year respectively. Work out investment and capacity of the unit.

Ans. The investment costs and operating costs for the next four years are given below:

MACHINE 'P'

(A) Investment (Rs)		**(B) Operating Costs (Rs)**	
Present	200,000	100	Per unit
After One (1) year	220,000	100	-do-
After two years	240,000	105	-do-
After three years	280,000	105	-do-

MACHINE 'Q'

(A) Investment (Rs)		(B) Operating Costs (Rs)	
Present	360,000	90	Per unit
After One (1) year	400,000	90	-do-
After two years	440,000	95	-do-
After three years	500,000	95	-do-

Find which of the following four plans is the most economical:

PLAN I

Capacity added is in increments of 4,000 units, i.e, it is added in the beginning of first year and third year.

PLAN II

Capacity added is in increments of 8,000 units.

PLAN III

Capacity added is in increments of 4,000 units, taking outside help, if needed, during first and third years.

PLAN IV

Capacity added is in increments of 4,000 units, taking outside help in first year.

The outside help is available @ Rs 180 per unit. Take average rate of interest @ 15%.

Sol. The demand increased uniformly @ 2,000 units per year

This means:

At the beginning of first year	=	0	units
At the end of first year	=	2,000	"
Second year	=	4,000	"
Third year	=	6,000	"
Fourth year	=	8,000	"

CAPACITY REQUIREMENTS

For First year	= (0 + 2000) ÷ 2 "	=	1,000 units
For Second year	= (2000 + 4000) ÷ 2 "	=	3,000 "
For Third year	= (4000 + 6000) ÷ 2 "	=	5,000"
For Fourth year	= (6000 + 8000) ÷ 2"	=	7,000"

PLAN I

Capacity added is in increments of 4,000 units, i.e., it is' added in first year and third year beginning.

Computation of Total Cost

(a) Fixed Costs

Investment in first year	=	Rs 200,000
At end of second year	=	(Rs 240,000)/ $(1+.15)^2$
	=	Rs 181,000
Total Fixed Cost	=	Rs.381, 000 approximately,

(b) Operating Costs

During first year	=	1000 x 100 x 1/ $(1 + 0.15)^{.5}$
	=	1000 x 100 x 0.935

= Rs.93, 500

During second year = $3000 \times 100 \times 1/\ (1+0.15)^{1.5}$

= $3000 \times 100 \times 0.813$

= Rs.2, 43,900

During third year = $5000 \times 105 \times 1/\ (1+0.15)^{2.5}$

= $5000 \times 105 \times 0.707$

= Rs.3, 71,000

During fourth year = $7000 \times 105 \times 1/\ (1+0.15)^{3.5}$

= $700 \times 105 \times 0.615$

= Rs.4, 52,000

Total Operating Costs = Rs.11, 61,000

Total Cost incurred during Plan I

= (a) + (b)

= 3, 81,000 + 11, 61,000

= Rs.15, 42,000

Plan II

Capacity added in increments of 8000 units

(a) Fixed Costs

Investment in first year = Rs.3, 60,000

Total Fixed Cost = Rs.3, 60,000

(b) Operating Costs

During first year = $1000 \times 90 \times 1/\ (1 + .15)^{.5}$

= $1000 \times 90 \times 0.935$

= Rs.84, 000 appx.

During second year = $3000 \times 90 \times 1/\ (1+.15)^{1.5}$

= $3000 \times 90 \times 0.813$

= Rs.2, 18,000

During third year = $5000 \times 95 \times 1/\ (1 + .15)^{2.5}$

= $5000 \times 95 \times 0.707$

= Rs.3, 35,000

During fourth year = $7000 \times 95 \times 1/\ (1+.15)^{3.5}$

= $7000 \times 95 \times 0.615$

= Rs 4, 06,000

Total Operating Costs = Rs.10, 43,000

Total Cost incurred during Plan II

= (a) + (b)

= 3, 60,000 + 10, 43,000

= Rs.14, 03,000

PLAN III

Capacity added in increments of 4000 units, taking outside help, if needed, during first and third year.

(a) Fixed Costs

Investment in second year = Rs $220{,}000 \times 1/\ (1+.15)^{1}$

= Rs.1, 91,000

At the end of third year = (Rs 280,000) $1/\ (1.15)^{3}$

= Rs 1, 82,000

Total Fixed Cost = Rs 3, 73,000 approx.

(b) Operating Costs

During first year = $1000 \times 180 \times 1/\ (1+.15)^{.5}$

= $1000 \times 180 \times 0.935$

= Rs 1, 68,000

During second year = 3000 x 100 x 1/ $(1+.15)^{1.5}$

= 3000 x 100 x 0.813

= Rs 2, 43,900

During third year = 1000 x 180 x 1/ $(1+.15)^{2.5}$ + 4,000 x 105 – (1+.15)

= 1000 x 180 x 0.707 + 4,000 x 105 x 0.707

= Rs 381,000

During fourth year = 7000 x 105 x 1/ $(1+.15)^{3.5}$

= 7000 x 105 x 0.615

= Rs 4, 52,000

Total Operating Costs = Rs 12, 45,000

Total Cost incurred during Plan III

= (A) + (B)

= 3, 73,000 + 12, 45,000

= Rs 16, 18,000

PLAN IV

Capacity added in increments 4000 units, taking outside help in first year.

(a) Fixed Costs

Investment in second year = Rs 4, 00,000 x 1/ $(1+.15)^{1}$

Total Fixed Cost = Rs 3, 48,000

(b) Operating Costs

During first year = 1000 x 80 x 1/ $(1+1.15)^{.5}$

= 1000 x 80 x 0.935

= Rs 1, 68,000

During second year = 3000 x 90 x 1/ $(1 + .15)^{1.5}$

	=	3000 x 90 x 0.813
	=	Rs 2, 19,000
During third year	=	5000 x 95 x 1/ $(1+.15)^{2.5}$
	=	5000 x 95 x 0.707
	=	Rs 3, 33,000
During fourth year	=	7000 x 95 x 1/ $(1+.15)^{3.5}$
	=	7000 x 95 x 0.615
	=	Rs 4, 05,000
Total Operating Costs	=	Rs 11, 25,000.

Total Cost incurred during Plan IV

	=	(A) + (B)
	=	3, 48,000 + 11, 25,000
	=	Rs 14, 73,000

Summary of result for the above four (4) plans is:

PLAN NO.	**TOTAL COST (Rs.)**
I	15, 42,000
II	14, 03,000
III	16, 18,000
IV	14, 73,000

Thus, the best plan is Plan II, i.e., capacity added in increments of 8,000 units per years i.e., at the beginning itself.

Student Activity 3

1. What is MRP and how is it beneficial in the modern assembly lines?
2. State whether the following formulate are true or false:
   a) Effective capacity =

$$\frac{\text{Achievable capacity} - \text{Designed capacity} \times 100}{\text{Designed capacity}}$$

b) Rated capacity = Achievable capacity x Efficiency

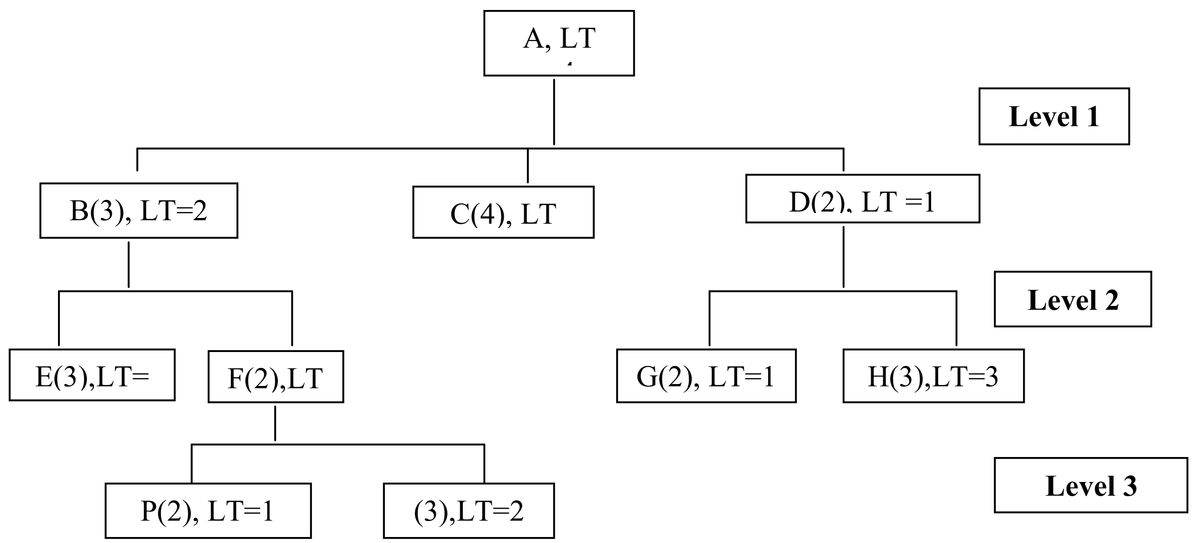
c) Achievable capacity = Effective capacity x Utilization

3. The manufacturer of Product A has the following product structure:

a) Prepare the Bill of Materials.

b) Find the requirement at each level.

Draw the plan order release.



4. If the rated capacity of a plant is 2205 tons per week, then find the effective capacity, given utilization of 140 hours per week and efficiency of 90 percent.

5.12 SUMMARY

Production Planning and Control (PPC) form the nerve centre of a production system. It is responsible for organizing all input resources and ensures coordinated flow of materials from raw to finished state. Thus, this section of the book dedicates itself to defining and analyzing

PPC. It also discusses aggregate planning and capacity utilization has been detail with, by appropriate theory and practical questions.

5.13 KEYWORDS

Production planning: Planning of various inputs for a given period so that the customer get the right quality of products at right place, price and in time.

Production control: It measures the actual performance of the production units and taking remedial action called for to see that the production actually achieved is not less than the target set in advance.

Aggregate planning: Intermediate planning which is normally done for a period of up to one year's time.

Capacity: Maximum or limiting capability of a production unit to produce in a specified job.

5.14 SELF ASSESSMENT EXERCISE

1. What is production planning and control? Discuss its importance.
2. What is manufacturing process? What are the main factors affecting the choice of selecting different manufacturing processes.
3. Give a detailed note on meaning, process, and importance of production planning.
4. What is aggregate planning? Enumerate the objective and advantages of aggregate planning.

5.15 FURTHER READINGS AND SOURCES

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Subject: Production and Operations Management

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Course: MBA Course Code: CP-204

LESSON: 6

MATERIAL REQUIREMENT PLANNING

Structure

OBJECTIVES

1. **Understand material requirement planning (MRP)**
2. **Understand the process of MRP**
3. **Put thought on practical Issues on MRP**

6.1 MATERIAL REQUIREMENT PLANNING (MRP)

The business environment today is complex with uncertainties, competition and change.

To be competitive, an enterprise should have good processes and systems, which should be able to adjust to the changes in the business environment. The change can be of technological innovations, government policies, interest rates, competition, changing customer perception and many other fluctuating forces.

To achieve competitive advantage companies differentiate themselves from other players in the market. There are various ways by which a company can do so.

- The products that are going to be produced should conform to the requirements of the market and the design should be such that it should forecast and accommodate customer's future needs.
- The marketing department, which keeps an eye on the trends and needs of the market, should give relevant information to the production department so that they would make periodic and relevant changes to the products.

- The demand-supply factor in the market should be analyzed for proper production planning and there should be some system that can assist management to take strategic decisions.
- Competitive advantage starts from sourcing the right raw material at the right time. For this, the organization should have a good system of managing its vendors, which includes parameters of quality, price and delivery schedules.
- Manufacturing inventory system should be optimum, which is essential in achieving the first stage of the cost reduction process.

The function of a manufacturing inventory system is to translate the Master Production Schedule into detailed component material requirements and orders, based on inventory. The system determines item-by-item, what is to be processed and when, as well as what is to be manufactured and when. This is based on order priorities and available capacities. As the purpose of manufacturing inventory is to satisfy production requirements, the production plan is the source of demand and thus the demand is deterministic.

From the point of view of quantity and timing of related production planning systems, four categories of systems are possible to manage and control inventories.

1. Statistical Order Point: The system provides optimal solutions by means of standard solutions to standard situations using statistical information to calculate optimal

item parameters, e.g., automatic recalculation of lead times, economic order quantities and reorder points.

2. Lot Requirement Planning: An order method that is driven by forecast periods. Order quantities are made to match demand in each specific forecast period.
3. Time Phased Order Point: Time-phased replenishment relies on actual demand not established stock levels - to drive the ordering and quantities of inventory for manufacture or distribution.
4. Material Requirements Planning: A Material Requirements Planning system, narrowly defined, consists of a set of logically related procedures, decision rules and records, designed to translate a Master Production Schedule into net requirements and the planned coverage of such requirements, for each component inventory item needed to implement this schedule.

MRP is probably the most comprehensive approach to manufacturing inventory and other dependents which demand an efficient inventory management system.

In the process of planning, MRP system allocates existing inventories on hand to which turns to be manufactured. And based on the gross requirements, it reevaluates the validity of the timing of any outstanding orders. The system establishes a schedule of planned orders for each item, including orders, if any, to be released immediately plus orders scheduled for release at specific future dates. Planned order quantities are computed using any of several lot sizing rules.

6.2 Assumptions and Prerequisites

There are a number of assumptions that are fundamental to all MRP models. In addition, there are also prerequisites that ensure that the assumptions provide the necessary optimum outputs. These are discussed below with some principles that are employed by MRP systems:

Assumptions: The MRP system makes certain assumptions regarding inventories. The models assume that:

- Lead times for all inventory items are known and can be supplied to the system, at least as estimates.
- Every inventory item under item control goes into and out of stock, i.e., there will be reportable receipts, following which the item will be in an 'on-hand' state and will eventually be disbursed to support an order for an item into which it is merged.
- All components of an assembly must be available at the time an order for that assembly is to be released to the factory.
- Components and materials are discretely disbursed and used. In the case of materials that come in continuous form (e.g., rolls of sheet metal), the standard planning procedures are modified

and the system adapted to handle such inventory items properly.

- The process is independent, i.e., a manufacturing order for any given inventory item can be started and completed on its own and not be contingent on the existence or progress of some other order for completing the process. Thus, 'mating part' relationships and set up dependencies do not fit the scheme of MRP.

Prerequisites: In order to develop a MRP model there are some prerequisites. The principle prerequisites for a standard MRP system are as follows.

1. A Master Production Schedule exists and can be stated in bill of materials form;
2. All inventory items are uniquely identified;
3. A bill of material exists at the time of planning;
4. Inventory records contain data on the status of every item;
5. There is integrity of file data;

In addition, other prerequisites in building MRP models are;

1. Individual item lead times are known;
2. Every inventory item goes into and out of stock;
3. All of the components of an assembly are needed at the time of release of assembly orders;

4. There is discrete disbursement and usage of component materials; and
5. Process independence of manufactured items is ensured.

6.3 Material Planning

Material Planning is a technique of determining the requirements of raw materials, components, and spares etc., required for the manufacturing of the product. If the delivery date of the finished product is known in advance, then the ordering time and quantity of other work-in-progress can be planned accurately with the help of mathematical calculations. This planning of work-in-progress of the finished goods is known as Material Requirement Planning (or MRP).

While doing Material Requirement Planning one has to look for the following things:

1. All the components, sub-assemblies and assemblies are known so that they all can participate for the planning of required materials.
2. The lead time of all the assemblies and sub-assemblies should be known.
3. The inventory already in hand should be considered for the present Material Requirement Planning.

6.4 The MRP Process

The MRP process is initiated once the customer orders for the finished goods from the supplier. Then the forecasting is done for the finished goods. A master plan is prepared for the production process. This master plan contains all the constituents of the production process that would finally lead to the resultant product. The master plan for production initiates the process of Material Requirement Planning. For MRP two other inputs are inventory which is already in hand and product design and development. Then we have to see whether the capacity is adequate for the production of requisite number of finished goods demanded by the customer. If the answer is negative, then again we have to reschedule our production plan. But if the answer is affirmative i.e., there is adequate capacity then we can go for the final master plan that would ultimately lead us to the Material Requirement Planning.

6.5 The MRP System

The MRP is applicable to any manufacturing system that involves discrete, engineered products involving assembling and part fabrication is dependent on the demand situation. Since master production schedule (MPS) is essentially an input to the system, MRP could be regarded primarily as a component requirement planning system.

The basis for MRP design is based on a concept of dependent demand and a time phasing approach. The approach combines three principles:

1. The inventory system deals with dependent demand.
2. Component demand can be precisely determined from the master schedule.

3. The optimum levels of inventory can be determined by time phasing, i.e., segmenting inventory status data by time.

Time phasing means adding the dimension of time to inventory data. The status is established by recording and storing information on either specific dates or planning periods with which the inventory are associated. The main aim of time phasing is to provide answers to questions related to manufacturing inventory management. It answers · all questions related to when the material is required.

6.6 Benefits of MRP System

The MRP system is very much commendable to computerization. Hence, for very large number of products e.g. for many assembled products, perhaps with sub-assemblies, the number of parts involved can easily be in thousands. Requirement generation, inventory control, time phased orders and capacity requirements, all have to be coordinated. All this can be done in a relatively straight forward manner. Thus practically all advantages of computerized planning can be thought of with MRP system e.g. change in production schedule due to change in market demand, cancellation of orders, change in procurement policy, delays in receipt of incoming materials and also the change in capacity planning etc. all this may reduce idle time at various stages and hence may increase productivity by men, machine & materials.

6.7 Outputs - The Materials Requirement Plan

The common objective of all MRP systems is to determine (gross and net) requirements, i.e. discrete period demands for each item of inventory, so as to be able to generate information needed for correct action in ordering inventory, i.e., relating to procurement and production. The action is either new action (release of an order) or a revision of previous action. The essential data elements that are required for any action to be taken are:

1. Item Identity (part number)
2. Order Quantity
3. Date of Order Release
4. Date of Order Completion (due date)

Once the order has been placed, the types of order action that are required when revising an action taken previously, are limited to the following:

1. Increase in Order Quantity.
2. Decrease in Order Quantity.
3. Order cancellation.
4. Advancement of Order Due Date.
5. Deferment of Order Due Date.
6. Order suspension (indefinite deferment).

MRP systems meet their objective by computing net requirement for each inventory item. The term component in MRP covers all inventory items other than products or end items. Requirements for end items are stated in the MPS. The latter are derived from forecasts, customer orders, field warehouse requirements, interplant orders, etc. Requirements for all component items (including raw material) and their timings are derived from the MPS by the system.

After determining the net requirements, these are time phased to ensure their proper coverage. Therefore, MRP converts the gross requirements into net requirements. The net requirements are always related to time, i.e., to some date or period. These are covered by planned orders. Their quantities and timing are determined by any of the lot sizing techniques. MRP signals, if necessary, the need to reschedule any of these orders forward or backward in time, so that the net requirements are directly related and are correctly timed with shop orders and purchase orders. Capacity considerations are taken into account in determining MPS; this is not the role determined by MRP.

All the inputs received above enable determination of correct inventory status of each item under the control of MRP. The MPS expresses the overall production plan and the span of time covered by it. This is termed the planning horizon. Item lead time, safety stock (if any), scrap allowances, lot-sizing algorithms, etc., are available from the inventory record file. This is used to determine the size and timing of the planned orders. The product structure file contains information on relationships of components and assemblies. The MRP system uses these inputs to provide a number of important outputs. These outputs can be classified as primary and secondary outputs. The primary outputs of an MRP system are:

1. Order- release notices: These determine the orders that need to be placed and the system makes the call for placement of planned order.
2. Rescheduling notices: Based on the feedback from manufacturing, it firms up requirements on open order due dates.
3. Cancellation notices: Wherever necessary, it calls for cancellation or suspension of open orders.
4. Item status analysis: It provides back-up data on the item. The output of the MRP includes the following information: (a) Requirements, (b) Coverage of requirements, and (c) Product structure.
5. Planned orders: It identifies factors considered for planning and on that basis schedules for releases of notices in the future.

The system is also capable to 'provide a number of secondary outputs. Apart from the primary outputs an MRP System can be used for:

a) Inventory order action,
b) Re-planning order quantities,
c) Safeguarding priority integrity,
d) Performance control, and

e) Reporting errors, incongruities and out-of-bounds situations in the system.

Some of the secondary outputs that can be provided by the MRP system are:

1. Exception notices reporting errors, incongruities, and out-of-bound situations.
2. Inventory level projections.
3. Purchase commitment reports.
4. Tracing demand sources.
5. Performance reports.

An MRP system that is properly designed, implemented and used will also contains valid and timely information that can assist in the functioning of the organization on three separate levels:

1. Planning and control inventories.
2. Planning of ‘open order’ priorities.
3. Inputs to the capacity requirements planning system.

6.8 Priority Planning

The validity and integrity of shop scheduling, loading, dispatching and job assignments are based on operational priorities. The priorities in a MRP system are derived from the MPS. Each shop order entails a number of operations that must be performed to complete the order. In order to complete these operations, there are priorities in two areas:

1. Order priority.
2. Operation priority.

Where there are valid open-orders, priority planning and priority control are the basis for decisions on due dates, re-planning of order quantities and releases of schedules in the future. But to be valid, they must derive from valid priorities, i.e., valid order due date. An MRP system has the capability to establish valid order priorities at the time of order release and maintain them up-to-date and valid.

In priority assignment and updating, the concept of dependent priority is very useful. The 'dependent priority' concept recognizes that the real priority of an order depends on the time of order completion and the availability of all inventory items that are required not only for the operation but also for previous operations. This can be thought of as vertical priority dependence. Due date-oriented priority ratio have been developed and are being used successfully in many MRP systems.

Dynamic updating of operating priority is based on the critical ratio and not due dates and established relative priorities. The 'dependent priority' procedure computes the value of the critical ratio for the next operation to be performed on every open shop order, as follows:

Ratio A = Quantity On-hand/Order Point

Ratio B = Lead time for Balance Work/Total Lead time

Critical Ratio = A/B

Ratio ‘A’ is a measure of need and represents the degree of stock depletion. Ratio ‘B’ is a measure of the response and reflects the degree of work completion. A critical ratio of ‘1’ signifies that work on the order has kept pace with the rate of stock depletion – the order is on ‘Schedule’. A value, lower than ‘1’, indicates an order ‘ahead of schedule’. The priority of the job becomes higher as the value of critical ratio falls or becomes lower.

In the case of assembly products, horizontal dependence exists. In such a situation, the MRP system must re-plan requirements and dates of need for the component orders in question, in case of change or rescheduling in parent product requirements. However, in independent demand situations, ratio ‘A’ is meaningless.

6.9 Capacity Requirement Planning

As the master schedule is developed, rough-cut capacity planning is used to check capacity requirements against capacity availability. But rough-cut capacity planning does not take into account lead time off setting, or the amount ahead of time component parts must be made to meet the master schedule for the end items. MRP forms the basis for detailed capacity calculations

The output of the MRP system indicates what component items will have to be produced and when, and this output can therefore be converted into the capacities required to produce these items. The explosion of the MPS results in details on machine load, or workload projections. The MRP then compares this with available departmental and work center capacities to answer such question as relating to overtime work, inter-departmental transfer of work/people, sub-contracting of work, starting new shifts, hiring more manpower, etc.

This exercise by using the routing sheet, which indicates the sequence of machines or work centers a part must go through during processing and the labor standards, makes it possible to determine capacity requirements at each operation.

The total capacity requirements placed on a work centre during a given time period are called the load. The output of Capacity Requirements Planning (CRP) is usually in the form of load report, or load profile, which is a graphical representation of the load on each work centre by time period. This report provides visibility into future and is based on valid order priorities. Hence, it facilitates capacity requirement planning by providing essential inputs for the capacity requirement planning system to function effectively.

Solved Problems on Material Requirement Planning

Prob.1: The figure below shows, the product structure of product 'A' where figures in brackets indicates number of units required and figure with LT are in weeks. If 100 units of 'A' are required to be shipped in 8 weeks then:

a) Prepare the bill of materials.

b) Find requirement of various items at different levels.

c) Draw the planned order release

A, LT = 2

B (2), LT = 1 C (4), LT = 3 D(3), LT = 2

E(3), LT = 3 F(3), LT = 3 G(5), LT=3 H(6), LT=1

Solution:

(a) Bill of Materials

ITEM: A			LEVEL = 0
Part		**Number Required**	**Level**
B	2	1	
	E	3	2
	F	3	2
C	4	1	
D	3	1	
	G	5	2
	H	6	2

(b) & (c) Computation of requirements and planned order release at various levels.

Item/ Part Code	Requirement for 1 unit of 'A'	Requirement for 100 units of 'A'	Level	Lead Time (wks)	Week Number	
					Require-ment	Order

A	I	100	0	2	8	6
B	2	200	I	2	6	5
E	3x2=6	600	2	3	5	2
F	3x2=6	600	2	3	5	2
C	4	400	I	3	6	3
D	3	300	I	2	6	4
G	3 x 5 = I5	1500	2	3	4	I
H	3 x 6 = 18	1800	2	I	4	3

Prob. 2: The manufacturer of a product (A) has the following product structure:

level 0 A, LT =2

level 1 B(2), LT =1 C(3), LT =2 D(1), LT=2

level 2 E(3), LT=3 F(2), LT=1 G(2), LT=2 H(3), LT=3

level 3 K(1), LT=1 I(2), LT=2 M(3), LT=3 N(2), LT=1 O(1), LT=2

level 4 P(2), LT=1 Q(3) LT=2

a) Based on the above product structure, explain the requirement at various levels in the form of a Bill of Materials for producing one unit of product (A).

b) If 1 00 units of' A' are required to be shipped on 12th day, then find the requirements of various sub-assemblies/parts as to when they should be ordered, presume nothing is available in stock or on order.

c) Calculate the net requirement if the inventory position (on hand/on order) is given here under.

Part/Component	On Hand	On Order
G	100	-
O	100	100

Sol.

(a) Bill of Materials

ITEM: A					**UNITS = ONE LEVEL = 0**
Part Code.				**Numbers**	**level**
B				2	1
	E			3	2
		K		1	3
		L		2	3
		M		3	3
	F			2	2

C				3	1
	G			2	2
		N		2	3
		0		1	3
			P	2	4
			Q	3	4
	H			3	2
D				1	1

(b) Requirement and Planned Order Release

Item I Part	**Numbers Required per unit of 'A'**	**Numbers Required for 100 units of 'A'**	**Level days**	**Lead Time hired**	**On Day Requirement release**	**Order require-ment**	**Remark! (for Re-require-ment)**
A	1 to 'self'	100	0	2	12	10	Related
B	2	200	1	1	10	9	'A'
C	3	300	1	2	10	8	'A'
D	1	100	1	2	10	8	'A'
E	2x3 = 6	600	2	3	9	6	'B'
F	2x2 = 4	400	2	1	9	8	'B'
G' ·	3x2 · '" 6	600	2	2	8	6	'c'
H'	3x3 = ·9	900	2	3	8	5	'c'
K	6xl = 6	600	3	1	6	5	'E'
I	6x2 = 12	1200	3	2	6	4	'E'
M	6x3 = 18	1800	3	3	6	3	'E'
N	6x2 = 12	1200	3	1	6	5	'G'
0	6xl = 6	600	3	2	6	4	'G'
p	6x2 = 12	1200	4	1	4	3	'0'
Q	. 6x3 = 18	1800	4	2	4	2	'0'

6.10 SUMMARY

The function of a manufacturing inventory system is to translate the Master Production Schedule into detailed component material requirements and orders, based on inventory. The system determines item-by-item, what is to be processed and when, as well as what is to be manufactured and when. This is based on order priorities and available capacities. Thus, this chapter dedicates itself to material requirement planning (MRP) meaning, underlying assumptions, prerequisites, process and benefits. It also discusses capacity requirements planning in details by appropriate theory and practical questions.

6.11 KEY WORDS

Material planning: A technique of determining the requirements of raw materials, components, spares etc required for the manufacturing of the product.

Material requirement planning: Planning of work- in-progress of the finished goods.

6.12 SELF ASSESSMENT EXERCISE

1. Give a detail note on Material Requirement Planning (MRP) Discuss the main assumptions and perquisites of MRP.
2. What type of the data required for calculating Material Requirement Planning (MRP)?
3. What is priority planning? Give a detail note on the type of priority planning.

6.13 FURTHER READINGS AND SOURCES

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Course : MBA	Course Code: CP-204
LESSON: 7	**Scheduling**

STRUCTURE

7.7 SCHEDULING FOR HIGH VOLUME CONTINUOUS SYSTEMS

7.8 PERT/CPM TECHNIQUES OF WORK ANALYSIS

7.8.1 BENEFITS OF NETWORK ANALYSIS

7.8.2 DRAWBACKS OF NETWORK ANALYSIS

7.8.3 DIFFERENT FORMS OF NETWORK ANALYSIS

7.9 A CRITICAL PATH METHOD (CPM)

7.10 PERT TECHNIQUE

7.11 PERT/CPM NETWORKS

7.12 SUMMARY

7.13 KEY WORDS

7.14 SELF ASSESSMENT EXERCISE

7.15 FURTHER READINGS AND SOURCES

7.0 OBJECTIVES

After going through this lesson, you will be able to:

- **Understand the issues related to work scheduling**
- **Understand the various techniques of scheduling to different type of work facilities.**
- **Applications of PERT/CPM techniques to work scheduling in production**

7.1 INTRODUCTION AND MEANING OF SCHEDULING

Scheduling refers to the process of preparing a time goal for all production operations including setup and other preparation time in executing a production order in the manufacturing organization. The scope of scheduling operations covers the following areas in particular:

- Assign job to a particular work centre/machine
- Time of assignment of job and its completion
- Allocation of resources like manpower and materials
- Time sequence of operations
- Feedback and control function to take care of deviations

The technique of scheduling system varies with the type of layout and type of job, viz. job-shop, batch production or mass production, etc. We have seen techniques like line balancing for automated mass production lines. In project type of work PERT/CPM techniques are also used. Production planning control (PPC) system covers routing, scheduling and dispatching operations.

In this chapter, we confine our discussions to scheduling operations only. Since scheduling involves loading of machines and work centers, these are often referred to as 'Scheduling and Loading'. The basic objectives of scheduling and loading are the following:

- Minimising production costs
- Minimising storage costs
- Minimising time of operation and 'throughput' time

7.2 SELECTION CRITERIA FOR THE TYPE OF SCHEDULING

There are various types of scheduling systems. These are discussed in this chapter. Selection of a particular system depends on a number of factors. Some of these are given below:

- Available infrastructure like machine capacity and number
- Type of layout like process and product types
- Volumes of production like low volume or high volume
- Type of products – standardised and non-standardised
- Type of production systems like job-shop, and mass production
- Priority of job

- Time schedules like operation, waiting and delivery time
- Cost aspects like set-up cost, change-over cost, etc.

Each system of scheduling has its merits and demerits. Hence there is nothing like an ideal system or a best system of scheduling. What is relevant is to select the most appropriate system of scheduling which suits a particular production background and working environment. This ability to select the most appropriate system depends on the professional and conceptual skill of managers. As the time and working conditions change we may also change even the existing scheduling system accordingly. Thus scheduling is a dynamic system. In order to assist students, certain working conditions are listed down below showing against each the most appropriate or likely schedule being used. Students must not read too much into such classification because, in certain conditions, more than one system was used. It depends on the ingenuity of the manager.

7.3 JOB SHOP SCHEDULING

In earlier chapter, types and characteristics of production systems were described. While scheduling problems occur to varying degrees in all types of systems, they are particularly salient in job shops. A job shop is a process-focused production system that employs general purpose processors. Production is to order, and a large number of different products are produced, each in relatively small volume. Examples of job shops include machining shops, multi-specialty clinics, computer centers, and consulting firms.

A production manager of a job shop will use the results of scheduling in several aspects of decision making. At the broadest level is capacity planning, in which the need for additional capacity and the type of capacity needed are identified. A simulations analysis of forecasted order patterns could reveal bottlenecks and the requirements for additional capacity. In some cases, efficient scheduling can improve the utilization of existing processors (machines) so the expensive additions to capacity can be postponed.

The next level at which the results of scheduling are useful is in decisions concerning order acceptance, due date specifications, and products mix considerations. For examples, scheduling may reveal that, given the nature of the processors in a job shop, accepting a mix of smaller volume and larger volume orders and quoting similar due dates for both types of orders create bottlenecks and late deliveries. Management may then wish either to focus on one type of order or to quote differential due dates to avoid bottlenecks and late deliveries.

Further down in the level of detail is shop loading, where the manager must decide on a daily basis how many jobs and which jobs to release to the shop for processing. The criteria of machine utilization and customer service will be important.

Finally, the manager must develop procedures for deciding the order in which the operations of different jobs should be performed on a processor if several operations are competing for the same processor. Simple procedures, such as "first come first served" or random selection, will often produce unacceptable solutions, resulting in delayed deliveries, the unbalanced utilization of processors, and the like. A clear understanding of the nature of scheduling problems at this most detailed level and of the procedures of scheduling will provide inputs to the higher level decisions discussed earlier. We will therefore focus on the job shop scheduling problem at this level of detail. To illustrate the differences among alternative scheduling procedures and the impact of a choice of a scheduling procedure on a desired performance measures, we will examine single processor scheduling in some detail.

7.3.1 Single Processor Scheduling

Consider a hypothetical automated chemical plant that produces several different products, but only one product can be produced at a time. Suppose that the production manager of the plant has to decide on the scheduling of four products, the production times and due dates for which are shown in Table 7.1. The table shows, for example, that product 4 will require 8 days in manufacturing and that it is due to be delivered in 17 days. The production manager has several alternatives for scheduling the production of these products. For example, he could produce product 1 first and then product 2, followed by product 3 and finally product 4. Alternatively, he could produce product 4 first, product 2 next, then product 1, and finally product 3. In fact, there are 4 x 3 x 2 x 1 = 24 distinct ways of scheduling the production of these four products. The decision facing the production manager is which one of these possible 24 schedules should be chosen?

This simplified example illustrates the problem of scheduling on a single processor. Single processor or single machine scheduling is of interest for the following reasons:

- There are many situations where an entire plant can be viewed as a single processor, as is the case in chemical manufacturing, paint manufacturing, and the manufacturing of products in automated plants.
- In plants that employ multiple processors, there is often a bottleneck processor that controls the output of the plant because of its limited capacity. The analysis of this bottleneck processor may determine the decisions for the entire plant.
- The analysis of a single processor illustrates many important problems that arise in more complex scheduling situations; therefore, it serves as a building block for understanding the decision problems in these more complex situations.

SCHEDULING EXAMPLE

Table 7.1

Product	Production Time, Days	Due Date, Days
1	4	6
2	7	9
3	2	19
4	8	17

For the single processor scheduling problem, we will assume that all jobs are available for processing at time zero; that set-up times for the jobs are independent of job sequence and can therefore be included in their processing times; that the processor is continuously available, without breakdown or other interruption, until all the jobs are completed; and that the processing of a job, once begun, is not interrupted until it is completed. These assumptions allow us to limit our attention to permutation schedules, which are completely specified by identifying the order in which the jobs will be processed. If n jobs are available for scheduling, then there will be n possible schedules.

Returning to the example in Table 7.1, the production manager faces precisely the single processor scheduling problem. (Assume that the set-up times are included in the production times and do not vary with the order in which the products are processed.) The choice of a schedule will depend on the criterion or objective that the production manager wishes to consider in his or her evaluation. We will now provide notation and definitions and discuss some criteria that are often employed in evaluating the desirability of alternative schedules.

7.3.1.1 Notation and Definitions

Each job in the single processor scheduling model is described by two parameters:

p_i = Processing time for job *i*

d_i = Due date for job *i*

In addition, in some cases, r_i, the ready time, release time, or arrival time of job i may be useful. In the models discussed here, all jobs are available for processing at time zero and hence $r_i = 0$ for all jobs.

The definition of pi includes set-up time for job *i*. If job i is defined as a lot of several identical pieces, then pi will denote the time required to process the complete lot. The due date, d_i, may be set by customer requirements or by internal planning considerations. We will consider the due date to be the time by which a job must be completed; otherwise, the job will be deemed late.

Several variables determine the solution of a scheduling decision. Some of the more important of these are

W_i = Waiting time for job i

C_i = Completion time of job i

F_i = Flow time of job i

L_i = Lateness of job i

T_i = Tardiness of job i

E_i = Earliness of job i

W_i is the amount of time job i has to wait before its processing begins. The first job on the schedule will have zero waiting time, and the second job on the schedule will have to wait by the amount of the processing time of the first job. C_i is simply the time at which the processing of job i is completed. Fi is the amount of time a job spends in the system; thus, Fi = $C_i - r_i$. Since in our case $r_i = 0$, $F_i = C_i$. Lateness,

L_i, is the amount of time by which the completion time of job i exceeds its due date.

Thus, $L_i = C_i - d_i$. Note that L_i can be either positive or negative. A positive lateness represents a violation of the due date and is called tardiness, T_i. Similarly, a negative lateness represents the completion of a job before its due date and is called earliness, E_i. Thus, the three measures of schedules, L_i, T_i, and E_i, measure the deviation of the completion time from the due date. Since there is often a penalty associated with not meeting due dates, the tardiness measure is usually used. However, in some cases there may be a penalty for being either too early or too late (e.g., crop harvesting), so both tardiness and earliness measures may be useful.

7.3.1.2 Criteria and Objective Functions for Scheduling

Several criteria can be employed to evaluate the performance of a schedule. The scheduling criteria chosen in a given situation depend on the objective function of the manager. For example, the underlying objective function or cost function of the company may be such that a penalty is associated with a tardy job, but once a job is delayed, the amount of tardiness does not influence the cost. In this situation, a scheduling criterion that minimizes the number of tardy jobs will be most appropriate for selecting an optimal schedule.

Suppose there are n jobs to be scheduled. Some commonly employed criteria are described in the following material:

$$\text{Mean tardiness} = F = \frac{1}{n}\sum_{i=1}^{n} Ti$$

This criterion is useful when the objective function of the company includes a penalty per unit of time if job completion is delayed beyond a specified due date. For example, a penalty of $X per day may be imposed for each job that is delayed beyond its specified due date.

$$\text{Maximum tardiness} = T_{max} = \max_{i} \{Ti\}$$

To compute maximum tardiness, the tardiness for each job is calculated. The job that has the largest tardiness of all the jobs determines T_{max}. For example, if $T_1 = 3$, $T_2 = 5$, $T_3 = 1$, and $T_4 = 4$, then $T_{max} = 5$ and is determined by job 2. This criterion is useful when the penalty per day for tardiness increases with the amount of tardiness.

$$\text{Number of tardy jobs} = n_T$$

This criterion simply counts the total number of jobs that are not completed by their due dates.

Several other criteria and procedures for selecting a schedule that optimize these criteria have been discussed in Conway, Maxwell, and Miler (1967) and Baker (1974).

7.3.1.3Scheduling Procedures

We will now illustrate several scheduling procedures using the example in Table 7.1.

Shortest Processing Time (SPT) Procedure: A schedule obtained by sequencing jobs in non-decreasing order of processing times is called a shortest processing time (SPT) schedule. This schedule minimizes mean flow time, F. In addition, the SPT rule also minimizes mean lateness and means waiting time. In the examples in Table 7.1, the SPT schedule is

$$< 3, 1, 2, 4, >$$

This shows that job 3 is processed first, followed by jobs 1, 2, and 4, in that order. In Table 7.2, the calculations for obtained the flow time for each job are shown. Job 3 is first in the sequence; hence, its completion time is 2 days. Job 1 is started after job 3 is finished and takes 4 days. Thus, the completion time for job 1 is 6 days. The completion times for the remaining jobs are similarly computed. Since all the jobs are available at time zero, the flow time or each job is identical to its completion time. The mean flow time is computed by simply adding the flow time for each job and dividing by 4.

$$F = \frac{F_1 + F_2 + F_3 \;\; + F_4)}{4} = \frac{(6 + 13 + 2 + 21)}{4} = \frac{42}{4} = 10.5$$

It can be checked that no other sequence can produce a better mean flow time than the sequence obtained by the SPT rule. The optimality of the SPT rule can be mathematically proved. By finishing the shorter jobs first, both the turnaround time and the work-in-process inventory are reduced. The SPT procedure is simple to implement and provides good results even in the more complex scheduling situations discussed later.

Due date (DD) Procedure: In the due date procedure, jobs are sequenced in the order of non-decreasing the dates. In our example, job 1 will be sequenced first because it has the earliest due date. The sequence obtained by this rule is

< 1, 2, 4, 3 >

The due date procedure minimizes the maximum tardiness. In Table 7.3, the computations for individual job tardiness, Ti, for the due date sequences are shown. The maximum tardiness is 2 days. No other schedule can produce a tardiness of less than 2 days. For comparison, the maximum tardiness for the SPT schedule is 4 days, as shown in Table 7.2.

TABLE 7.2

COMPUTATIONS USING THE SPT PROCEDURE FOR THE DATA IN TABLE 7.1

Job	Processing Time (p_i)	Due Date (d_i)	Completion Time for SPT Schedule (C_i)	Flow Time (F_i)	Tardiness (T_i)
1	4	6	6	6	0
2	7	9	13	13	4
3	2	19	2	2	0
4	8	17	21	21	4

Moore Procedure: The number of jobs tardy for the SPT schedule is 2 (Table 7.2), and for the DD schedule, it is 3 (Table 7.3). The Moore procedure minimizes the total number of tardy jobs. This procedure is described in the following steps.

Step 1 Arrange the jobs in non-decreasing order of their due dates (DD schedule) if this sequence yields one or zero tardy jobs, then the DD schedule is optimal and the procedure stops. In our example, 3 jobs are tardy in the DD schedule (Table 7.3), so we proceed to step 2.

Step 2 Identify the first tardy job in the DD schedule. In our example, the first tardy job in the DD schedule is job 2, which is marked by an asterisk (*) in the following schedule:

DD schedule	<1	2*	4	3 >
Completion time	4	11	19	21
Due date	6	9	17	19

Step 3 Identify the longest job from among the jobs including and to the left of the job marked with the * in the schedule in step 2. That is, we pick the longest job among the jobs that are completed no later than the completion time of the first tardy job in step 2. In our example, jobs 1 and 2 are candidates, and since job 2 has the longer processing time of the two, it is identified.

TABLE 7.3

COMPUTATIONS USING THE DD PROCEDURE FOR THE DATA IN TABLE 7.1

Job	Processing Time (p_i)	Due Date (d_i)	Completion Time for DD Schedule (C_i)	Tardiness (T_i)
1	4	6	4	0
2	7	9	11	2
3	2	19	21	2
4	8	17	19	2

The identified job is removed and the completion times for the remaining jobs are revised.

	< 1	4	3 >
Completion time	4	12	14
Due date	6	17	19

We now repeat step 2. In our example, al the jobs are now on time, so we terminate the procedure. The Moore schedule is

< 1, 4, 3, 2 >

which is obtained by simply putting the jobs removed in step 3 at the end of the schedule.

Weighted Shortest Processing Time (WSPT) Procedure. If jobs are not of equal importance, then it may be more appropriate to minimize the weighted flow time

$$\sum_{i=1}^{n} w_i F_i$$

Where w_i is the weight associated with the flow time of job i. The weights reflect the relative importance of individual job flow time. For example, if $w_1 = 1$ and $w_2 = 2$, it is as desirable to reduce the flow time of job 1 by 2 days as it is to reduce the flow time of job 2 by 1 day. Considerations of the relative costs of each job, the importance of the customer requiring a job, and so forth will influence the determination of w_i's.

A simple procedure to minimize the weighted flow time as to compute the weighted processing time, p_i w_i, for each job. Now, the job with the smallest p_i w_i is scheduled first in the sequence. From the remaining jobs, the job with the lowest pi w_i is selected and is placed in the second position in the schedule. The procedure is repeated until all of the jobs are scheduled. Essentially, the schedule is obtained by arranging the jobs in order of non-decreasing p_i w_i ratios.

Other Procedures: Several other procedures for optimizing a specified criterion are available in the literature. However, even or single processor scheduling, optimization for some criteria is quite difficult. For example, no simple procedure exists for minimizing mean tardiness, T. In such cases, a manager has the choice of using either a simpler procedure that produces good results but cannot guarantee an optimal solution (called a heuristic) or a complex procedure utilizing techniques of combinatorial optimization, which will require the use of a computer and may be expensive to implement but will guarantee optimal results.

Several extensions of the basic single processor scheduling model have been examined in the literature. These include the non-simultaneous arrival of jobs, the incorporation of dependence among jobs (e.g., a precedence constraint, such as job i must be completed before job j), and the allowance for set-up times that depend on the sequence (e.g., the processing of beige paint after black paint may require a higher set-up time than the processing of beige paint after white paint). In addition, probabilistic situations, where the arrival of jobs is uncertain or jobs have random processing times or due dates, have also been examined.

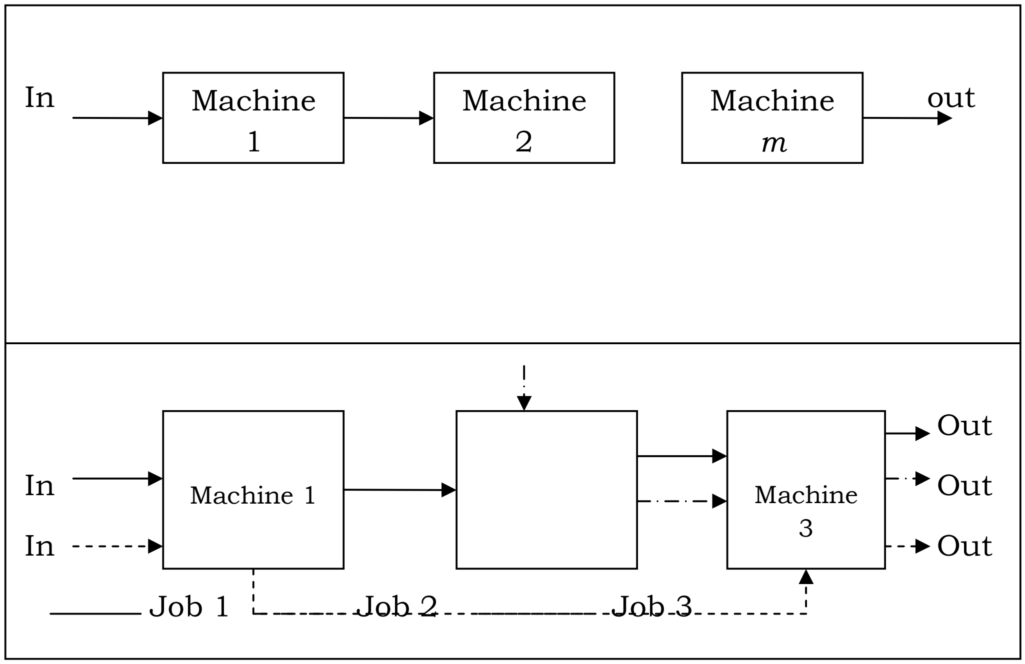
7.4 FLOW SHOP SCHEDULING

In many situations, there is more than one processor and a job consists of several operations that are to be performed in a specific order. Moving from a single processor job shop to a multiple processor job shop poses a formidable challenge. We first consider a special job shop case in which the flow of work is unidirectional.

A flow shop is a special type of job shop in which m machines are numbered 1, 2, ..., m and a job may require a maximum of m operations – one operation on each machine. Further, for every job, if operation j precedes operation k, then the machine required for operation j has a lowest number than the machine required for operation k. An example of a flow shop is shown in Figure 7.1. In Figure 7.1a, all the jobs require one operation on each processor; such a shop is called a "pure" flow shop. In Figure 7.1b, even though the flow of work is unidirectional, a job may require fewer than m operations and the operations need not be performed on adjacent processors. In Figure 7.1b, job 1 is processed on all three processors, job 2 is processed on processors 2 and 3, and job 3 is processed on processors 1 and 3. An example of a flow shop is an assembly line where work progresses from one stage to the next in the same direction. In several manufacturing situations (e.g., the manufacture of printed circuit boards), the same sequence of operations is required for a large number of orders. Further, in many cases, manufacturing can be divided into two stages. One stage is like a flow shop with all jobs having the same sequence, whereas the second stage requires a more complex routing of operations. One example of such a process is furniture manufacturing, where the front end is a flow shop and customization for upholstery, paint, and the like is accomplished at the back end of the manufacturing process.

Figure 7.1

Schematic of Flow Shops: (a) A Pure Flow Shop; (b) A General Flow Shop



To demonstrate scheduling procedures for flow shops, consider the example problem in Table 7.4. In this example, there are two machines and five jobs.

If we schedule the jobs on machines 1 and 2 in the order of the job numbers, we obtain the schedule shown in Figure 7.2a. The shaded areas show the amount of time during which a machine is idle. The completion time of last job determines the make span of the schedule, which measures machine utilization. In Figures 7.2a, the make span is 33 units of time.

For the special case of a two-machine flow shop, Johnson's procedure minimizes the make span. This procedure works as follows:

Step 1 Determine the minimum processing time on either machine. In our example, it is 2 for job 3 on machine 1.

Step 2a if the minimum processing time occurs on machine 1, place the associated job in the first available position in the sequence. In our example, job 3 is placed in the first position. Processed to step 3.

Step 2b If the minimum processing time occurs on machine 2, place the associated job in the last available position in sequence. Proceed to step 3.

Step 3 The job sequenced by either step 2a or step 2b is removed from consideration. The process is repeated, starting with step 1, until all the jobs are sequenced. Ties can be broken arbitrarily.

TABLE 7.4

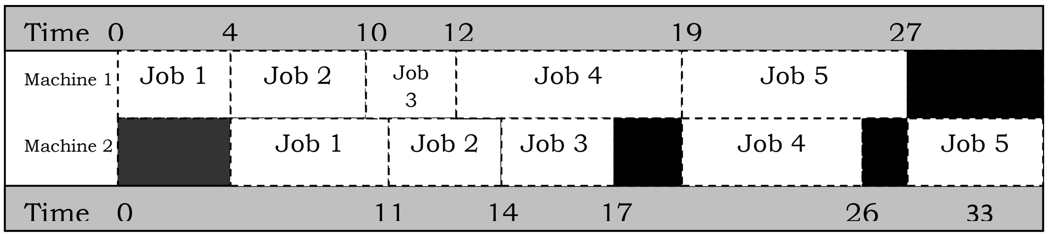
Flow Shop Scheduling Example (All Jobs Must Be Processed First On Machine 1 and Then on Machine 2)

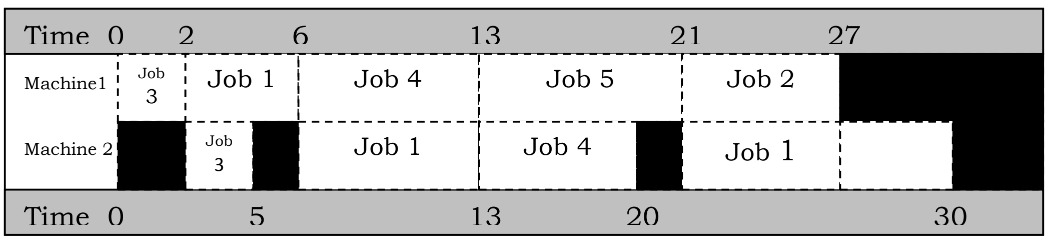
Jobs	Processing Time on Machine 1	Processing Time on Machine 2
1	4	7
2	6	3
3	2	3
4	7	7
5	8	6

In our example, once job 3 is removed, the minimum processing time occurs for job 2 on machine 2; hence, by step 2b, job 2 is placed last in the sequence. For the remaining jobs, 1, 4 and 5, the minimum processing time occurs for 5 on machine 2; using step 2b again, job 5 is placed in the last available position (the fourth position). Finally, job 4 is placed in the sole available position, the third position. The sequence obtained is <3, 1, 4, 5, 2 >. As shown in Figure 7.2b, this sequence gives a make span of 30 units.

Figure 7.2

Schedule for Flow Shop Example in Table 7.4. (a) Schedule for Sequence <1, 2, 3, 4, 5> on Each Machine. (b) Schedule Using Johnson's Procedure.





Even though the make span can be minimized using Johnsons' procedure for a two-machine flow shop, few results are available for other criteria. In fact, for scheduling a flow shop with m machines, one has to rely on combinatorial techniques or heuristic procedures. This shows the difficulty in scheduling and the combinatorial nature of the problem for even a well-structured environment like a flow shop.

7.5 GENERAL JOB SHOP SCHEDULING

Our conclusion in the preceding discussion of flow shops provides a guide for our introduction to general job shops, in which the flow of work may take any pattern. There are no optimal rules or procedures for job shops with more than two machines and two jobs. We will therefore focus on some rules that provide "good" solutions most of the time.

To illustrate the preparation of schedules for general job shops, we will use the example in Table 7.5. Job 3 in this example is due in 12 days, and it must be processed first on machine B for 4 days, then on machine A for 4 days and finally on machine C for 3 days.

As we begin scheduling with machine A, we face the decision of whether job 1 or job 2 should be scheduled first. Several simple rules can be employed to resolve the choice of a job from a set of available jobs waiting to be processed on the same machine at a given point in time. Some commonly employed rules are

Earliest Due Date First (EDD).	Priority is given to the job with the earliest due date. Job 1 will be chosen for scheduling on machine A at time zero.)

Table 7.5

General Job Shop Example

Job	Sequence and Processing Times	Due Date
1	A(3), B(3), C(2	10
2	A(5), C(2)	13
3	B(4), A(4), C(3)	12
4	B(3), C(5), A(2)	18
5	C(5), B(4)	14
6	C(2), A(5), B(5)	15

First In System First Served (FISFS). Priority is given to the job that arrived in the shop (not on the machine) first.

First Come First Served (FCFS). Priority is given to the processing of the job that arrived at the machine first.

Least Slack First (LSF). Priority is given to the processing of the job that has least slack. Slack is the difference between the due

	date and the work remaining on the job. At time zero, the slack for job 1 is 10 – (3 + 3 + 2) = 2 days in our example.
Shortest Processing Time (SPT).	Priority is given to the job with the shortest processing time on the machine under consideration.
Least Work Remaining (LWR).	Priority is given to the job with the least amount of total processing remaining to be done.

Several other rules can be devised to select a job from a set of waiting jobs for scheduling on a machine. The managerial objectives are the simplicity of implementation of a rule as well as the attainment of some desired performance, such as reducing the congestion in the shop, improving machine utilization, and meeting job due dates.

A figure 7.3 contains Gantt charts that show the schedules developed using the aforementioned rules. A Gantt chart is prepared by determining the set of jobs waiting for each machine. If more than one job is waiting for a machine, a rule is used to choose a job to be processed next. When the processing of a job on one machine is completed, that job is added to the waiting list for the machine it needs to be processed by next. The procedure is repeated each day (or unit of time) until all the jobs are scheduled.

It is clear from Figure 7.3 that different rules produce different schedules. In Table 7.6, the performance of these rules on the criteria number of jobs tardy, total tardiness, mean flow time, and make span is evaluated. The relative performance of a rule may change if the problem data are modified. In a static situation where all jobs are available simultaneously, it is possible to compare the performance of

Figure 7.3: Gantt Charts Showing the Schedules Developed Using Alternative Rules for the Example in Table 7.5

Scheduling Rule: EDD

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Machine A	1	1	1	2	2	2	2	2	3	3	3	3	6	6	6	6	6	-	-	-	4	4
Machine B	3	3	3	3	1	1	1	5	5	5	5	4	4	4	-	-	-	6	6	6	6	6
Machine C	5	5	5	5	5	6	6	1	1	2	2	-	3	3	3	4	4	4	4	4	-	-

Finished jobs 1 2 3 4

5

6

Scheduling Rule: FISFS

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Machine A	1	1	1	2	2	2	2	2	3	3	3	3	6	6	6	6	6	4	4	-	-	-
Machine B	3	3	3	3	1	1	1	4	4	4	5	5	5	5	-	-	-	6	6	6	6	6
Machine C	5	5	5	5	5	6	6	1	1	2	2	4	4	4	4	4	3	3	3	-	-	-

Finished jobs 1 2 5 3

6

4

Scheduling Rule: FCFS **Tie Breaker: FISFS**

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Machine A	1	1	1	2	2	2	2	2	3	3	3	3	6	6	6	6	6	4	4	-	-	-
Machine B	3	3	3	3	4	4	4	1	1	1	5	5	5	5	-	-	-	6	6	6	6	6
Machine C	5	5	5	5	5	6	6	4	4	4	4	4	2	2	1	1	3	3	3	-	-	-

Finished jobs 2 1 3 6

5 4

Scheduling Rule: LS

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Machine A	1	1	1	6	6	6	6	6	3	3	3	3	2	2	2	2	2	4	4	-
Machine B	3	3	3	3	1	1	1	4	4	4	5	5	5	5	6	6	6	6	6	-
Machine C	6	6	5	5	5	5	5	1	1	-	4	4	4	4	4	3	3	3	2	2

Finished jobs 1 5 3 4

2

6

Scheduling Rule: SPT **Tie Breaker: FISFS**

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Machine A	1	1	1	2	2	2	2	2	6	6	6	6	6	3	3	3	3	4	4	-
Machine B	4	4	4	1	1	1	3	3	3	3	5	5	5	5	6	6	6	6	6	-
Machine C	6	6	5	5	5	5	5	1	1	2	2	4	4	4	4	4	-	3	3	3

Finished jobs 1 2 5 4

3

6

Scheduling Rule: FCFS **Tie Breaker: FISFS**

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Machine A	2	2	2	2	2	1	1	1	3	3	3	3	4	4	-	-	-	-	-	6	6	6	6	6	-	-
Machine B	4	4	4	3	3	3	3	5	5	5	5	1	1	1	-	-	-	-	-	-	-	-	-	-	6	6
Machine C	5	5	5	5	5	2	2	4	4	4	4	4	3	3	3	1	1	6	6	-	-	-	-	-	-	-

Finished jobs 2 5 4 3 1
6

alternative rules. The rule and the associated schedule that meet the managerial objectives may then be selected for implementation.

However, in a dynamic situation where jobs are arriving over time and the universe of jobs in the system is continuously changing, prior knowledge of which rules perform well on the average for some selected measures of performance will be useful.

For dynamic job shops, several studies have been conducted to evaluate the relative performance of various rules (often called dispatching rules). These studies employ computer simulation models, and several of them are reported in Buffa and Miller (1979).

A clear conclusion that can be derived from over a dozen studies is that the SPT rule performs the best if the objective is to minimize shop congestion as measured by the mean flow time or the mean number of jobs in the system. The improved turnaround that can be achieved by using the SPT rule implies lower work-in-process inventories and can provide a competitive sales advantage as well. Note that for the single machine case, the SPT rule was indeed optimal with respect to mean flow time.

Table 7.6

A Summary of the Performance of the Scheduling Rules on Several Criteria for the Example in Table 7.5

Criteria				
Rule	**Number of Tardy Jobs (n_T)**	**Total Tardiness ($\sum T_i$)**	**Mean Flow Time F)**	**Mekespan (F_{max})**
Earliest due date for (EDD)	3	14	15	22
First in system first severed (FISFS)	3	15	15.67	22
First come first served (FCFS)	5	22	17.33	22
Least slack (LS)	4	18	16.5	20
Shortest processing time (SPT)	3	13	15.33	20
Least work remaining (LWKR)	3	24	15.5	29

Intuitively, the SPT rule performs well because the progress of jobs with shorter operation times is accelerated by giving them priority. Thus, shop congestion is reduced as jobs are turned around fast and machines are made available for other jobs. However, as can be expected, a few longer jobs may encounter very long delays as they get stuck in the system.

When customer service is a dominant concern, then tardiness-based criteria, such as the proportion of jobs tardy or the mean tardiness, may be relevant. Surprisingly, the SPT rule does very well even for tardiness-based criteria. This result is bewildering because the SPT rule ignores the due dates. However, the selection of best rule critically depends on such factors as the level of the shop load, the procedure for setting due dates, and the tightness of the due dates.

7.6 SCHEDULING FOR BATCH SHOPS

In the preceding discussion of job shop scheduling, the processing time for a job on a given machine was specified. The processing time could be defined as the time required for manufacturing a batch of several identical items, where the entire batch of items is distinct from another batch of items either because of different processing requirements or because each batch is manufactured for a different customer. Job shop analysis is applicable when each job has its own identity (processing requirements, due date, customer type, etc.) and production is customized to the order.

As we discussed in Chapter 2, batch production falls between job shop production system when the output is inventoriable and is produced in substantial volume, even though the volume may not justify continuous production. In these situations, the manager must determine the lot size for a batch to be produced at one time in addition to scheduling the batch on the facilities. An example of batch production is the bottling of gin, vodka, rum, and the like using the same production facility. The manager must decide how many cases of vodka in a given bottle size (e.g., a quart) should be bottled at one time (the determination of lot size) and when the processing of this batch should begin (the scheduling decision). If 12,000 cases of vodka in a quart size are required in a year, many options, such as to produce 6000 cases twice a year or 3000 cases four times a year, are available. A key trade-off in the determination of the lot size for an item is between set-up costs and inventory holding costs. Another equally important consideration is the requirement to produce a feasible schedule that meets the demand for all items. For example, if set-up costs are low relative to holding costs, indicating small lot sizes, it may not be possible to produce the required quantities of all items within the specified time period if these small lot sizes are employed. This will happen if much of the time is consumed by merely setting up machines, thereby reducing the available production time. In order to meet requirements for different items, larger lot sizes may have to be employed. We will now illustrate this problem of obtaining a feasible schedule, and we will discuss a method for computing lot sizes while maintaining feasibility in scheduling the batches of items under consideration.

7.6.1 Independent EOQ Scheduling

Why not determine lot sizes economically, according to the EOQ equations? EOQs would be computed independently for each item and processed through the system as a lot. Sometimes this decision may be a good one, but quite often the EOQ equations are oversimplifications of the true situations, and improved decision policies can be used. Some of the complexities that commonly intrude on the simplicity of EOQ equations are as follows:

1. Because of differing requirements, set-up costs, and inventory carrying costs for each job, inventories that result from EOQ lots may not last through a complete cycle. Because of stock-outs, special orders of smaller size may then be needed, resulting in capacity dilution.
2. When operating near capacity limits, competition for machine and/or worker time may cause scheduling interference. In order to maintain scheduled commitments, lots may be split. Again, a side effect of this is reduced capacity.
3. Sometimes there is a bottleneck machine or process through which all or most of the jobs must be sequenced. Its limited capacity may exert pressure toward smaller lot sizes, diluting capacity in order to meet scheduled commitments on at least a part of job orders.
4. Where parts or products are produced in regular cycles, individual lot sizes are constructed to fit in with the cycles, rather than from the balance of set-up and inventory holding costs for each individual item.
5. The assumption of constant demand is not met, either as a result of seasonal usage or sales or because demand is dependent on the production schedules of other parts, subassemblies, or products.

6. The process and transit lot sizes are not equal, so that the inventory structure of the EOQ formulation is not valid.

Most of these reasons for deviating from the concepts of the EOQ equations lead to smaller lot sizes and to reductions in effective capacity. Under these conditions, relatively larger fractions of the available machine and worker time are devoted to machine set-up. Note that items 1 through 4 in the preceding list all indicate some kind of dependence of the individual lot size on the other orders in the system.

Example

Table 7.7 gives data on requirements, costs, and production for 10 products that are processed on the same equipment. The capacity of the equipment is limited to 250 days of usage per year. When the daily production rates for each products listed in column 4 are converted to required production days in column 5, we see that the total annual production requirement of 241 days falls within the 250-day maximum limit (set-up times are included). Our particular interest is in columns 8 through 11 of Table 7.7. The lot sizes are computed using Equation 7.1 and the number of runs per year, the production days per lot, and the costs are computed for the independent EOQ scheduling of the 10 products.

$$Q_p = \sqrt{\frac{2R_{cp}}{C_H(1 - \frac{r}{p})}} \quad \text{------------7.1}$$

Where

r = Requirements or usage rate (short term, perhaps daily or weekly)

p = Production rate (on same time basis as for r)

c_p = ordering and setup cost

C_H = Unit inventory cost

Q_p = Minimum cost production order quantity

R = Annual requirements

Total incremental cost of the optimal production order quantity is

$$TIC_0 = \sqrt{2c_p c_H R(1 - \frac{r}{p})} \quad \text{---------7.2}$$

Table 7.7

Requirements, Costs, and Production Data for 10 Products Run On the Same Equipment

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Prod-uct Num-ber	Annual Requirements R_i	Sales per Production Day (25) days per year), Col. 2/250, r_i	Daily Production Rate, pi	Production Days Required, Co.2/ Col.4	Inventory Holding Cost per Unit per Year, c_{H_i}	Machine Setup Cost per Run, c_{P_i}	EOQ, Equation 7.1	Number of Runs per year, Col.2/Col. 8	Production Days per Lot, Col.8/ Col.4	TIC_0 Equation 7.2
1	9,000	36	225	40	$.10	$40	2928	3.1	13.0	$245.93
2	20,000	80	500	40	0.20	25	2440	8.2	4.9	409.88

3	6,000	24	200	30	0.15	50	2132	2.8	10.7	281/42
4	12,000	48	600	20	0.10	40	3230	3.7	5.4	297.19
5	16,000	64	500	32	0.02	50	9578	1.7	19.2	167.04
6	15,000	60	500	30	0.50	40	1651	9.1	3.3	726.64
7	8,000	32	1000	8	0.35	30	1190	6.7	1.2	403.27
8	9,000	36	900	10	0.05	60	4743	1.9	5.3	227.68
9	2,000	8	125	16	0.55	25	441	4.5	3.5	226.89
10	3,000	12	200	15	0.20	20	799	3.8	4.0	150.20
				241		$380			70.5	$3136.14

Because only 1 product can be produced at a time, problems result from an attempt to schedule the 10 products independently (see Table 7.8). Each EOQ lot provides inventories to be used at the daily usage rate, r_i, of that product. These inventories will be depleted in EOQ/R_i days, as shown in column 4. Therefore, the inventory cycle must be long enough for that product to be recycled. The total number of column 4, we see that the inventory for products 2, 4, 6, 7, 9 and 10 will be depleted before the cycle can be repeated.

Clearly, independent scheduling will not provide a feasible solution. This infeasibility is not surprising because the schedule of each product is not independent of the other products since they are all processed on the same equipment, which has limited capacity. We must therefore treat the 10 products as a system. Before considering the alternatives, note that our system is operating near capacity, with 241 production days scheduled, 241 × 100/250 = 96.4 percent of the days available. Scheduling interference would probably not occur if we were operating at relatively low loads. Under conditions of low load, slack capacity would be available to make the system work.

Table 7.8

Calculation of Production Days Required, Peak Inventory, and Number of Days of Sales Requirements Met By an EOQ For 10 Products

(1) Product Number	(2) Production Days Required, EOQ/pi	(3) Peak Inventory, Production Days × (pi – r_i)	(4) Days to Deplete EOQ, EOQ/r^i
1	13.0	2457	81.3
2	4.9	2058	30.6a
3	10.7	1883	88.8
4	5.4	2980	67.3[a]
5	19.2	8371	149.7
6	3.3	1452	27.5[a]
7	1.2	1162	37.2[a]
8	5.3	4579	131.8
9	3.5	410	55.1[a]
10	4.0	752	66.6[a]
	70.5		

*Items that stock out, inventory lasts less than 70.5 days.

7.7 SCHEDULING FOR HIGH VOLUME CONTINUOUS SYSTEMS

For high volume continuous systems the aggregate plan determines the production levels, work force requirements, and resulting inventory levels in aggregate terms. The scheduling problem for such system is to develop detailed master schedules or individual end products and for facilities and personnel within the constraints of aggregate plan. Master schedules are stated specifically in terms of the quantities of each individual product to be produced and the time periods for production. For example, the aggregate schedule might call for 1000 units in planning period 1, where the planning period might be a month or perhaps a four-week period. If there were three products, the more detailed master schedule would indicate the quantities of each of the three products to be produced in each week of the planning period, consistent with the aggregate schedule.

As an example, assume that the aggregate schedule calls for a level production rate during the three-period planning horizon. The periods of planning horizons are often months or four-week periods. The latter is particularly convenient because it breaks the year into 52/4=13 periods of equal size. The weekly master schedule then conveniently fits most work schedules. In our example we will assume three four-week periods in the planning horizon.

The aggregate plan may have produced the following:

Aggregate Plan

Period. 4 weeks	Initial	1	2	3
Aggregate forecast	__	1200	1100	800
Production	__	1000	1000	1000
Aggregate inventories	800	600	500	700

Now we must disaggregate the forecasts on a weekly basis for the three products. Suppose that the composition of the forecasts is as follow:

Period	1				2				3				
Week	1	2	3	4	5	6	7	8	9	10	11	12	Total
Product 1	100	100	100	100	100	80	75	75	75	75	65	50	995
Product 2	150	125	125	100	75	75	75	65	65	65	60	50	1030
Product 3	75	75	75	75	100	120	125	135	135	60	50	50	1075
Total	325	300	300	275	275	275	275	275	275	200	175	150	3100
Period Total	1200				1100				800				3100

The aggregate schedule calls for level production at 1000 units per four-week period. The aggregate forecasts decline, but the forecasts by weeks for the three products follow different patterns. Products 1 and 2 decline, but product 3 increases during the second four-week period, although it declines rapidly in the third four-week period.

The master scheduling problem requires the construction of schedules for each of the products, consistent with the aggregate plan, the forecasts, and planned inventories. Table 7.12 shows a master schedule that fits these requirements. The production plan in Table 7.12a indicates the initial cycling among the three products, where productive capacity is allocated to one of the products each week. In the fifth week, the strategy changes to cycle product 3 every other week to take account of the high forecast requirements for that product during the fifth through the ninth weeks. In the tenth week, the plan returns to a three-week cycling of the three products.

The individual product inventory profiles that would result from the master schedule are shown in Table 7.12b. Note that the individual inventory balances, I_t, are end-of-week figures that result from the simple accounting equation, $I_t = I_{t-1} – F_t + P_t$, where F_t is the forecast and P_t is the production during the week. For example, in Table 7.12b, the initial inventory for product 3 is I_0 = 150 units, requirements were forecast as F_1 = 75 units, and production is scheduled at P_1 = 250 units. Therefore, the projected inventory at the end of week 1 is I_1 = 150 -75 + 250 = 325 units, as indicated in Table7.12b for product 3. The total end-of-week inventory is simply the sum of the inventories for the three products. The inventory called for by the aggregate plan was an end-of-period (four-week) figure, so there are deviations from the plan in the first three weeks of each four-week period, but the deviation is zero in the last week of each four-week planning period.

The master scheduling methods indicated by this discussion follow from the simple logic of the disaggregation of aggregate plans. In more complex situations, problems might have occurred because of conflicts in forecast requirements, production capacities, and inventory position, resulting in stock-outs. Alternative plans could be tried to see if the problem can be solved. It may be necessary to cycle back to a reevaluation of the aggregate plan, with changes in it possibly being required.

In the master schedule of Table 7.12, no attempt was made to consider the balance between set-up and inventory costs. Optimizing methods for master scheduling are developed by Hax and Meal (1975) in a hierarchical production planning system.

Table 7.12a

Master Schedule for Three Products Consistent With Forecast and Aggregate Production Plan

Period		1				2				3			
Week	0	1	2	3	4	5	6	7	8	9	10	11	12
Product 1, production		--	--	250	--	--	125	--	125	--	250	--	--
Product 2, production		--	250	--	250	--	125	--	125	--	--	250	--
Product 3, production		250	--	--	--	250	--	250	--	250	--	--	250
Total production		250	250	250	250	250	250	250	250	250	250	250	250
Capacity, aggregate plan		250	0	250	250	250	250	250	250	250	250	250	250
Deviation		0		0	0	0	0	0	0	0	0	0	0

Table 7.12b

Production End-Of-Week Inventory Profiles Associated With Master Schedule

Period		1				2				3			
Week	0	1	2	3	4	5	6	7	8	9	10	11	12
Product 1, inventory	400	300	200	350	250	150	195	120	170	95	270	205	155
Product 2, inventory	250	100	225	100	250	175	225	150	210	145	80	270	220
Product 3, inventory	150	325	250	175	100	250	130	255	120	235	175	125	325
Total inventory	800	725	675	625	600	575	550	525	500	475	525	600	700
Capacity, aggregate plan	800	600	600	600	600	500	500	500	500	700	700	700	700
Deviation	0	125	75	25	0	75	50	25	0	225	175	100	0

The master schedule provides the basis for detailed plans concerning material flow, equipment, and personnel schedules. Obviously all materials, components and subassemblies need to be coordinated with the master schedule.

7.8 PERT/CPM TECHNIQUES OF WORK ANALYSIS

Network Analysis is a managerial technique which helps to identify the inter-connecting links in a single system. It is a useful tool in systems design which assists in recognising or identifying the relationships that exist among the sub-systems.

It is done by describing each segment or linkage of the system in terms of other components or activities of the system. Thus, it makes explicit the total system and the inter-relationships among the parts. A network is illustrated by a flow chart or diagram. The flow of materials and/or information is measured as volume, specifications, or time.

7.8.1 Benefits of Network Analysis

1. It helps to reappraise existing system design and identify duplication and overlapping that may detract from the effectiveness.
2. It helps management to evaluate the sub-system changes on other sub-systems and/or the total system. A change in type of output or a change is scheduling in a particular sub-system can affect operations in other areas. This effect can be determined in units of time, money, facilities, or other resources.
3. It encourages introspection of an existing system or provides the framework for visualising the make-up of a proposed system.

7.8.2 Drawbacks of Network Analysis

1. It provides no guarantee for effective system design, as variations in performance could always occur.
2. There always exists the danger of assuming relationships among segments which do not exist, ignoring important relationships which should be considered, or weighing existing relationships improperly.
3. It requires constant follow up as relationship among the segments may change with time.

7.8.3 Different Forms of Network Analysis

There are different forms of network analysis, which may be simple or complex, may be much generalized or may be exclusively designed for specific types of projects. PERT and CPM are the most widely used techniques used in network analysis.

7.9 A CRITICAL PATH METHOD (CPM)

This technique is used for planning, scheduling, estimating and controlling engineering and construction. This method was used by Du Pont in 1959 to schedule plant maintenance shutdowns during change-overs. The lessons learned through this application were later on used to plan building construction and other large construction projects.

The key tool in this technique of planning, scheduling, and controlling complex construction jobs, is a diagram using arrows to represent specific jobs. Such line diagrams clarify the relationships of every task to every other task, which cannot be explained using bar chart. Critical jobs are those jobs which relate to one another (from start to finish of a project), each depending upon completion of the one before it. Total project time, therefore, is the summation of the time to be taken by critical job.

A simplest form of CPM diagram illustrates the jobs to be performed to finish a project (in order of sequence), timing and costs. Once all these elements are specified, both the total time and total cost of the project can be determined by adding the different sub-elements.

The consequence of various managerial decisions can be predicted by simulating their impact.

7.10 PERT TECHNIQUE

The PERT Technique is based on critical-path scheduling. However, there is a fundamental difference between PERT and critical-path scheduling. The PERT technique is applicable where there is no established system for doing the task and therefore no exact basis for estimating the required time to complete each task. Critical Path Scheduling, on the other hand, usually is applied to jobs which are established or have been done before and where it is possible to predict performance accurately. Consequently, more sophisticated mathematical models must be used in the PERT technique.

PERT is statistical technique diagnostic and prognostic for quantifying knowledge about uncertainties faced in completing intellectual and physical activities essential for timely achievement of programme deadlines. It is a technique for focusing management attention or danger signals that require remedial decisions and on areas of efforts for which trade-offs in time, resources, or technical performance, might improve capability to meet major deadlines.

The PERT technique is, therefore, based on the concept that in any programme, there are three variables:

(i) Time

(ii) Resources (HR, facilities, funds)

(iii) Performance Specifications.

Any one of these may vary within certain limits established for such programme, while holding the other two constant. For example, holding time and performance constant, the requirements for resources may be determined.

Thus, instead of having a single estimate, there may be three estimates for an activity as under:

a. **Optimistic Time (a)** – This is the shortest time a particular activity can take to complete and is therefore an ideal estimate.
b. **Most Likely Time (m)** – This is the modal time, which is expected to be taken to complete a job and is based on past record.
c. **Pessimistic Time (b)** – This is the longest time and it occurs with a probability of less than one per cent. This, therefore, is the worst time estimate, for any eventualities.

With these three time estimates, a single expected time to complete a project is determined with the following weighted average formula:

$$t = \frac{a+4m+b}{6}$$

Where t = expected time of the i_{th} activity,

a = optimistic time

m = most likely, or modal time

b = pessimistic time.

The standard deviation is of the completion time of an activity is calculated as follows:

$$\sigma i = \frac{b-a}{6}$$

$$\text{Variance} = \sigma^2 i = \left(\frac{b-a}{6}\right)^2$$

It is, therefore, clear that both PERT and CPM have similarities in terms of concepts and methodology. We use these techniques in project scheduling problems. However, we use PERT in analyzing project scheduling, where completion time is not certain and CPM, where activity durations are known with certainty. In essence, therefore, PERT is probabilistic in nature and more appropriately used in R & D Projects, while CPM is a deterministic technique and thus finds application more appropriately in the construction projects.

7.11 PERT/CPM NETWORKS

A project is a set of activities or jobs (tasks or operations) that are performed in a certain sequence determined logically or technologically. Initially, therefore, it is necessary to determine all specific activities that comprise the project and their inter-dependence relationships. We can illustrate this with the following example:

Let us assume that a new CNC machine has been procured from abroad and now it requires installation. For this example, the activity starts with the procurement of manpower (both from internally and from the firm, from which the machine has been procured), doing grouting and foundation work, doing electrical work, installing the machine, training of the operators and finally the trial run. Various activities required to be performed then can be distributed, time-wise as below:

List of activities with precedence relationships for installing CNC Machine

Activity Code	Job Description	Job Duration (in days)	Immediate Predecessor/s
A	Procurement of Manpower	2	-
B	Grouting and Foundation	5	A
C	Electrical Work	1	A
D	Installing the Machine	1	B
E	Train the operators	6	C
F	Trial Run	1	D, E

The immediate predecessors for a particular activity indicate that those activities are required to be completed before the starting of this job. Once the activities comprising a project and their inter-relationships are identified, we can graphically portray by a network or arrow diagram. We can depict the network as under:

Rule of Network Construction

1. Each defined activity is represented by a single arrow. Thus a single can not be represented twice in the network.
2. Before undertaking a particular activity, all activities, preceding it, should be completed.

3. Events are identified by numbers and hence duplication of event numbers must be avoided.
4. All Networks should have one initial and one terminal node.
5. There may be a situation where more than one activity needs to be simultaneously completed, which we call merge event or more than one activity needs to be simultaneously initiated, which we call burst event.
6. Parallel activities, without having intervening relationships are prohibited.
7. It may be necessary to incorporate dummy activity when two or more activities have identical predecessor and successor activities.

Important characteristics of a critical path

1. Every network should have a critical path.
2. A single network may have more than one critical path.
3. A critical path is one of the connecting links (in a network, we may have more than one connecting links) between the initial and terminal activity.
4. Number of activities in a critical path may be less than the activities in non-critical path.
5. A critical path may have dummy activity.
6. A critical path determines project duration time.
7. Activities on critical path are by nature critical activities.
8. If the project duration time need to be shortened then activities of critical path need to be shortened.

How to find out critical path in a network?

1. Draw the network enumerating all the paths.
2. List the activities on each of the path.
3. Sum up the activities along each path.
4. Identify the longest duration along each path. The longest duration is obviously the critical path in the network.

Illustration

Consider the following network, with optimistic (a), most likely (m) and pessimistic time (b) given against each arrow. Find out the expected project completion time, duly identifying the critical path. Also find out variance and standard deviation of the project length.

Activity	Time			Tie = $\frac{a+4+m+b}{6}$	$s_i = \frac{b-a}{6}$ standard deviation of completion time of an activity	σ^2i=variance of completion time of an activity
	a	m	b			
A 1-2	2	4	6	4	4/6	4/9
B 2-3	3	5	13	6	10/6	25/9
C 2-4	2	6	10	6	8/6	16/9
D 3-6	13	18	23	18	10/6	25/9
E 3-5	8	16	24	16	16/6	64/9
F 4-6	6	7	14	8	8/6	16/9
G 5-7	2	6	10	6	8/6	16/9
H 6-7	2	4	6	4	4/6	4/9
I 7-8	4	5	6	5	2/6	1/9

Now let us put the computed time in parenthesis against each activity, duly redrawing the network as under:

We find the critical path in the network is 1-2-3-5-7-8 or A-B-E-G-I. Thus expected project length would be the summation of the individual expected activity time along this path, which is 37 days.

Variance of the expected project length = 4/9+25/9+64/9+ 16/9+1/9 = 110/9 days Standard deviation of expected

$$\text{Project length} = \sqrt{\frac{110}{9}}$$

$$= 3.496 \text{ days}$$

Crashing of Project

Basic assumptions of CPM analysis are that activities and functions of a project can be crashed to reduce time requirement for project completion. However, crashing increases direct costs, obviously for increasing the man-hours (which consequently increases wage payment and wastages, like normal scrap-arising, etc.). Whether project crashing is beneficial or not, is weighed by finding out the difference between crash cost and normal cost. If crashing seems to be the better alternative, then Critical Path is re-drawn by correspondingly reducing the time requirement. It is important to note that crashing will not eliminate the requirement of any activity, but it reduces the time requirement of any activity or activities.

7.12 SUMMARY

The technique of scheduling system varies with the type of layout and type of job, viz. job-shop, batch production or mass production, etc. We have seen techniques like line balancing for automated mass production lines. In project type of work PERT/CPM techniques are also used. Each system of scheduling has its merits and demerits. Hence there is nothing like an ideal system or a best system of scheduling. What is relevant is to select the most appropriate system of scheduling which suits a particular production background and working environment.

7.13 KEY WORDS

Scheduling refers to the process of preparing a time goal for all production operations including setup and other preparation time in executing a production order in the manufacturing organization.

Network analysis: A managerial technique which help in identifying the interconnected links in a single system.

PERT: A statistical technique for qualifying knowledge about uncertainties faced in completing intellectual and physical activities essential for timely achievement of program deadline.

Project: A one shot, time-limited, goal directed, major undertaking, requiring the commitment of varied skills and resources.

7.14 SELF ASSESSMENT EXERCISE

1. Write an essay on production scheduling and control in manufacturing organization, stating its objectives and constraints.
2. Discuss the popular methods of scheduling and loading used in batch/process layout.
3. What is the advantages and disadvantages of Gantt Charts? Are dispatching and LOB better alternative than Gantt Charts?
4. Give a detailed note on PERT/CPM.

7.15 FURTHER READINGS AND SOURCES

1. Proud, John F. Master Scheduling: A Practical Guide to Competitive Manufacturing. NY: John Wiley & Sons, 1990
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3. Nair, N.G *Production and Operation Management*, ND: Tata McGraw-Hill, 2007
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Subject: Production and Operations Management

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Course: MBA | Course Code: CP-204

LESSON: 8 | **Work Study**

STRUCTURE

7.0 OBJECTIVES

After going through this lesson, you will be able to:

- **Understand the meaning and importance of work study**
- **Define the method study and procedure**
- **Understand the concept of work measurement and its procedure**
- **Define ergonomics and related issues**
- **Understand the fundamentals of work sampling**

8.1 INTRODUCTION

The objective of work study is to assist management to obtain the optimum use of the human and material resources available to an organisation for the accomplishment of the work upon which it is engaged.

Fundamentally, this objective has three aspects:

(1) The most effective use of plant and equipment.

(2) The most effective use of human effort.

(3) The evaluation of human work.

Work study is one of the major techniques in the group called as "Productivity Science". The other techniques are Organisation and Methods, Operational Research, Network Analysis, Systems Analysis, Ergonomics and Value Engineering.

The function of work study is to obtain facts, and then to use those facts as a means of improvement. It may be regarded principally as a procedure for determining the truth about the activities of existing people and existing plant and equipment as a means to the improvement of these activities. It will provide the means of achieving higher productive efficiency under prevailing circumstances.

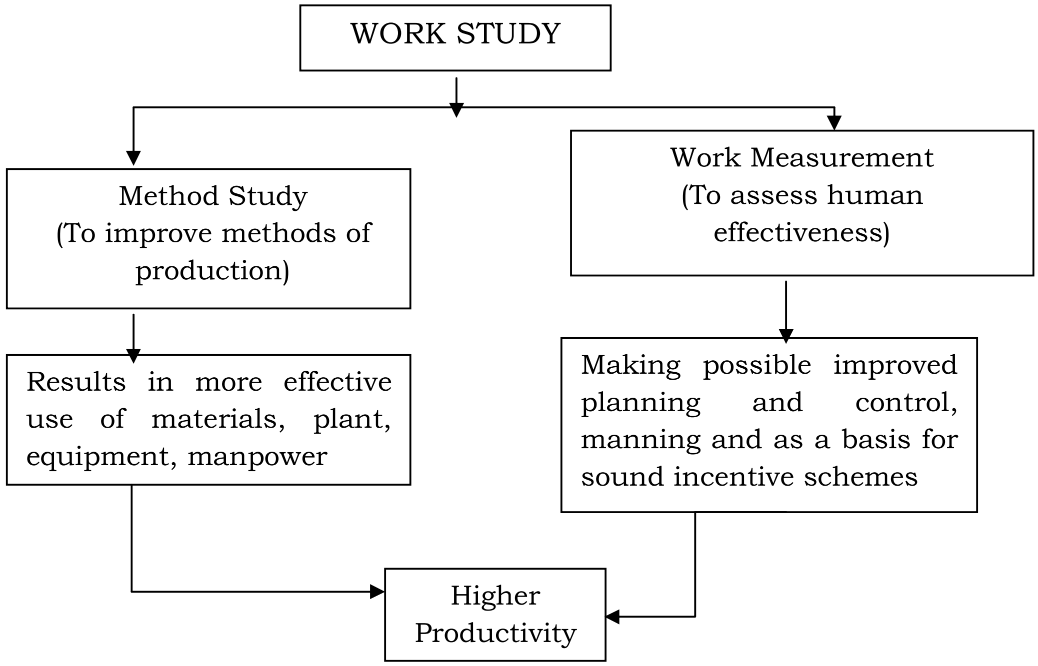
8.2 DEFINITION OF WORK STUDY

Work study, as the name implies, is the study of work of human work in the deepest sense and dignity of the word, and not merely in the special and more restricted meaning used in the physical sciences.

Work study is not limited to the shop-floor, nor even to manufacturing industry, could be used in any situation where human work is performed.

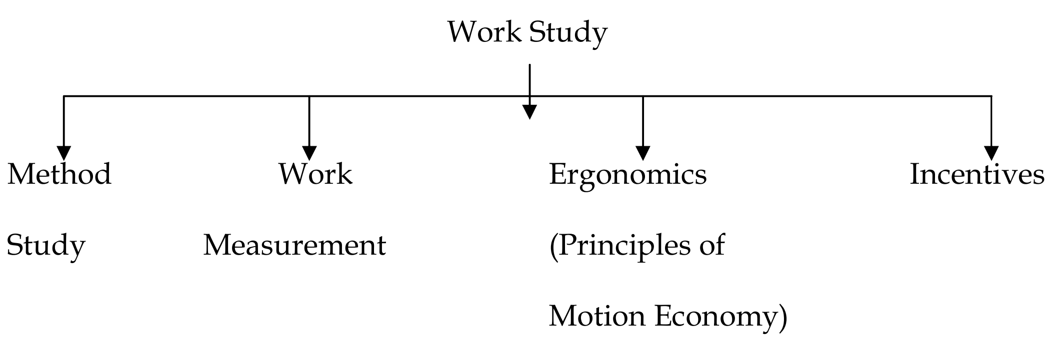
The term "work study" as defined by British Glossary:

"A management service based on those techniques, particularly method studies work measurements, which are used in the examination of human work in all its contexts and which lead to the systematic investigation of all the resources and factors which affect the efficiency and economy of the situation being reviewed in order to effect improvement."



8.3 WORK STUDY APPROACH

Work study can be diagrammatically presented as follows:



Work Study is defined as a technique that embraces method study and work measurement which are employed to ensure the best possible use of human and material resources in carrying out the specified activity.

The main objective of WS is to improve productivity of men, machines and materials.

Method Study is the systematic recording and critical examination of existing and proposed ways of doing work as to develop/apply easier/more effective methods and to reduce costs. It investigates how jobs are done and how the method of doing them can be improved.

Work Measurement is the application of techniques designed to establish the time for a qualified worker to carry out a specified job at a defined level of performance. It tries to estimate how long jobs should take once the method is decided.

Both the above concepts – Method Study and Work Measurement – are closely linked. The former intends to reduce the work-content, and the latter establishes time standards on the basis of work-content as determined by the former. Generally, a method study precedes work measurement. In some instances, time standards do indicate occurrence of ineffective time in work sampling for corrective action in anticipation of method study. Time study also enables comparison of alternative methods.

8.4 METHOD STUDY

Method study as defined by British standard is:

"The systematic recording and critical examination of the factors and resources involved in existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducting costs."

Work Measurement is defined as:

"The application for techniques designed to establish the time for a qualified worker to carry out a specified job at a defined level of performance."

8.4.1 BASIC METHOD STUDY PROCEDURE

WS consists of eight basic steps, some of which are common to both method study (MS) and work measurement (WM).

Sr. No.	Basic Step	MS	WM
1.	Select	✓	✓
2.	Record	✓	✓
3.	Examine	✓	✓
4.	Develop	✓	-
5.	Measure	-	✓
6.	Define	-	✓
7.	Install	✓	-
8.	Maintain	✓	-

Thus, Method Study (MS) has six steps:

1. SELECT the job to be studied.
2. RECORD how it is performed right now.
3. EXAMINE the existing method critically.
4. DEVELOP an improve method
5. INSTALL the improved method
6. MAINTAIN it is practice.

The acronym SREDIM will help you to remember the steps.

To conduct MS, we should have conducive human relations climate, top management support, supervisory co-operation. WS, if properly applied, tends to improve industrial relations. WS should not be conducted amidst an atmosphere of distrust. Skilled seniors may resist changes. WS results may render some worker redundant, leading to retrenchment/ redeployment/transfer. In developing counties, this causes the greatest anxiety. In the long run, however, the technique benefits all. WS is to be conducted by a properly qualified person, who can win confidence of both the supervisors and the workers. He should be able to deal with people. WS results are to be applied with tact.

8.4.2 IMPORTANCE AND OBJECTIVE OF METHOD STUDY

The objective of Method Study is to find better ways of doing things and to contribute to the improved efficiency by eliminating unnecessary work, avoidable delays and other forms of waste. Through systematic recording, analysis and critical examination of methods and movements involved in the performance of existing or proposed ways of doing work, it achieves the above-stated objectives. However, important or objectives of Method Study would be more clear once we review its contribution that flow from its above role. The contribution of Method Study could be indicated below:

1. Reorientation of the corporate objectives and mission
2. Review of the plans and programmes
3. Evaluation of the tasks, targets and available resources

4. Balancing the structure of the organisation
5. Introduction of a good communication system in the organisation
6. Better design of plans and equipments
7. Simplification of processes and methods
8. Standardisation of products and procedures
9. Improvement of work flow
10. Planning and Control of work
11. Managing resources, inventory control and replacement of plants and machineries
12. Quality and cost control
13. Improving the layout of the shop floor
14. Betterment of working environment and working conditions
15. Optimum utilisation of resources
16. Higher standards of safety, security and health
17. Performance satisfaction

8.4.3 DETAILED METHOD STUDY PROCEDURES

Procedures/steps in detail in any method study investigation may be enumerated as follows:

1. **Selection of the Job:** Once the method study idea is conceived, the first step is orientation and determination of objectives. The problem must be defined. The method study investigator face the following types of problem and normally required to solve:

a. Bottlenecks, which disrupt smooth flow of materials of processes.
b. Products which may be required to produce economically by application of cost reducing techniques.
c. Economic utilisation of space, including land and buildings.
d. Economic utilisation of labour, material and plant.
e. Elimination of idle item or non-value adding time caused due to problems of flow, queues and congestion.

While selecting the subjects for study, it is essential to keep in mind that the ultimate objective of the method study is to improve the achievement by raising the level of productivity and increasing satisfaction at work. Secondly, the term 'select' should not be taken in a narrow sense, i.e., to choose from among others, but it must include a preliminary survey, which enables the investigator to decide on the continuity of the study. Similarly, select does not necessarily mean just selection of the job but also selection of the appropriate techniques to achieve the end-result.

2. **Record the Facts:** Before discarding the existing method or procedure, adequate facts about the present system must be collected. This is required to prepare an objective record of the way the job is carried out. To eliminate the change of bias, this record is not compiled from second-hand accounts or on the manager's version as to how he thinks the job is done or an operator's description of how the job is done but based on direct observation by the concerned investigator.

3. **Critically Examine the Facts:** It is also an important stage of method study. Information collected are scrutinized in this stage and each part of the job critically examined to determine whether any part may be:

   a. Eliminated altogether.
   b. Combined with any other part of the job.
   c. Changed in sequence.
   d. Simplified to reduce the content of the work involved.

   For effective examination of the facts, following questions are generally asked:

   a. What is done and why?
   b. Who are doer and what that person does?
   c. Where is it done and why there?
   d. When is it done and why then?
   e. How is it done and why this way?

   By rearranging, simplifying, combining, eliminating or modifying the facts or records, a basis is obtained for an improved method.

4. **Develop the New Method:** Alternatives selected are used to reshape and develop the new method, layout or procedure. These may require test runs to determine their feasibility. Tests of this nature may be preferably carried out at a place, away from the work site, if possible. To ease the problems of acceptance for the new method in the department, it is good to involve the departmental officers. The end result must be an improved method and must be acceptable to

the departmental staff and workers. It must be acceptable to the departmental staff and workers. It must meet all their practical requirements and technical specifications.

5. **Install the Method:** To install the method, decision must be taken on ordering of new plants or material (if any), phasing in changes in production process, deciding the extent of redeployment, training, introducing new documentation procedures, setting new quality standards and test procedures. It is good to have a detailed time table for effecting such changes. The end-product of the installation stage is that the new method is in operation at the work site; the line management complete control is in and finally that all members of the department are fully conversant with the method.

6. **Maintaining the Method:** When a method has been installed, it tends to change slowly for obvious small alternations made by the operators or supervisors. A reference standard (job instruction sheet) is needed against which the job can be compared to detect any alterations. Similarly, a corresponding document for an incentive scheme, which also contains details of the standard time for each job, called a job specification, is prepared. With these data, changes in method can be detected. If changes are considered to be useful, the instruction sheet can be amended to incorporate them and if they are thought undesirable, they can be removed through line management.

8.5 WORK MEASUREMENT

Work measurement is concerned with determination of the amount of time required to perform a unit of work. It answers the questions 'how long should this job take to do?' It enables management to compare alternative methods, and also to do initial staffing. It makes available the data for planning and scheduling and becomes a basis for wage and salary administration, especially for devising incentive schemes.

The measurement of human work has always been a problem for management, as plans for the provision of goods or services to a reliable programme and at a predetermined cost are often dependent on the accuracy with which the amount and type of human work involved can be forecast and organized. While it has commonly been the practice to make estimates and state targets based on past experience, these too frequently prove a rough and unsatisfactory guide.

Work measurement, by enabling target times to be set, into which are incorporated rest allowances appropriate to the type of work involved, provides a far more satisfactory basis on which to plan.

It has been defined by the British Standard Institution as–

"The application of techniques designed to establish the time for a qualified worker to carry out a specified job at a defined level of performance."

8.5.1 THE OBJECTIVES

Using as a target the times established for jobs at the defined level of performance, work measurement will be found to have the following uses:

(1) To assist in method study by comparison of times for alternative methods and for allocating labour to jobs in proportion to the work involved so that the labour on a job is properly balanced.

(2) To enable realistic schedules of work to be prepared by relating reasonably accurate assessments of human work to plant capacity.

(3) As the basis of realistic and fair incentive schemes.

(4) To assist in the organisation of labour by enabling a daily comparison to be made between actual times and target times.

(5) As a basis for labour budgeting and budgetary control systems.

(6) To enable estimates to be prepared of future labour requirements and costs.

Comparison and contrast of Method Study and Work Measurement	
Method Study	**Work Measurement**
(1) Method study is the principal technique for reducing the work involved primarily by eliminating unnecessary movement on the part of materials or operatives and by substituting good methods for poor ones.	(1) Work measurement is concerned with investigating and reducing and subsequently eliminating ineffective time. Not only can it reveal the existence of ineffective time, but it can be used to set standard times for carrying out the work, so that, if any ineffective time does evolve later, it will immediately be found out by the
(2) Method study can reveal shortcomings of design, materials, and method of manufacture and as such affects mainly technical people.	(2) Work measurement is more likely to show up the management itself and the behaviour of the workers.

Work Measurement

(i) Reduces ineffective time.

(ii) Suggest rest pauses and other allowances as a result the operators are in position to maintain effective efficiency.

(iii) Provides a sound basis of giving incentive wage.

(iv) Calculate the correct manpower required for doing a job and hence aid's economizing manpower.

(v) Aids in accurate production planning.

8.5.2 THE PRACTICE OF WORK MEASUREMENT

It can be depicted as:

(a) The job is broken down into its elements.

(b) For the elements of human work, the records of basic or normal times are consulted for this time for each element.

(c) For those elements for which there is no basic time already available, the basic time is determined by the appropriate work measurement technique.

(d) The values so determined for any of the elements which could conceivably recur in another job are added to the records of basic times.

(e) The proportion of rest required is assessed and added to the basic time, to arrive at the time for doing the work at the standard rate of working and for recovering from the effort i.e. the work content.

(f) The addition of relaxation allowance may be made element by element or the basic times for the elements may be summed and the relaxation allowance added job wise, again to give the work content.

(g) The necessary technical data are collected for any machine involved in the job.

(h) The values for the human work, the technical data and any other appropriate allowances are combined to arrive at the standard time for the job.

8.5.3 DEFINITIONS OF TERMS

Work Measurement: It is the application of the technique designed to establish the time taken for a qualified worker to carry out a specified job at a defined level of performance.

Standard Performance: It is that optimum rate of output that can be achieved by a qualified worker as an average per working day or shift, due allowance being made for the necessary time required for rest.

Qualified Worker: He has the necessary physical attributes, intelligence and education, and has acquired the necessary skill and knowledge to carry out the work in hand to the satisfactory standards of safety, quantity and quality.

Element: An element is a distinct part of a specified job selected for convenience by observation, measurement and analysis. There are eight types of elements, viz. repetitive, occasional, constant, variable, manual, machine, governing and foreign.

Work cycle: It is the sequence of elements which are required to perform a job or yield a unit of production. The sequence may sometimes include occasional elements.

Rating: Rating is the assessment of a worker’s rate of working relative to the observer’s concept of rate corresponding to the standard pace.

Standard Rating: It is defined as the rate of output which qualified workers will naturally achieve as an average output for a given period of time. This rating is denoted as 100.

Basic (Normal) Time: This is the time taken by a qualified worker to do a piece of work at the standard rate of performance.

Basic time = Observed time × Rating factor

= Observed time × (Observed rating ÷100)

Take the following example:

Person	Observed Time	Rating	Basic Time
A	0.20	100	0.20
B	0.16	125	0.20
C	0.25	80	0.20

From the above table, we gather the following:

(i) A is a standard worker, B is a fast worker and C is a slow worker.

(ii) While the observed time varies, the basic (normal) time is constant which is obtained by multiplying the observed time by the rating factor.

(iii) For a standard worker the rating is 100, for a fast worker it is more than 100 and for a slow worker it is less than 100

Relaxation Allowance: It is the additional time that is allowed to a worker for a specified over and above the basic time. This time is allowed so that he can recover from the physical and psychological effect of the job performed under specified conditions and also for attending to his personal needs. It is computed as a percentage of basic time and taken into account several factors depending upon the job.

Work Content: The work content of a job consists of work plus allowance for rest, personal needs, contingencies and so on, given in work units, viz.

Work content = Basic time and relaxation allowance and any other allowance for additional work, viz. that part of the contingency allowance which represents work.

Standard Time: It is the total time in which a job should be completed at standard performance.

Standard time = Basic time + Allowance

Allowed Time: A time allowed for payment purposes to the factory worker where the standard time (or some constituent part of it, viz. work content) is increased appropriately by a factor representing a bonus and/or policy allowance.

Standard Minutes: A standard minute (SM) expresses a unit of work in terms of the 100 BS scale. Standard performance is recognized as being 60 SMs an hour. It is different from standard time, in that the latter includes ineffective and unoccupied time.

8.5.4 TECHNIQUES OF WORK MEASUREMENT

A number of work measurement techniques have been developed to suit different types of work. These are:

(a)	Time study	Applicable to repetitive work
(b)	Synthetic data or synthesis from element times	Applicable to repetitive and non-repetitive
(c)	Predetermined Motion Time Systems (PMTS)	Work
(d)	Analytical estimating	Applicable to non-repetitive work
(e)	Activity sampling	Applicable to repetitive work

These techniques are briefly discussed here.

8.5.4.1 TIME STUDY

Time study is the most widely used techniques in work measurement. It is carried out with the direct observation of a work while it is being performed. It records the time required to perform a task during a cycle and also the rate or pace at which the operator is working under specified conditions. In spite of its wide applicability in industry, this method has been severely criticised, as being subjective and susceptible to bias errors. Time studies cannot be made in hurry, nor can values once estimated be altered, unless the work content of the job and the conditions of work change.

Definition: Time study is a technique for determining as accurately as possible, the time required to carry out a specified task by a qualified worker at a defined level of performance.

Preparation for Study

The essentials for time study are as under:-

- An accurate specification of when the job begins and when it ends, and of the method by which it is to be carried out including details of materials, equipment, conditions, etc.
- A system of recording the observed (actual time taken by workers to do the job while under observation
- A clear concept of what is meant by standard rating
- A means of assessing the amount of rest which should be associated with the job
- Availability of measuring equipment like stop watches, stationeries, time study sheet, etc. (see specimen in fig. 8.3).

Breaking the Operation into Elements

An element is defined as a distinct part of a specified job, selected for convenience of observation, measurement and analysis. The question of breaking the operation into elements for time-study is based on the above considerations. It depends upon the nature of the job and the purpose of study.

TIME STUDY TOP SHEET

Operation M.S.NO	Study No. :
	Sheet No. :
Plant/Machine: No.	Time Off : Of
	Time On :

Tools and Gauges:	Elapsed Time : Operator : Clock No. :
Product/Part: No. Drg. No.: Material Quality:	Studied by : Date : Checked :

N.B. Sketch the Workplace Layout/Set-up/Part on the reverse or on a separate sheet and attach

Element Description	R	WR	ST	BT	Element Description	R	WR	ST	BT
Symbols: R= Rating, WR= Watch reading, St= Subtracted time, BT= Basic Time									

Fig. 8.3 General Purpose Time Study Sheet

Number of Cycles to be timed

An operator does not work continuously at the same identical pace. Therefore, it is necessary to time several cycles of the job in order to get a representative sample of the time required by him to perform the task. The number of cycle is a question of economy and expediency, depending on the consistency or variability of elemental time. However statistical methods are now available.

This is derived as follows:

We know standard deviation (σ) is given by the following formula in Normal Distribution.

$$\sigma = \sqrt{\frac{\sum x^2}{N} - \left(\frac{\sum x^2}{N}\right)}$$

$$= \frac{1}{N}\sqrt{N\sum x^2 - \left(\sum x\right)^2}$$

We also know in a Normal Distribution curve, Standard Error (SE) is given by the following formula.

$$SE = \frac{\sigma}{\sqrt{N}}$$

Where n = Number of samples reading required

N = Number of reading already taken

x = Individual time reading

Substituting value of σ is SE, we have

$$SE = \frac{\sigma}{\sqrt{n}}\left[\frac{1}{N}\sqrt{N\sum x^2 - \left(\sum x\right)^2}\right]$$

Applying this formula, we can now determine the number of samples required for any desired accuracy and confidential level. This is illustated as follows:

Suppose the desired accuracy = $\pm 5\%$

Required confidence level = 95%

We then have

$$SE = 0.05\frac{\sum x}{N}$$

At 95% confidence level, the standard deviation = 2 σ

SE = 2 σ

Substituting the values

$$0.05\frac{\sum x}{N} = \frac{2}{\sqrt{N}}\left[\frac{1}{N}\sqrt{N\sum x^2 - (\sum x)^2}\right]$$

Solving

$$\sqrt{n} = \frac{\frac{2}{0.05}\sqrt{N\sum x^2 - (\sum x)^2}}{\sum x} = \frac{40\sqrt{N\sum x^2 - (\sum x)^2}}{\sum x}$$

In general

$$n = \left(\frac{K}{E}\right)^2\left[\frac{\sqrt{N\sum x^2 - (\sum x)^2}}{\sum x}\right]$$

Where K = Number of standard deviation for a given confidence level.

E = Desired accuracy (precision) level

K/E ratio is called the 'confidence-precision ration'.

The above equation shows the following:

- ‘n’ is inversely proportional to the square of the confidence precision ration
- ‘n’ is directly proportional to the confidential level
- ‘n’ is inversely proportional to the accuracy (precision) level.

As an illustration, this ratio is computed for different combinations of confidence level and precision level of measurement, in Table 8.1.

TABLE 8.1

Confidence Level	50%	68%	95%	99%	95%	99%
K-value	0.7	1	2	3	2	3
Precision level	±10%	±5%	±5%	±5%	±2%	±1%
E-Value	0.10	0.05	0.05	0.05	0.02	0.01
K/E	7	20	40	60	100	300

Observing and Recording the Time Taken

The observer should take up a position from where he can observe all actions clearly, but should not make his presence felt too much upon the worker to the extent of diverting his attention or make him conscious of being watched.

Having made the necessary preparation and obtaining the assent of the operator, timing of the work can begin. While taking a time study, the stop watch can be read in the 'Continuous' Method or 'Snap Bank' Method.

Performance Rating

All operators do not work at the same pace. Thus it would not be fair to establish a standard for work performance based on the time required by either a fast or a slow operator. Some speed allowance therefore must be made in the time values obtained through time study for the pace at which the operator performs the task. Determining the relative speed or temp at which an operator works is known as the rating.

Rating the speed of an operator is a matter of judgement on the part of the time study analyst. This is one of the aspects in time study which has been considered as being too subjective. Although most of us agree that a more precise measure of an employee's performance would be desirable, we have not been able to devise any means that would overcome relying on the analyst's judgment. Several methods of rating and rating scales are used in the industry. Some of these are explained below:

(a) Westinghouse Rating

In this method, the rating takes into account four factors, namely, skill, effort, working condition and consistency. The analyst determines the rating for each and converts these into percentage value from a fixed table. For example, skill has value of 0.15 to 0.22; effort has a value from 0.13 to 0.17; working conditions has a value of 0.06 to 0.07 and consistency 0.02 to 0.04. Different attributes are marked. The sum of these indicates the rating of the operator.

(b) 100% Rating

The most widely used system of rating is the 'overall 100% rating' scale. Under this system an operator working at normal or average pace is said to be working at 100% pace. Thus, if an operator was working slower than the rating factor would be less than 100%, say 85%. If, on the other hand, he is working faster than normal, the rating factor would be over 100%, say 120%. In order to determine whether an operator is above or below normal, some concept of normal or average must be established. For example, a normal, (or 100%) walking pace on a level ground is three miles per hour. Rating factors for speeds greater than or less than three miles per hour are greater than or less than 100%. By studying persons walking at various speeds observers can be trained to rate their speeds very closely, and reduce them in percentage value of rating factors.

Obtaining Basic Time

The object of time study is to establish a basic time to perform a job at standard rating. It is, therefore, necessary to convert the observed time into basic time by multiplying the former with the rating factor.

Basic Time = Observed time × Rating factor

Example Suppose the average observed time for an element was 0.15 minute and the rating factor was 90.

$$\text{Basic} = \frac{0.15 \times 90}{100} = 0.135 \text{ minute}$$

0.135 minute is the time that would be taken at standard rating. He has taken more time because he is a slow worker having a rating of 90% which is less than the standard rating (i.e. 100%). If the operator had been working better than the standard rating, say 120, then the time expected from a standard rating would be

$$0.15 \times \frac{120}{100} = 0.180 \text{ minute}$$

Here he has taken less time than the basic time because he is a fast worker having a rating of 120%, which is better than the standard (100%).

Allowances

A human being is not a machine and cannot be expected to work like a robot. In order to determine a fair and just time standard, some allowances must be made for normal work interruption, fatigue, and personal need. These allowances may fall into one or more of the following categories:

(a) Process allowance
(b) Relaxation allowance
(c) Special allowance
(d) Policy allowance

Process Allowance: A process allowance is an allowance of time given to compensate for enforced idleness (which would otherwise cause loss of earning power) on the part of an operator due to the character of the process or operation on which he is employed. For example, an operator may not be able to work because he has to wait for a machine to complete its own part of teh cycle. Again, he may be member of the team in a line which is not balanced or he may be in-charge of several machines, some of which are periodically idle because he is unable to attend to all when required. In all these cases there is a loss of production for which the operator is not responsible. He must therefore be covered against these losses. This allowance is also called unavoidable delay allowance. Five percent of the basic time is generally considered as this allowance.

Relaxation Allowance: The relaxation allowance is an addition to the basic time (usually calculated as a percentage) intended to provide the workers with an opportunity to recover from the physiological and psychological effects of expending energy in the performance of specified work under specified conditions and to allow attention to personal needs. This is also known as rest allowance, compensatory rest allowance or fatigue allowance. Relaxation allowances are given as percentages of the basic time (generally 3% of the basic time). However, the exact percentage depends on various factors of the individual job. These are to be considered when establishing this allowance. As for example, work study school at Cranfield had identified 11 factors where 4 are on physiological aspects, 4 on physical factors and 3 on psychological aspects. Under each factor different degrees are also identified.

Special Allowances: Special allowances are given for activities not normally forming part of the operation cycle but essential to satisfactory performance of the work. Such allowances may be permanent or temporary and fall into three broad classes:

1. Periodic activity Allowances	Allowances for activities carried out at definite intervals or after performing a specified number of cycles, e.g. regrinding tools, cleaning machines, resetting machines, etc.
	Allowance for activities carried out once only in the course of a batch or order, irrespective of the size of the batch or duration of the work, viz. setting up a machine tool at the beginning of a batch.
2. Interference Allowances	The machines may complete their working cycles at random intervals and because of this one or more of them may be idle, awaiting the attention of the operator who is busy attending to another machine. This allowance is given to compensate for the loss of earnings as a result of the production loss.

3.	Contingency Allowance	A small allowance of the order of 5% given to cover irregular occurrences which are known to happen but whose incidence it may not be possible or economic to study.

Policy Allowance: This allowance is given at the discretion of the management over and above the allowances given to features inherent in the work under consideration. This is used for calculating payments only in order to enhance the performance of the worker.

Allowed Time

Where a standard time has been added to policy allowance, the new time is known as the allowance time. For instance, a certain job may carry a standard time of 1.4 SM (Standard Minutes) with a policy allowance of 0.2. Allowance time = 1.6 SM.

8.5.4.2 SYNTHESIS

In many industries the work done is of a repetitive nature that is the product is produced in large numbers or in batches of varying sizes at irregular intervals. Even when the products are made only once, it is done by operations which are frequently used in the factory. In such cases it is not necessary to carry out time study techniques. Synthetic techniques are used where standard time is computed by adding various elemental times which constitute the work. Standard data is made available or most of the known elemental operations such as for preparatory, setting, manipulating, removing, clearing, tool positioning, holding and tightening. The data should be stored in a library in such a manner for easy reference when required for estimating scheduling or nay other purpose. These standards cannot be transferred to other factories as they refer to the particular conditions prevailing in a specific workshop at a given factory.

Advantages

The advantages gained from synthesis data techniques are:

- Reduction in the number of time studies and consequently in the cost of running the time study department
- Reduction in time required to issue a time standard for a job
- Consistency in the time standards

8.5.4.3 PRE-DETERMINED MOTION TIME SYSTEMS (PMTS)

The ratings of the observed time by stop watch time studies have always been objected to by labour and union representatives. Their contention is that rating is a subjective process and can never be accurate. Various systems of predetermined time standards have therefore been developed in an attempt to overcome the time and expense of making many studies of the same job and to meet criticism of the rating procedure. These systems are based on the theory that all manually performed work is done by motions of the human body-human motions of the arms, fingers, body and so on. For practical purposes, there can be only a finite number of motions. An operator performing work will, consciously or unconsciously, select from this finite number, a sequence of motions and use them to do the work. In this method, the work is visualised as a predetermined motion. This method avoids the costly and lengthy time studies, which has its own limitations affecting the accuracy of estimate. In this method, the actions involved are the following.

- Breakdown the work into list of motion,
- Arrange the list of motions in correct sequence,
- Enter against each motion the rated time.

The rated time of motions are obtained from a set of tables which have been compiled for various motions. The sum of the times gives the total time to perform the work. All times have been standardized at normal rating. Allowances are later added. For example, the motions required to pick up a pencil might,; 'reach' or 'grasp' the pencil, and 'move' it to the desired location. Time values for 'reach', 'grasp' and 'move' which are basic motions and are predetermined, and can be assigned to these motions. Adding these values will yield a total time to perform the operation.

Types

Several types of predetermined systems are used in industry. Some well-known types are Methods Time Measurement (MTM), work factor, and basic motion time study.

Method Time Measurement (MTM); This is a procedure which analyses any manual operation or method into the basic motions required to perform it and assigns to each motion a pre-determined time standard which is determined by the nature of the motion and the conditions in which they are made. The Method Time Measurement procedure consists of the following.

- Data tables giving the predetermined standard time for the basic motions
- Establishing the laws and concepts about the sequences these motions will follow

The MTM procedure recognises 8 manual movements, 9 pedal and trunk movements, and 2 ocular movements. Thus there are 19 fundamental motions for which standard times are determined, taking into account the physical conditions and the nature of the conditions. The law, governing the usage of these fundamental motions, is the 'Principle of Limiting Motions'. This principle segregates these motions which are capable of being performed simultaneously by a qualified operator from those operations which are not.

MTM tables can be found in any standard handbook on industrial or production engineering. It can be applied easily without much training and is capable of giving fairly accurate results which are invaluable for planning purposes.

Work Factor System: This is another system using PMTS and is the trademark of the Work Factor Company, an industrial consultants firm. This was known for a short time in the UK and Europe as the QSK system (Quick-Shea-Kochler), after the names of its authors.

Three types of work factor systems were developed:

(a) Detailed WF system

(b) Simplified WF system

(c) Abbreviated WF system

The WF time units are 0.0001 minute in (a) and (b) and 0.005 minutes in (c) above.

The work factor system is based on the principle that the four major variables which affect performance of manual motions are:

- Body member used
- Distance moved
- Amount of control required
- Weight or resistance involved

Tables and WF units then prepared for a variety of combination of the above factors for use as systematic or synthesis data.

Motion Time System: Basic motions are classified as finger, hand, arm, foot, leg and body motions. Finger, hand and arm motions are each classified into a Class A, B and C types of motions. Class A motions are those where no muscular movement is required for stopping the motions (Hammering-down-stroke). Class B motions are those where movement is stopped entirely due to muscular control (stopping the movement of the hand-in mind-air). Class motions are those where muscular control is required for both slowing the motion and stopping it subsequently. Other factors influencing BMT are:

- Distance moved
- Visual attention
- Precision requirements

- Weight
- Simultaneous motions

After exhaustive time studies, data is tabulated as in MTM and WF systems.

8.5.4.4 ANALYTICAL ESTIMATING

Analytical estimating is a technique developed to enable study of non-repetitive jobs. Developed in the 1940s, it is a system of synthesis in which the elements are estimated instead of timed. Where the times taken are many hours or many days, an hours or two is not going to affect the overall time. This technique is extensively used in planned maintenance, engineering construction on-off jobs and tool-room work.

Procedure

An example of carrying out analytical estimating for the removal and replacement of boiler manhole doors is shown in Table 8.2. The work to be done is broken down into elements of longer duration, for craftsman and laborer, and listed as shown in the table. The estimated time for each element (at 100% rating) is then entered in the appropriate columns. If any machining is to be done, the time required can be obtained from synthesis data or can be calculated from first principles. The total elemental time plus the necessary allowances give the time to be allowed.

In exceptional cases, such as a bolt getting jammed against a bulk head, the 'degree of abnormality' should be specified against that element and a reasonable allowance provided to take care of the time lost.

Actual time taken should always be checked against the estimated time so that records can be built up and estimating improved. In case where the work is not getting done according to the estimated time, then an extra work authorisation slip has to be initiated by the section, indicating the reasons for demanding the extra time.

Training

The success and accuracy of the technique depends to a great extent on the character and ability of the estimator. If he is an experienced person then the estimates will be fairly accurate. The qualifications of the estimator should therefore be that he should be competent, intelligent and has sufficient experience, not only in work study but also as a worker and a supervisor. Only then are his judgments' likely to be accepted by other workers.

Illustration

An illustration of analytical estimating is given in Table 8.2.

Table 8.2 Analytical Estimating

Date	: 10th August 90	Maintenance Estimate
Job	: Boiler Manhole doors, Remove clean, and renew joints, replace	No. 77
Location	: Boiler House building No.6	Estimator: Dr. Brown

Element No.	Element Description	Fitter's Time	Labourer's Time	Overall Time
1	Remove holding nut and clamp and lay aside	2.00	1.00	2.00
2	Get door out of boiler	2.00	2.00	2.00
3	Remove old joint	2.00	--	2.00
4	Clean and inspect door clamp and nut	6.50	--	6.50
5	Prepare new joint	--	1.50	1.50
6	Fit new joint	2.00	--	2.00
7	Replace door in boiler	3.0	3.00	3.00
8	Replace clamp and nut and tighten up	2.00	2.00	2.00
	Totals	19.50	9.50	21.00
	Plus 12.5% allowance	22.00	10.70	23.63 say 25

Time allowed for one door at standard performance = 25 minutes

Time allowed for three doors, at standard performance = 75 minutes

Time allowed for job, including moving around boiler = 90 minutes for one fitter and one labourer.

8.5.4.5 ACTIVITY SAMAPLING

There are two main methods by which the activities of a group of men or machines can be studied. In the fist method, namely, production or continuous study, the activities are observed and recorded continuously over a long period of time. This type of study not only consumes time and effort, but is also costly. In many cases, the needed information can be obtained in less time and at lower cost by a second method called activity sampling. This type of study consists of taking a number of observations at random intervals, wherein the state or conditions of the object of study is noted and classified into predefined categories pertinent to the situation. The percentage of observation recorded for a particular activity or delay, within reasonable limits, is a measure of the percentage of total time during which that activity or delay occurs. For example, if 16 random visits were made during the day to a work place to observe the delays occurring on a certain machine, and the machine was idle during four of those visits, then the deduction made is that the machine was idle for 25% of the time. This method is most appropriate when the cycle time very long and/or continuous direct observation is is not feasible or when tasks are required at unexpected times.

Activity sampling is also known by the following names:

- Work sampling
- Ratio delay
- Snap reading method of observing

Historical Background

K.H.C. Tipett, a statistician, carried out a series of research works on effective utilisation of men and machines in the English textile industry and published his findings in the Journal of Textile Institute Transactions in February 1935. These studies showed that statistical means can be employed to arrive at highly practical and accurate results at less cost than methods previously employed. These observations were the basis of considerable discussion both by scientific societies and industry. This technique gained immediate recognition and was introduced in the USA in 1940 by Professor Morrow of the New York University. This technique was put into practical tests in separate industries by graduate time-study students under the direction of the Department of Administrative Engineering of New York University. These studies confirmed Tipett's findings. This has emphasized the importance of this method as a management tool and also highlighted the practical utility of this method where the result is obtained with minimum cost. Soon this technique gained wide application and popularity in USA and was known as 'Work Sampling' or 'Ratio Delay'. Some authors also call it 'Observation Ratios' an in Britain, it is known as 'Activity Sampling'.

Definition

British Standards Institute defines Activity Sampling as "A technique in which a large number of instantaneous observations are made over a period of time of a group of machines, process or workers. Each observation records what is happening at that instant and the percentage of observation recorded for a particular activity or delay is a measure of the percentage of time during which that activity or delay occurs."

Theoretical Basis

The theory behind an activity sampling study is that the percentage of occurrence of a condition as found in a random sample, reflects to a known degree of accuracy, the percentage of that condition in the total activity. The degree of accuracy can be regulated by varying the number of observations (size of sample). This method is similar to that used in Statistical Quality Control and is essentially a sampling technique. Sample is the term used for small number taken from a group. Population or universe is the term used for a large group. It is possible to draw conclusions about the proportion of defective articles in a large number by sampling method. Subject to the adoption of a satisfactory procedure, the results shown by the sample can be taken to indicate, within definable limits, the proportion of a defective article in the total. Time can be considered to be composed of a large number of 'moments', a proportion of which can be sampled.

In the case of an operator or machine, samples will indicate different activities or delays as a proportion of the total 'moments'. The larger the number of observations made, the closer it will be with the results obtained from those of a production or continuous study; for a particular study, a balance is achieved between the number of observations made and the accuracy required of the results.

Simple Example of an Activity Sampling Study

Activity sampling study in its simplest form consists in making observation at random intervals of one or more operators or machines and noting whether they are working or idle. If the operator is working he is given a tally mark (a stroke show under working. If he is idle, he is given a tally mark under 'idle'. The percentage of the day that the worker is idle is the ratio of the number of idle tally marks to the total number of idle and working tally marks. Take for example the following observation on an operator:

State	Tally	Total
Working		15
Idle		5

Note: A diagonal stroke across a set of four vertical strokes indicates a tally mark of five.

Out of total of 20 observations, there are 5 idle observations. Therefore, the percentage of idle time is 5/20 × 100, i.e. 25%. Percentage of working time 15/20 × 100, i.e. 75% (or 100% - 25% = 75%).

If the study is covered during an eight-hour shift of an operation, then it would indicate that the worker was idle during 25% of the time or two hours and was working during the remaining period of six hours.

Statistics

Some statistical concepts connected with activity sampling studies are given below.

Random Sample: The term 'random' is a description of the manner in which the sample is selected. It implies that the method of selection gives each individual sample an equal chance of being selected. In other words, sample must be selected at a random unbiased and independent basis.

Arithmetic Mean: The arithmetic mean or average of a set of values is the sum of the values divided by the number of values.

Standard Deviation: The standard deviation of a set of values is a measure of the extent to which they are dispersed about their arithmetic mean. It is normally expressed as "Sigma" and represented by the Greek letter 'σ'.

Population: This represents the total quantity of a class or time. When doing an activity sampling study of the working/not working type, the population would be total time during which the study takes place.

Normal Distribution Curve: The Normal Distribution Curve is typical of the kind of frequency distribution which is of importance in activity sampling because it represents graphically the probability of the occurrence of certain chance phenomena. The confidence level depends on the Standard Deviation (SD) allowed.

For example

1. SD = 68.27% confidence level
2. SD = 95.45%
3. SD = 99.73%, etc.

The normal curve is significant because of the relationship between the area under the curve and ordinates at various distances on either sides of the mean ordinate.

Confidence Limit: In any activity sampling study, it is necessary to decide at the outset the level of confidence desired in the final results. Normally a confidence level used in the study is 95%. This means that the probability is that during 95% of the time, the random observation will represent the facts, and 5% of the time, it will not. This also means the precision or accuracy level of observation. In other words, the analyst is sure that his result will be correct, 19 times out of 20. One sigma would give a confidence limit of 68%. This means that the data obtained by random sampling has a 68% chance of representing the true facts, and will also have an error of 32%.

Number of Observations

We have developed a formula for time study which gives us information as regards the number of cycles to be timed so that the observed result falls within a desired confidence level, at the existing accuracy limits. The frequency distribution assumed in such a case is that of standard (normal) distribution. In activity sampling, specialists visit the work centre at random intervals and observe whether work is in 'operation' or 'not'. Thus the occurrences of events follow a binomial distribution. As the numbers of observations are more and takes place at random, the binomial distribution closely approximates to that of a 'normal distribution' curve. In a normal distribution curve, it is possible to improve the confidence level by adjusting the standard deviation. In this case, the following two aspects are important:

- Desired accuracy limit (Standard Error)
- Required number of observations to give the desired confidence level

For Binomial Distribution, value of mean (x) and standard deviation (σ) are given by equations

$$x = np, \sigma = \sqrt{npq}$$

As 3 σ limit, the amount of its expected variation is given by,

$$np \pm 3\sqrt{npq}$$

If p and q are expressed as proportions of total observation, Equation can be written as

$$\frac{np}{n} \pm \frac{3}{n}\sqrt{npq}$$

or $$p \pm 3\sqrt{\frac{pq}{n}}$$

Hence a general expression for standard error (E) = K $\sqrt{\frac{pq}{n}}$ -------------- 8.7

Note: We have used letter E instead of S to represent Standard Error to distinguish p and q given as a proportion here.

(a) When Occurrence is given in Percentage

In this case, Equation 8.7 takes the following form:

$$E = K\sqrt{\frac{P(1-P)}{N}}$$

Where P = Proportion of occurrence given in percentage value.

K = Number of Standard Deviation for a given confidence level (for example, K = 1, 2, and 3 corresponds to confidence levels of 68%, 95% and 99% respectively).

N = Required number of observations.

Q = 1 – P

Rearranging terms,

$$N = \left(\frac{k}{s}\right)^2 p(1\text{-}p)$$

(b) When Occurrence is given in Fraction and Relative Error (S)

$$s\,p. = K\sqrt{\frac{p\,(1-p)}{N}}$$

and $$N = \left(\frac{k}{s}\right)^2 \left(\frac{1-p}{p}\right)$$

where s= Relative error = $\frac{E}{P}$ or E = s × p

p = Proportion of occurrence given in fraction.

Procedure

The following steps are involved in activity sampling.

Step 1: Planning this involves selection of the work to be timed, the desired accuracy limit (E) and the confidence level.

Step 2: Pilot study A pilot study must be conducted before the main study is carried out. This is necessary to decide the value of 'P' and determine the minimum number of observations (N) from the formula.

$$N = \left(\frac{k}{s}\right)^2 P\,(100 - P)$$

Where value of P is given in percentage.

Step 3: Actual study now the actual activity sampling study is carried out. A minimum number of observations (N) are conducted as per the figure obtained in Step 2 above. This will give the result for the desired confidence level. Having conducted N observations we estimate the mean value of P for a given K-value. In this step the standard error is determined from the following equation:

$$E = \pm K \sqrt{\frac{P\,(100 - P)}{N}}$$

Having determined the Standard Error, we fined the range of 'P', viz.

$$P_{max} = (P + E)$$

and $$P_{max} = (P - E)$$

Step 4: Basic Time (BT) from the mean value of 'P', the basic time is established by the equation:

$$BT = P \times T$$

where T = Total time of operation

P= Percentage of the total time utilized for the work.

Basic Time will also have maximum and minimum limits depending upon the maximum and minimum of P respectively.

Step 5: Standard Time (ST) Standard Time is calculated by the equation:

$$ST = BT + A$$

Where A = Allowances.

Worked-out Examples

Problem 1 A shop supervisor wants to know the percentage of time a shop in his department is idle. Estimate the minimum number of observations necessary to give a 95% confidence level so that the results are accurate within $\pm$5%. A pilot study showed that 40 times out of 100 observations the shop was idle.

Solution Given $P = \frac{40}{100} = 40\% \; E = 5\%$

K value at 95% confidence level = 2.

Minimum number of observations N $= \left(\frac{k}{s}\right)^2 P(1 - P) = 400$ say

$$= \left(\frac{2}{5}\right)^2 \times 40 \times 60 = 384$$

Problem 2 A pilot study conducted to establish the utilisation time of a lathe through work sampling, had shown that it was idling 45 times out of 180 observations. Estimate the number of observations required to give a 95% confidence level so that the result falls within the relative accuracy of $\pm$5%. Relative accuracy level (s) is given as 5% (S = 0.05).

Solution At 95% confidence level K = 2.

Proportion of idling time

$$= \frac{45}{180} = \frac{1}{4}$$

p = proportion of working time = 1 - $\frac{1}{4}$ = $\frac{3}{4}$ = 0.75

Minimum number of cycles

$$N = \left(\frac{k}{s}\right)^2 \frac{1-p}{p}$$

$$= \left(\frac{2}{0.05}\right)^2 \times \left(\frac{1-0.75}{0.75}\right)$$

= 533.3, say 534

Problem 3 The following data is observed from a work sampling technique:

Occasion when operator was idling = 500

Occasion when he was found working = 1500

Examine whether this data is within $\pm$ 5% accuracy level at 95% confidence level. Also estimate the range of his operating time.

Solution

Idling = 500

Working = 1500, p = $\frac{1500}{2000} - 0.75\ K - 2$

N = 2000

Let 'S' be the relative accuracy

$$S\,p = K\sqrt{\frac{p\,(1-p)}{N}}$$

$$= 2\sqrt{\frac{0.75\times0.25}{2000}} = 0.01936$$

We also know

$$S = \frac{E}{P} = \frac{0.01936}{0.75} = 0.0258 \text{ or } 2.58\%$$

Since 2.58% is less than 5%, the results are within the prescribed accuracy level. This means we are 95% confident that the operator will be working 75% of the time.

Since S= 2.58%, is the relative error of P value, the real value (range) of P varies between the limits of $\pm$ 2.58% of 75%, viz. 1.94%

Hence the range of P = 75 $\pm$ 1.94%

= 73.06% to 76.94%

8.6 CONCEPT AND DEFINITION OF ERGONOMICS

Ergonomics is derived from two Greek words; ergon, meaning work and enomos, meaning laws. It is the study of the effects of work system on workers and it aims at fitting the work to the men to increase their efficiency, comfort and satisfaction. ILO defined ergonomics as:

"The application of human biological sciences in conjunction with engineering sciences to the worker and his working environment, so as to obtain maximum satisfaction for the work which, at the same time, enhances productivity."

Contextual analysis of ILO definition, therefore, provides more meaningful basis of understanding ergonomics. An ergonomist for effective accomplishment of work tries to integrate the work system (which broadly includes the tasks, working equipments, working conditions and working space) with the capabilities and requirements of work. In this process, he, therefore, tries to ensure job satisfaction for the workers, which, inter alia, increases their productivity.

In all schemes of human activity ergonomics can be applied be it in offices, factories, shops, ships, air and even in the space. Some of the areas where ergonomics has been successfully applied are as under :

a. Design of equipment, power and hand tools.
b. Design of display and warning systems.
c. Design of furniture, seats, rests and steps for operations.
d. Design of tools, jigs and fixtures.
e. Plant layout.
f. Improvement in working conditions and environments.
g. Computation of relaxation allowances of workers.
h. Selection, training and placement of personnel.
i. Motivation of workers.

However, for better understanding, the areas of ergonomic investigation of a work system may be grouped as below.

Human Characteristics

Health, physique, anthropometric data, personal background, education, training, experience, age, sex, intelligence, aptitude, reaction time, interest, personality characteristics, temperament, attitude towards work, motivation.

Work

Physical loads, perceptual loads, mental loads, displays and warning systems, controls, compatibility of inputs an output.

Working Conditions

Workplace layout, postures, motion and movements, fatigue, monotony and relaxation allowances, comfort, safety and health, working hours and shift work conditions.

Environment

Illumination, ventilation, temperature and humidity, colour dynamics, fumes, dust, odor and smoke, landscape, scenery and garden, cleanliness and sanitation.

Many alternative terms like; human engineering, human factors in engineering, engineering psychology, applied experimental psychology, applied and human engineering research, man-machine system analysis, etc., are used to designate the discipline. This subject has developed during World War II with the coordinated efforts of physiologists, psychologists and the design engineer. Its earliest application can be traced to Frederick Winslow Taylor (1856-1915). Taylor's experiments were mainly to arrive at the optimum design of equipment for specific types of work and so also to train the workers to suit them for each type of task. Frank Bunker Gilberth (1869-1924) and his wife Lillian elaborated the principles of motion economy and introduced the rest pauses and spacing out of work to reduce the fatigue and eliminate stresses. Since then, with the advancement of experimental physiology, psychology and method study, the subject delved deeper into the human make-up for better and scientific understanding of the effects of working conditions and environment on human body and mind.

8.6.1 IMPACT OF ERGONOMICS ON WORK STUDY

Work study, which aims at scientific analysis of a work system to increase productivity and satisfaction at work, is dependent on ergonomics for the research data on many facets of human reaction to a given work situation. Such input information makes the task of work study practitioner more scientific and result-oriented. These input information/data mostly relate to the following areas:

i) Limits of sustained physical endurance, normal speeds of movement and optimum method of handling of controls.

ii) Receptivity to sensory inputs and time required for perception of deviations.

iii) Reaction time for motion output and time required for evaluation and decision making.

iv) Anthropometric data to guide the design and layout of equipment, work place and furniture.

v) Effects of different types of environmental conditions on the human being in order to generate improvements.

vi) Effects of working conditions so as to raise the standards of comfort, safety and health.

vii) Qualitative and quantitative analysis of factors contributing to industrial fatigue for computation of 'relaxation allowances'.

8.6.2 ERGONOMICS AND MANAGEMENT

Ergonomics is a discipline at the service of management from the very planning and design stage of a work system. In the organisation and control of human effort directed to specific ends, management needs to have an appreciation of the human factors involved in a work system.

The findings of ergonomic research, particularly in the field of perceptual and mental loading have a special bearing on the work situation confronting managerial performance in an organisation. The aim here will be to eliminate all perceptual and mental loading that may arise from the perusal and evaluation of reports on the normal activities of the organisation, thereby highlighting only the deviations from the equilibrium state. This will permit more effective application of the managerial talent to really important problems over a wide span. In other words, ergonomics can help in increasing the productivity of managerial brain power. This single improvement, by itself, without any changes in the methods on the shop floor will lead to spectacular increase in the overall productivity of the organizations.

8.7 SUMMARY

The objective of work study is to assist management to obtain the optimum use of the human and material resources available to an organisation for the accomplishment of the work upon which it is engaged. While selecting the subjects for study, it is essential to keep in mind that the ultimate objective of the method study is to improve the achievement by raising the level of productivity and increasing satisfaction at work. A number of work measurement techniques have been developed to suit different types of work. Work study, which aims at scientific analysis of a work system to increase productivity and satisfaction at work, is dependent on ergonomics for the research data on many facets of human reaction to a given work situation. Such input information makes the task of work study practitioner more scientific and result-oriented.

8.8 KEY WORDS

Work Study is defined as a technique that embraces method study and work measurement which are employed to ensure the best possible use of human and material resources in carrying out the specified activity.

Method Study is the systematic recording and critical examination of existing and proposed ways of doing work as to develop/apply easier/more effective methods and to reduce costs. It investigates how jobs are done and how the method of doing them can be improved.

Work Measurement is the application of techniques designed to establish the time for a qualified worker to carry out a specified job at a defined level of performance. It tries to estimate how long jobs should take once the method is decided.

Time study is a technique for determining as accurately as possible, the time required to carry out a specified task by a qualified worker at a defined level of performance.

Standard Performance: It is that optimum rate of output that can be achieved by a qualified worker as an average per working day or shift, due allowance being made for the necessary time required for rest.

Activity Sampling as a technique in which a large number of instantaneous observations are made over a period of time of a group of machines, process or workers. Each observation records what is happening at that instant and the percentage of observation recorded for a particular activity or delay is a measure of the percentage of time during which that activity or delay occurs.

Arithmetic Mean: The arithmetic mean or average of a set of values is the sum of the values divided by the number of values.

Standard Deviation: The standard deviation of a set of values is a measure of the extent to which they are dispersed about their; arithmetic mean.

Ergonomics is the application of human biological sciences in conjunction with engineering sciences to the worker and his working environment, so as to obtain maximum satisfaction for the work which, at the same time, enhances productivity

8.9 SELF ASSESSMENT EXERCISE

1. Define work study. What are their importances?
2. What is the importance of method study? Identify the important contributions of method study and discuss at least five such contributions.
3. Define work measurement. Write a detailed note on the different techniques of work measurement.
4. What are the steps in time study programme? How does it help work measurement programme in an industrial unit?
5. What is ergonomics? How does it help to increase productivity? Discuss with examples.

8.10 FURTHER READINGS AND SOURCES

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Course: MBA Course Code: CP-204

LESSON: 9 **MATERIAL MANAGEMENT**

Structure

9.0 OBJECTIVES

After going through this lesson, you will be able to:

- **Describe the role and importance of material management.**
- **Understand the concept of material requirement planning.**
- **Understand the issues of store management.**
- **Applications of inventory control techniques.**
- **Understand the use of computer in material management.**

9.1 INTRODUCTION

The broad functions in any manufacturing concern are:

(i) Designing product and manufacturing its production.
(ii) Managing materials.
(iii) Selling the product.
(iv) Controlling finance and cost.
(v) Handling personnel matters.
(vi) Quality functions.

Material Management (MM) and Quality Control have not been given their due place earlier but today these functions have acquired an important position in the organisation. MM is recognised as one of the very important functions of the organisation and QA services for the satisfaction of the customer.

Material management is defined as the integrated function of purchasing and allied activities so as to achieve the maximum coordination and optimum expenditure in the area of materials.

Various functions served by material management include:

Material planning	Purchasing	Receiving
Stores	Inventory control	Waste management

Keeping above functions in mind, MM is the function responsible for the coordination of material planning, sourcing and purchasing, stocking and controlling materials in an optimum manner so as to provide a pre-decided service to the organisation at a minimum cost. Hence, material management can be re-defined as:

"Function responsible for the co-ordination of planning, sourcing, purchasing, moving, storing and controlling materials in an optimum manner so as to provide a pre-decided service to the customer at a Minimum Cost."

9.2 IMPORTANCE OF MATERIAL MANAGEMENT

Organizations which have gone in a big way for the integrated materials management usually enjoy the following advantages:

(i) Better accountability: Clear cut accountability is established because there is centralisation of authority and responsibility for all aspects of material management functions. Various user departments. can direct their problems or requirements, with regard to materials to one central point so that the action can be taken immediately. This also helps in evaluating the performance of materials management in an objective manner.

(ii) Better Coordination: The centralisation results in better support and co-operation in the accomplishment of the material function. This creates an atmosphere of trust and better relations between user departments and MM.

(iii) Better performance: 1. Effective communication; 2. Better speed; 3. Accurate results; 4. Judicious decisions: Leading to lower costs. Through better inventory turnover, reduced stock-outs, reduced lead times and reduction in paper work.

(iv) Adaptability to EDP (Computerisation): The centralisation of materials management function has made it possible to design the Data Processing System – whose facilities are: data collection, data presentation and analysis, preparation of special reports. All these lead to better decisions.

(v) Team spirit, better morale opportunities for growth and development.

9.3 MATERIALS REQUIREMENT PLANNING (MRP)

Materials Requirement Planning is a special technique to plan the requirements of materials for production. How is it different from techniques such as Economic Order Quantities and Safety Stock

Computations? In order to understand the differences we need to take another look at our EOQ and Safety Stock Computational Methods.

It is not uncommon for the practicing production managers to come across a situation where out of 10 raw materials needed at a point of time to run a particular product-line, excepting for one raw material, all the rest (nine) are available. And for want of one, the production of the product-line cannot be undertaken.

When we are formulating chemical or pharmaceutical products, or when we are making assemblies out of various components (manufactured or bought-out), we are dealing with bunched requirement of materials. The requirement of raw materials then depends upon the requirement of production of the finished product (assembly, or a shampoo, or a medical formulation). It seems, it would be better if we know the production plan/schedule for the assembly of the finished product and accordingly arrange for all the raw materials that go into the finished products, rather than depending upon statistics and probabilities. This is precisely what MRP attempts to do. It is simple system of calculating (arithmetically) the requirement of the input materials at different points of time based on the plan or schedule for production of the finished good.

There are no probabilities involved anywhere, only the derivation of the requirements of input materials based on the requirement or plan for production of the final products. Such a system will work well for materials that have no direct demand of their own, but have only a derived demand. These materials can be called dependent demand items. The finished assembly has a direct demand of its own and therefore it is an independent demand item.

Let us also review the EOQ model/s. All of them assume a uniform (or a more or less uniform) pattern of consumption of material. Based on averaged consumption, the EOQ model answers the 'how much' and 'when' questions for optimal cost considerations. Optimal cost or otherwise, the basic difficulty in some peculiar production situations arises because of the averaging of the consumption of materials.

When we are dealing with five different varieties of shampoos, five varieties of soaps, another five of cleaning powders or solutions, the requirement for many raw materials over time for these formulations does not fall in the smooth average consumption pattern. On the contrary, we may observe the requirement of materials over time as shown in Fig.9.1

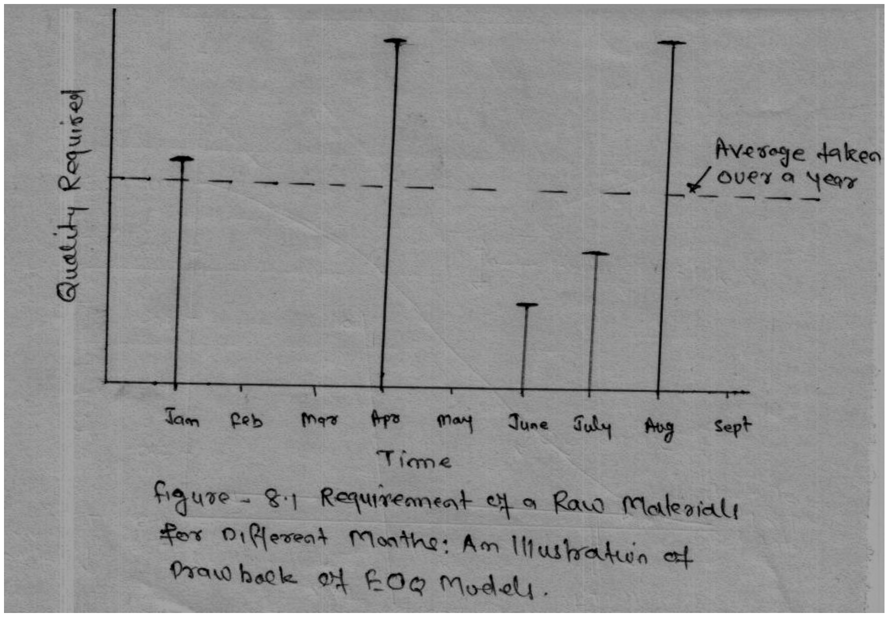

figure - 8.1 Requirement of a Raw Materials for Different Months: An Illustration of Drawback of EOQ Models.

Figure 9.1 Requirement of Raw Materials for Different Months: An Illustration of the Drawback of EOQ Models

It is interesting to note in Fig. 9.1 that if the material is stocked as per EOQ, we may have excess materials in inventory during February, March, May and September months when we do not need the material at all. Also, in April and August we fall terribly short of the required material. In all good faith, the EOQ model tries to answer the questions of 'how much?' and 'when to stock'? but fails miserably when encountered with an erratic (seemingly) requirement pattern for the material. But, in many industries particularly for dependent demand items such seemingly erratic requirement pattern are common.

Statistics is the science of averages. And precisely because of this characteristic, the statistical or averaging methods fail in situations such as the above.

9.3.1 DRAWBACKS OF SERVICE LEVELS AND SAFETY STOCK COMPUTATIONS

Let us say 10 different chemicals are needs to make a particular brand of shampoo. A cautious manager fixed 95% service level for the stock of raw materials and, therefore, expects a stock-out to occur only 5% of the time. He is confident 95% of the time about the availability of the materials. In spite of such precaution, he observes that production stoppages due to the lack of raw materials are such more than 5% of the time. Where has he gone wrong?

Let us examine the basics of his computation. He needs 10 materials at a time. Each material is stored with 95% service level. The probability that each material is separately available over a long length of time is 0.95. But, the probability that all the ten materials are available simultaneously is

$0.95 \times 0.95 \times 0.95 \times 0.95 \times 0.95 \times 0.95 \times 0.95 \times 0.95 \times 0.95 \times 0.95 = 0.5987 \approx 0.60$

The result is that the actual availability is only 60% of the time. Four out of ten times he should expect inability to run the particular shampoo line. This is how limited statistical methods of computation are if not interpreted and understood properly. Safety stock calculations were made for individual item requirements and never for bunched requirements of materials. In many production situations the latter is the case. Probably, in such cases we need not adopt statistical safety calculations in the first place.

MRP CALCULATIONS – AN ILLUSTRATION

It seems, therefore, that for assembling (or similar) situations it is better on our part to calculate the requirement of materials from the production schedule/plan of the final goods. Let us illustrate how we many do those calculations (Table. 9.1)

Master Schedule, Table (desks)

Week No.							
1	2	3	4	5	6	7	8
50	0	30	2	0	0	70	20

Lead time = 3; Order quantity = 100

MRP – Desk – Tops

Requirements		50	0	30	20	0	0	70	20
Schedule Receipts			100						
On hand	60	10	110	80	60	60	60	-10	-30
Planned Order Release					100				

Lead time = 5; Order quantity = 250

MRP-Plywood Sheets for Desk-Tops										
	Requirements			40*		100			90*	
	Schedule Receipts									
	On hand	160	160	120	120	20	20	20	-70	-70
	Planned order Release			250						

* Requirements from other variety of furniture.

Table 9.1

In Table 9.1 note how the requirements of desks generate requirements of lower level components such as desk-tops and plywood sheets. Note how the on-hand balances, the scheduled receipts of materials have been taken into account. The scheduled receipt is due to some plan (MRP) generated earlier. This material is already on order and is scheduled to arrive. The desk-tops calculation gives us a negative figure in the 7th week. Therefore, 3 weeks prior to it (lead time is 3 weeks), i.e. in the 4th week, we must order for desk-tops. Although the requirement is only 10 units, we order for 100 units, because that is the economic lot size. We have combined the benefits of EOQ an MRP in this illustration. MRP is for generating correct calculated requirements for lower category materials at appropriate times as per the need of the Master Schedule. EOQ concept is also utilized for generating additional cost economics of larger lot sizes.

9.3.2 PURCHASING

Definition: "Purchasing is the acquisition of needed goods and services at min. cost from competent, reliable sources." This definition reveals:

- Purchasing is to procure materials and services, (inside or outside).
- Purchasing is to procure items not necessarily at the lowest possible cost but at best cost. Cost is a combination of price & quality.
- Purchasing requires great care in source selection.
- Purchasing has to make sure that supplied live up to their commitments and promises.
- Purchasing has to examine that a materials is needed on the date and in the quantity specified (when and how much?).
- Purchasing has to ensure about timely supply from vendors (JIT concept).

Thus purchasing function includes:

- Selection of sources of supply (sourcing)
- finalisation of terms of purchasing
- placement of purchase orders follow-up
- maintenance of smooth relations with suppliers
- approval of payment to suppliers
- evaluation and rating of suppliers (vendor rating)

9.3.3 OBJECTIVES OF PURCHASING

The basic objective is "Ensuring continuity of supply of raw materials, sub-contracted items and spare parts and at the same time reduce the ultimate cost of the finished goods."

This objective can be achieved by obeying the following "Ten Commandments of Purchasing" given below:

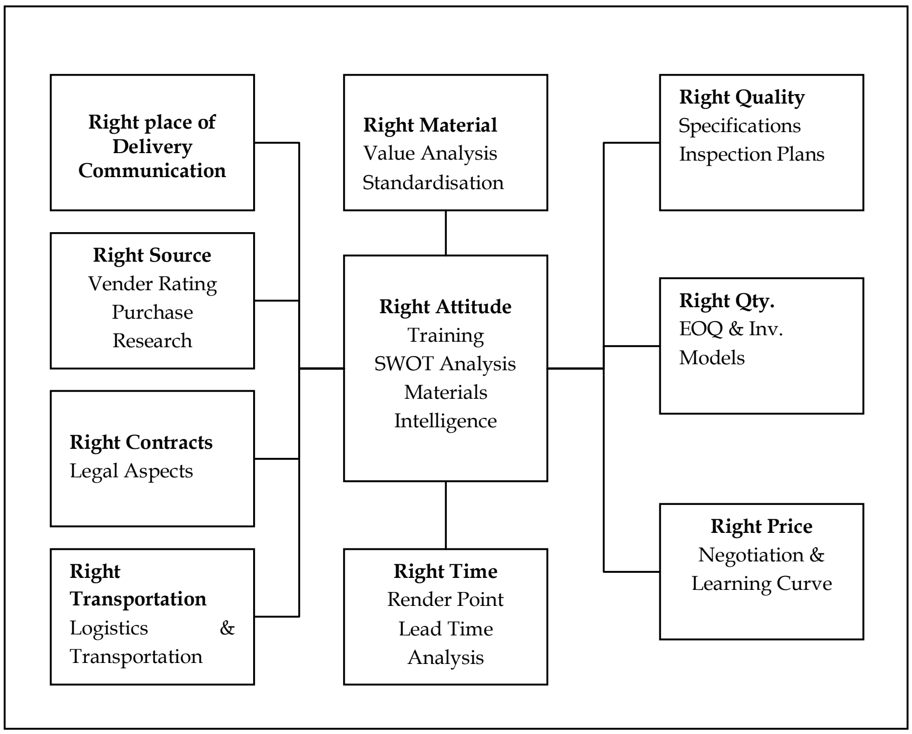

Figure 9.2: Ten Commandments

9.4 MANAGEMENT OF SUPPLY: AN INTEGRATED APPROACH

However, the Purchasing Manager is not always the final decision-making authority regarding the quality, quantity, time or cost of the materials. It may be so in some organizations, and not so in many others. What we said earlier emphasizes the integrated approach towards the management of supply of materials by being sensitive to the internal and external environment, and being one of a team of decision-makers for the input materials. The Purchasing Manager should serve as a link for the various internal departments and external environment. He should be an advisor, informer to various departments and a consolidator of various conflicting objectives/ opinions inside and outside the company. Often this is misunderstood to mean that the Purchasing Executive should have an authority over all the segments of the function of procuring the input materials. Such authority may not exist in most of the cases. A Purchasing Executive has to produce results by advising and coordinating his activities with that of various other internal departments and the external market.

9.4.1 BAYESIAN ANALYSIS

Let us see how a Purchasing Executive might provide his knowledge of the outside environment to help the functional departments within the company. Suppose a company is buying a petroleum derivative as raw material. The Purchasing Executive feels that there might be a meeting of the OPEC countries in the near future resulting in an increase in petroleum prices which in turn will result in increase in the price of its raw materials. He also figures out that even if the meeting does not materialize, the supplying company may increase the price of the raw materials due to escalation of the cost of various other inputs. Of course, the price increases in the latter event will be lower than the price increase in the former event. The Purchasing Manager, therefore, based on qualitative and quantitative data gathered, estimates the probabilities of the petroleum price hike by the petroleum producing countries. The following are his estimates of various probabilities:

1. He estimates that the probability of the OPEC meeting materializing is 60%.
2. If this materializes, he estimates an increase of 10% in the price of his company's input material at a probability level of 50%. Moreover there is 30% chance that the price may increase by 5%, and 20% chances that the price may increase by as much as 15%.
3. Even if the OPEC countries postpone their meeting, he estimates that the probability of price rise for the raw material is 30% for a price rise of 5%, 30% for a price rise of 2% and 40% for no change in the prices.

The Purchasing Manager is assessing the impact this information may have on the requirement of finance for the procurement of this material. At present, the company is buying Rs.1,00,00,000/- worth of this input material.

Figure 9.3 shows the decision – making process used by the Purchasing Manager.

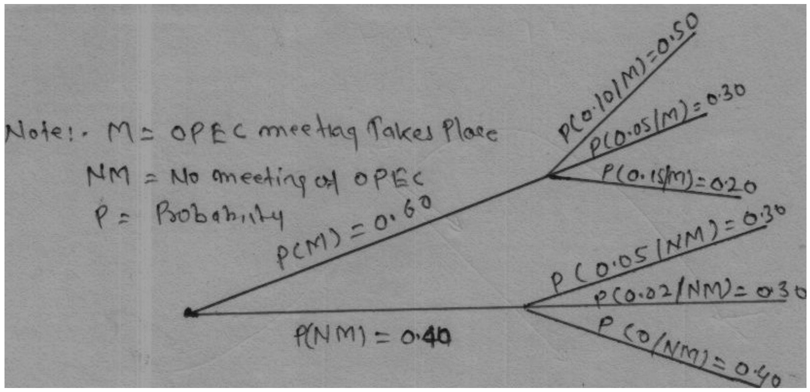

Figure 9.3 Bayesian Analysis for Purchasing

We can use Bayesian Analysis to determine the impact of various possibilities on the ultimate financial needs. The Bayesian Theorem states that the probability of a certain event occurring, if it is conditional on the occurrence of a previous event, is given by the product of the probability of the previous event and that of the present event. For instance, the probability of 10% price rise, given that the event of OPEC meeting occurs, is calculated to be: P (M) × P (0.10/M) = 0.60 × 0.50 = 0.30.

Likewise, the probabilities of various events can be calculated as given below:

Probability (0.05) = (0.60 × 0.30) + (0.40 × 0.30) = 0.30

Probability (0.15) = (0.60 × 0.20) = 0.12

Probability (0.02) = (0.40 × 0.30) = 0.12

Probability (0) = (0.40 × 0.40) = 0.16

Based on the above probabilities, the following calculations are made for the expected price to be paid for the same quantity of the input materials:

Rs.1, 10, 00,000 × 0.30 = Rs.33, 00,000

Rs.1, 05, 00,000 × 0.30 = Rs.31, 50,000

Rs.1, 15, 00,000 × 0.12 = Rs.13, 80,000

Rs.1, 00, 00,000 × 0.16 = Rs.16, 00,000

Expected Value = Rs.1, 06, 54,000

Therefore, the Purchasing Executive informs the Finance Department of the need for extra funds worth Rs1, 06, 54,000 for the purchase of the petroleum derivative.

Such Bayesian Analysis is of much utility for the purchasing function. One may not be able to hit the probability figures right on the dot; but if this analysis is done, one may not be caught totally unprepared for the financial and other implications to follow. Instead of taking a broad level or general hunch for the total increase in the financial outlay, one may approach the problem more scientifically.

9.5 VALUE ANALYSIS/VALUE ENGINEERING

Another important job of the purchasing executive, as mentioned earlier, is that of finding proper substitutes for raw materials. For this, a management technique developed during the Second World War period called Value Analysis (VA) or Value Engineering (VE) might be of much help. It is systematic method of thinking about substitutes. It basically consists of studying in detail the 'value' of the material. The value could be due to the functional characteristics (i.e. performance) of the product or due to the considerations of value such as the 'esteem' value. In organizational purchasing we largely do not encounter the latter kind of value. The idea behind Value Analysis is to find a substitute giving the same functional value, yet costing the same or less.

In general, we can divide the Value Analysis into the following steps:

Step I – Information Stage

Here, all the relevant information regarding raw material and the finished product in which it is incorporated, such as the cost, the manufacturing method, the performance characteristics, etc. is gathered. The more detailed the information gathered in this initial stage, the better will be the Value Analysis. Here one may ask questions in detail, such as what, where, when, how and why (for each of them).

Step – 2 Functional Analysis

At this stage, the functions that the material performs are listed in terms of basic function and secondary functions. It is advised that the functions be described in two words – a verb and a noun – as far as possible. This is to avoid long winding descriptions of the functions. After having listed the functions, each of these functions is given the value points or the weightages in terms of its importance or desirability. If the value (or worth, as it is alternatively called) is expressed in terms of 0-100 points, then the total for all the functions of a material should add to 100 points. Alongside, we also mention the cost incurred (or price paid) for each of the functions. Placing the cost and the value points side by side immediately reveals those areas of the material where much money is spent for little value. These high cost-to-worth functions are the focus of our attention in suggesting a substitute design of a bought-out part or a substitute material. If the value of a function is small, then that function can be dropped altogether in the substitute product.

Step 3 – Brain Storming

Having done the analysis of the functions and costs of the material, we are now ready to think of various alternative possibilities for the material. The main idea, here, is to encourage creativity. Many of the suggestions may seem like wild guesses. Still, these are recorded even if all suggestions are not feasible. The idea is to break away from rigid thinking and encourage creativity. Some systems of brainstorming start idea-generation from such widely differing 'triggers' as politics and geography, and develop them further so as to apply to the problem at hand (which could be finding an alternative product design). For such idea-generation, a heterogeneous group is preferred.

Step 4 – Evaluation Phase

Each of the ideas is evaluated again in terms of a functional analysis, i.e. by finding the various functions that the substitute can perform – to what extent and at what cost for each of those functions. Such an analysis will indicate a few of the alternatives which might offer similar functional value as the earlier material, but at a reduced cost. We may even find some substitutes with enhanced important functional values.

Step 5 – Implementation

In this phase, the selected substitutes, or new ideas are discussed with their cost structure will help the purchasing executive in finding alternative materials of equal functional value or better value while reducing the procurement costs. Value analysis, of course, should be done as a team work since it involves a lot of creative and interdisciplinary thinking.

9.6 PURCHASING RESEARCH

Another function of purchasing is that of Purchasing Research. In many large and well-managed organizations there is a group of people doing formal purchasing research. This is not only the study of substitute materials to get over a recent problem of procurement, but also a long range study of the requirements of the present as well as anticipated products. Purchasing Research, understandably also has the task of studying the trends and future forecasts of the cost of various input materials; and also that of the general economic conditions, industrial conditions, and national and international developments of interest for the task. Purchasing Research will have to interact with the R&D and Engineering departments of the company on a continual basis. The idea is that when the crunch comes in the future, the company should not crumble under the pressure. The other tasks of Purchase Research include: make or buy studies, studies of alternative vendors, studies in developing the vendors (in terms of their technical financial capabilities and needs), etc. In short, Purchasing Research includes short and long-range studies of the internal company requirements and the external supply market. This is an important aspect of purchasing, and all organizations that can afford it, should launch formal purchasing research programmes.

9.6.1 VENDOR RELATIONS

Another important objective in purchasing management is that of maintaining good relations with vendors. A good vendor is an asset to the company; and, therefore, just as customer goodwill is considered important, a good relationship with the vendor should also be treated likewise. A vendor who supplies the proper quality material in proper amounts in proper time is not very easy to find. Moreover, there are many situations where materials are required in a hurry. There are situations where materials are in shortage in the supply market. In all such situations, good relationships with the vendors pay dividends. This may entail: personal relationship, professional relationship:

(a) by helping the vendor in times of stress and strain with financial aid, technical aid, by providing management skills if necessary, and

(b) maintaining a healthy professional relationship by fair negotiations, fair evaluations and fair compensation.

The modern management theory and world-class manufacturing call for a long-term, almost a lifetime, association with the vendors. This also means that there will be fewer venders but these will be dedicated vendors-almost as a part of the organizational family.

Until the present and even now, the Indian industry has not given/is not giving much attention and importance to vendor relations. The emphasis, if any, has been on vendor selection and on monitoring the performance of the vendor's relations. The emphasis, if any, has been on vendor selection and on monitoring the performance of the vendors through a vendor rating system. Vendor is an entity that is, generally, taken for granted. The attitude is: All said and done, the vendors for the company may change over a period of time. They may change to another business; some of them may not give the desired performance in quality, delivery and price, and therefore, one should always expect a drop-out rate in the vendors list of the company.

In any case, a continuous programme of developing vendors and of selecting new vendors, if and where necessary, should be in existence in any organization. When selecting new vendors what should a buyer look for?

9.6.2 SELECTION OF VENDORS

1. The production capabilities of the vendor:
    a. Company to manufacture the required product in desired quantities.
    b. Possibility of future expansion in capacity.

    c. The understanding or the knowledge of the vendor regarding the buying company and its needs.
2. The financial soundness of the company:
    a. The vendor company's capital structure.
    b. Whether it belongs to a larger group of companies; whether it is a Private Limited or a Public Limited company.
    c. The profitability record of the company in the past.
    d. Expansion plans of the company in the future.
3. Technical capabilities (these are mostly regarding the quality capabalities):
    a. Whether the available machines are capable of the required quality of materials? What are the future plans of the vendor?
    b. Whether there are enough technical skills (skilled manpower) available with the vendor?
    c. Whether there is proper research, design and development facility available with the vendor?
    d. What is the record of the vendor in filling the orders of other buying companies in the same business?
    e. What has been the consistency in the quality produced by the vendor?
    f. Whether the vendor has appropriate storage and warehouse facilities to retain the quality of the produced product?
    g. Whether proper quality control procedures are being followed in the vendor company?

4. Other consideration:
    a. What are the working conditions in the vendor company?
    b. How are the industrial relations in the vendor company?
    c. Whether there is any possibility of disruption of the supply of materials in terms of quantity and/or quality due to human relations problem in the vendor company?

While getting this information the Purchasing Executive should take the help of his colleagues in production, engineering, quality control, industrial relations, finance and other functional areas so as to get a proper evaluation of the potential supplier.

9.6.3 VENDOR RATING OR PERFORMANCE MONITORING

Although this prior evaluation is necessary, vendors who are already on the regular list should be periodically appraised for their performance. This performance appraisal, which is and should be done as a continuous monitoring exercise, is termed as Vendor Rating. Vendors can be rated on various characteristics:

1. Delivery (to deliver on time as per order).
2. Quality (to deliver as per the quality specifications).
3. Price (to supply the materials at as low a price as possible).
4. Other factors such as (a) capability to meet emergency orders and (b) help in various other aspects such as supplying useful market information, readiness to try out new designs or new orders, etc.

In the vendor rating system, one usually gives weightages to these various characteristics and measures the performance of vendors periodically on the basis of certain norms or standards. The total of the vendor's performance is thus calculated, and, based on this information; the vendors are coaxed, cajoled or sometimes dropped from the company's list. A formal system of vendor evaluation should exist in every company so that an objective evaluation is done.

In order to illustrate the formal vendor rating system, let us consider the following example: Suppose a buying company gives 40% weightage to 'delivery' on time, 30% to the 'quality' and the rest (30%) to the 'price performance' of the vendor. If the vendor, during the past six months, has made 17 deliveries on time out of 20 orders, has given an average of 5% rejects, and delivered the items at the performance index of Rs.110 when the average price performance index is Rs.100, the rating of the vendor is calculated as follows:

$$0.40 \times 17/20 \times 100 = 34.0 \text{ points}$$

$$0.30 \times 95/100 \times 100 = 28.5 \text{ points}$$

$$0.30 \times 100/110 \times 100 = 27.3 \text{ points}$$

$$\text{Total Rating} = 89.8 \text{ points}$$

The above example gives the vendor in terms of his overall performance for all the items that he supplies. Although some organizations prefer an overall vendor rating, a few others prefer to rate the vendors for the individual items of supply. A vendor's performance is rated and compared with other vendors supplying the same or similar kinds of items. Sometimes, this gives better flexibility to the buyer organization in terms of continuing or discontinuing the vendor for only specific items of purchase; a vendor need not be totally dropped, but only one of his products needs to be dropped – one which might be giving a problem to the buying company. However, in general, a vendor rating system should be used constructively. This kind of a vendor rating system should allow a more detailed and better evaluation of the different vendors. The problem areas can then be pin-pointed and rectified with the help of the vendor.

Vendor rating is a beneficial devise not only for the buying company, but also for the supplier company. The supplier company gets information regarding its own performance compared with the performance of its competitors. It is a fair evaluation since the rating is based on fact and not on opinion. The vendor company can know its shortcomings, and can, therefore, try to improve them. Some suppliers even use a good vendor rating, by some of the large reputed companies, as a sort of merit certificate to deal with other companies.

9.7 STORES MANAGEMENT

An important component of materials management is the storage of materials. Basically the function of stores management is to be a custodian, looking after the items and controlling their flow. This is the component of the materials management with which the production department relates directly on a day-to-day or perhaps hour-to-hour basis.

In this custodial and controlling function, the important issue is that of having good information and record system on the (a) incoming, (b) outgoing and (c) remaining items of materials. A good MIS is the heart of stores management.

The various operations related to stores management are:

- (i) Receiving and inspection,
- (ii) Issue and dispatch,
- (iii) Stock-records,
- (iv) Stores accounting,
- (v) Stock-taking and checking,
- (vi) Stores preservation, and
- (vii) Stores arrangement.

9.7.1 RECEIVING AND INSPECTION

The important duties, here; are that of

- (a) checking ; supplies for quantity and quality,
- (b) Preparing documents: (i) posting to stock-records and stores accounts accordingly, and (ii) for providing evidence of receipt.

In order to help the stores personnel in the checking function, the stores may be advised about the items requisitioned (what, when, value of items). A copy of the purchase order would generally suffice. The supplier may also, for non-routine and high-value items, send in advance an advice note giving details of goods being shipped, quantity, mode of transport, date of dispatch, etc. The items, when they arrive, may also be accompanied by the supplier's packing information and the carrier's consignment note.

On the basis of the checking of the consignment, a Goods Received Note (GRN) is made by the store-keeper. Since this document will be used for settling bills, it should contain all the details such as, supplier name, his advice note number, purchase order number, date and time received, mode of transport, vehicle number, description of the item, code number, number and type of packages, shortage discovered if any, damage to the goods if any, excess items if any, and inspected by who. A separate damage/shortage report or a rejection report also needs to be prepared.

9.7.2 ISSUES

Since this is the outflow point, the authorization for issue should be proper, carrying' details such as the code number, description, job number for which required, quantity required, quantity issued, person authorizing, date of issue, and value of items issued. Such individual document is not always necessary for all items, for example, issues for assemblies or a production batch – where only the number of assemblies or the particular production programme may be sufficient for the stores to supply all the necessary materials.

9.7.3 STOCK RECORDS

The purpose of record-keeping is to facilitate materials control by bringing information on actual stock position, consumption rates, and order and supply position up to-date along with the proper pricing and evaluation of the usage and of the balance of stock. Whether the system is manual or mechanised or a combination of both, the important managerial control information should be provided by this stock-records system. The management should, thus, get information on:

(i) Daily operations of the stores giving details on receipts, issues, direct deliveries, etc.

(ii) stock at each location – flashed at the location, as in 'bin cards', and also as a separate information document;

(iii) allocation of stocks for certain project or jobs;

(iv) review and provisional of stock;

(v) order performance giving details on quantity ordered, supplier, delivery promised, progress-chasing action, when delivery received, etc.;

(vi) stocks consumption history and changes in consumption rates; and

(vii) Money value of the movement/consumption of stocks and balances on hand.

9.7.4 STORES ACCOUNTING

This information system is necessary in order to:

(a) know, and show the value of stock in the balance-sheet, and

(b) help in production (and other functions') cost control.

The alternative methods of costing the issues are:

(i) cost price,

(ii) average price,

(iii) market price, and

(iv) Standard price.

Cost Pricing uses actual purchase price paid (up to the point of delivery) of the items when accounting for receipt and issue of these items. Whereas, Average Pricing averages the price of the item and uses this average price figure while computing the issues and stock balances. Market Pricing involves pricing of all material issues (or stocks) at the prevailing market price at the time of issues (or stock-accounting). It is not very easy to get information on current market prices. More over, in a fluctuating price situation, the method of market pricing for issues results in faulty accounting of the stock balances. Standard Pricing avoids the latter problem by having a predetermined (standard) price fixed on the basis of the knowledge of market prices and trends.

For balance sheet purposes, the stock balance needs to be shown at either the market price or the cost price whichever is lower. However for internal costing purposes, any method may be uses. Due to its obvious advantages, standard pricing is widely used with a 'Variation Account' to take care of the difference between the actual purchase price and the standard price.

Stores accounting is an important feedback information for the production and other materials-using departments to asses their own efficiency in material usage. It is also important from the viewpoint of the valuation of the stock-balance and movement at any point of time.

9.7.5 STORES ARRANGEMENT

Proper arrangement and documentation of the storage spaces and storage facilities is helpful in getting materials for production on time as requisitioned from the stores. The arrangement of the racks, shelves, bins, and spaces for movement of material-handling equipment should facilitate quick location, and transporting of the desired materials. The important features of a good stores arrangement are:

- (i) Correct knowledge of which particular item exists where;
- (ii) Easy accessibility of the items;
- (iii) Easy movement of the materials-handling equipment and men;
- (iv) Minimal spoilage of the materials in store; and
- (v) Proper utilization of the available stores space.

The store should be so arranged that different types of materials (tubular sheet, heavy materials, bulky materials, small size materials, breakable materials etc.) can be stored in distinct areas.

Bars, tubes, rods, and such lengthy items may be stored in specially designed 'antler racks'. As the name indicates, these are a number of antler type of projections on a vertical frame. The bundle of tubes is held horizontally on the projection or antler. In order to save floor space and use the vertical space, in some cases these long items are stacked vertically. However, the latter type of stacking is not amenable to handling by machines. For plates and sheets of metal, the best form of storage is that of keeping them on the floor itself.

While making the arrangement for gangways, aisles, doors, inlets and exits, ceilings and floors, the materials handling equipment used for this purpose should be kept in mind. For example, a gangway of 3′ to 3′6″ between a pair of shelves will be comfortable for an operator with a small hand-truck to collect the materials. The main aisle should be wide enough to allow two people with hand-trucks. For fork lift operation, different dimensions may have to be used for the space between two rows of racks.

The location of the materials should be appropriately numbered so that locating a location (bin, rack, shelf, etc.) would be easy. Care should be taken to store the same materials at the same location and to document the material location.

9.7.6 STOCK-TAKING

This is essential in order to verify the stock records with the actual count. Lacunae in stock-record keeping and control are, thus checked. Stock-taking is either continuous or periodic. The latter is done once in a year generally, and the stores then have to be closed for the days of stock-taking. The former is done throughout the year in accordance with a predetermined programme. Each item should be physically verified at least once in a year. Advantage of continuous stock-taking are that (i) the normal business of the stores can go on as usual and (ii) more importantly, the discrepancies do not come out all at once as in the annual stock-taking, so there is time to investigate discrepancies thoroughly. However, continuous stock-taking can be done only if complete detailed stock records are kept showing receipts, issues, and balances.

Stores management is the vital and direct link between the production and materials functions. Therefore, it is necessary that adequate attention is paid to the management of stores.

9.8 INVENTORY CONTROL

Inventory is the stock of items or resources required in an organisation for running production smoothly.

Inventory is necessary because of the following reasons:

(1) To meet customers' requirement
(2) Smooth functioning of production process.
(3) Uncertainty due to irregular demand and supply.
(4) Economics of scale.
(5) Best utilisation of equipment and resources.

There are two basic questions to be answered in any Inventory Control System. They are:

(1) When to Order?

(2) How much to Order?

Differences between P and Q types of Inventory Control Systems:

BASIS	P TYPE	Q TYPE
1. Triggering	Time triggered	Event triggered
2. When to place	The time period is	The time is not fixed to

order	fixed for this and hence also called Periodic Review System.	pace an order.
3. Order Quantity	The order quantity is not fixed. It depends upon lead time and the quantity on hand at the time of ordering also called Fixed Order Quantity System	In this system, EOQ is ordered each time, as soon as the Re-Order Level is reached.
4. Size of inventory	The inventory size is large as compared to fixed quantity system.	The inventory is small as compared to fixed review period.
5. Supervision	It does not need constant supervision as the quantity on hand is the only requirement of the time of ordering.	It needs constant supervision as the quantity received each time has to be recorded and EOQ reached has to be found.
6. System time	It has fixed time period system, also called 1-Bin System	It has fixed quantity system, also called 2-Bin System.

9.8.1 MAJOR INVENTORY RELATED COSTS

Major inventory related costs can be classified into the following four categories:

(a) Inventory carrying cost

(b) Ordering cost

(c) Cost of under-stocking

(d) Cost of over-stocking

(a) **Inventory carrying cost:** Carrying inventory costs money. This is the cost a company has to incur for maintaining stocks to run the works smoothly. It involves the following costs:

(i) Blocking working capital such as interest on capital and depreciation etc.

(ii) Occupying space, thereby incurring warehouse rent and cost of facilities like bins, racks, etc.

(iii) Increasing risks of spoilage, obsolescence, theft, leakage, etc.,

(iv) Salary of stores staff, etc.

(v) Insurance premium.

Thus, cost s measured in terms of per unit/per year or as %age of the inventory value. The inventory carrying cost varies and is generally taken as 25%.

(b) **Ordering cost:** Every time an order is placed for replenishment, certain costs are involved.

The ordering cost involves paperwork expenses, follow-up cost, cost of transporting the material and its receipt and inspection everytime the material is procured. The average ordering cost is Rs.100 in India.

(c) **Under stocking cost:** This cost Ku, is the cost incurred when an item is out of stock. It includes the cost of lost production during the period of stock out and the extra cost per unit, which might have to be paid for an emergency purchase.

(d) **Over stocking cost:** This cost Ko, is the inventory carrying cost (which is calculated per year) for a specific period of time.

Based on above costs several scientific inventory models have been developed.

9.8.2 INVENTORY MODEL UNDER CERTAINTY

- In case of Inventory Model under Certainty:
- Demand is certain and hence constant

Supply is timely and hence no overstocking or under stocking

Thus the only two costs relevant in this case are:

(i) Cost of inventory carrying

(ii) Cost of Ordering

Depending on quantity to be ordered for purchase, the inventory carrying cost increases with increases in purchase quantity whereas the ordering cost decreases as the number of orders to be placed decreases. Thus ordering costs and inventory carrying costs oppose each other. This indicates that there exists a point at which the total inventory carrying costs is minimum.

Let, D- be the Annual Demand (Constant)

A- be the Cost of Ordering

I - be the Inventory Carrying Cost

C – be the Unit Cost of the item

Q – is the order- quantity

Then, Ordering Cost = D/Q × A ____________ (i)

Inventory carrying = Q/2 (C.i) _______________(ii)

(Average inventory carried is Q/2)

Total Annual Cost = (i) + (ii) = D/Q × A + Q/2 C.i.

For the costs to be minimum,

$\frac{d\,[Ts]}{dQ} = 0$

i.e. $\frac{d\,[\frac{D}{Q}.\ A + \frac{Q}{2}.C.i\,]}{dQ}$

i.e. $DA/Q^2 + C.i./2 = 0$

i.e. $C.i/2 = DA/Q^2$

or Q^2 = @AD / C.i

or $Q = \sqrt{2\ AD/C.i}$

Q (opt.) = EOQ = $\sqrt{2\ AD/C.i}$

Another method to find our EOQ is by opposing nature of costs i.e. Ordering Costs and Inventory Carrying Cost.

9.8.3 INVENTORY CONTROL SYSTEM UNDER CERTAINTY

- Demand is constraint under system of certainty
- Supply is Timely & hence no under stock (i.e., shortage cost) or overstock costs is involved.

Therefore, the only two costs involved are:

(i) The ordering cost

(ii) The inventory carrying cost.

Both these costs are opposite in nature as shown below:

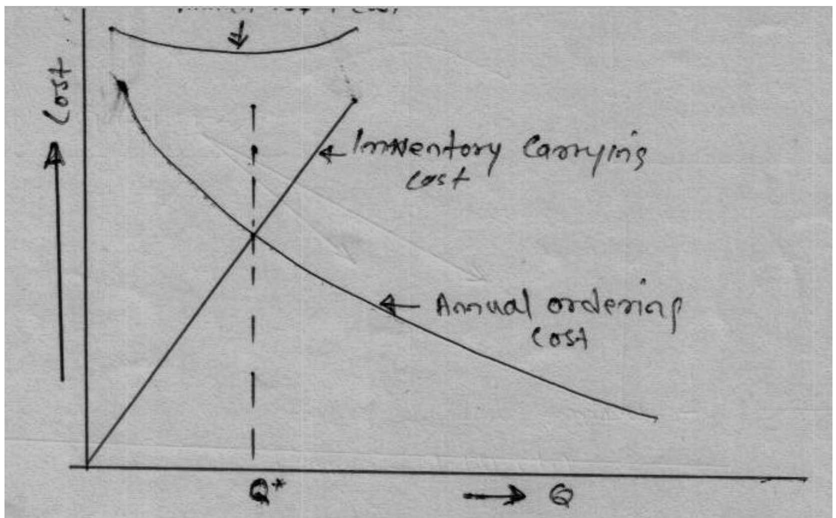

figure- 8.4.

The point of intersection suggests that there is a point at which the costs of Inventory Carrying equal the ordering cost. The quantity to be ordered is given by the projection on X axis the quantity Q to be ordered. This quantity referring to the point of intersection is called "EOQ" is given by EOQ = $\sqrt{\frac{2AD}{Ci}}$

Solved Problems on Inventory Control

Prob 1(a)

For an item costing Rs.50 per unit, there is a constant demand of 15,000 units per annum. The estimated cost of placing an order is Rs.150 and the inventory carrying cost is 24%. Find the Economic Order Quantity (EOQ).

Solution:

For the given problem:

D = 15,000 units

A = Rs.150 per order

C = Rs. 50 per unit

i = 0.24

Inv. holding cost = c h = c × i

= 50 × .24 = Rs. 12 per annum

$$EOQ = \sqrt{\frac{2AD}{CH}}$$

$$= \sqrt{\frac{2 \times 150 \times 15000}{12}}$$

$$= \sqrt{375000}$$

= 612 Units.

No. of orders per year = d/ Q

= 15,000/ 612

= 24.5 (say 25)

Therefore, revised EOQ = 15000 / 25

= 600 units.

Prob 1(b)

For the above given data, the supplier offers 5% discount if the order quantity is made double of the EOQ. Should he accept the discount offer or not?

Solution:

Please find out

(i) EOQ = Q

(ii) Let total Cost (without discount offer) = TC & Total Cost (with discount offer) = TC

= Material cost + Inventory, Carrying Cost + Ordering Cost

(iii) If TC >TC, accept offer of discount, otherwise reject.

Prob 2 : For the data given below

D = 60 units per year

Q = 15 units per order

L = 1 month or 1/12 of a year

R = 9 units (here R = re-order level)

The demand during lead time is Poisson distribution. Find the number of stock outs per year.

Solution:

Number of orders per year = D / Q

= 60 / 15 = 4

Average demand in lead time 60 x 1/12 = 5 units

Hence, from Poisson's table, probability of stock out = 1 P (9)

1 - .968

= 0.032

Thus number of stock outs per year = 0.032 × 4

= 0.12

or one stock out in roughly 7 years

9.9 WASTE MANAGEMENT

Waste management (WM) has several dimensions – engineering, economic, geographic. Its basic purpose is to minimise the overall waste in a given system. Waste here refers to waste of all kinds of resources, but especially the material resources which constitute a significant portion. Some waste is inevitable in any conversion process of inputs into outputs. To reduce waste, we have therefore to maximize the use of resources. Resource Management and Waste Management are thus supportive to each other.

9.9.1 CLASSIFICATION OF WASTE

Waste can be classified on the basis of:

(1) resources wasted
(2) origin
(3) property
(4) recoverability

Waste Resources: Material resources like solids, liquids, and gases can be wasted. Energy resources like physical, human and solar energy can be wasted. Time resource can be wasted. Capital in the form of capacity, equipment, machine hours and inventory can be wasted. Services like communication, transport, health etc. can be wasted. Life or human resources, data and information may also suffer wastages.

Origin of waste: It could be industrial, residential, commercial, office, municipal, construction and demolition, agricultural etc.

Property: Materials wasted are either hazardous or non-hazardous.

Recoverable: Wastes can be recovered into some useful resource, material waste recycled. Non-recoverable wastes are lost with time.

Waste exists in myriad forms – non-workable components, excess inventory, machine downtime, re-work, non-conformance, warranties. Any activity that does not add value is a waste, re-work is the biggest non-value added activity that a company performs. If we reduce the unnecessary activities or eliminate them, costs will come down drastically.

9.9.2 MEASUREMENT OF WASTE

Wastivity = $\frac{Waste\ (W)}{Input\ (I)}$

Gross Wastivity = $\frac{Total\ Waste}{Total\ Input}$

Net Waste = Total Waste–Waste Recycled within the system.

Net Wastivity = $\frac{Net\ Waste}{Total\ Input}$

9.9.3 WASTIVITY AND PRODUCTIVITY

Waste is an indirect measure of productivity. If Wastivity is checked, the effect, productivity will be automatically improved.

Causes of Waste

Various causes are responsible for wastes. An illustrative list is given below. The highest waste causing factors are considered to be critical. Following are the Causes of Waste

(1) Faulty planning and policies, systems and procedures
(2) Faulty organization structure
(3) Environmental pressures
(4) Tardiness
(5) Lack of accountability
(6) Unawareness of technological advances
(7) Non-responsiveness to automation/computerization
(8) Wrong specifications, standards, codes
(9) Wrong raw materials

(10) Lack of inventory control

(11) Lack of proper storage, layout of facilities, handling of material

(12) Communication gaps

(13) Faulty work-method

(14) Less emphasis on PPC

(15) Lax supervision and control

(16) Wrong recruitment/selection policies

(17) Lack of motivation/incentives

(18) Poor working conditions

(19) Unsafe practices

(20) Poor IR: Industrial Relations

(21) Maintenance failure

(22) Power failure

(23) Distribution problems

(24) Less attention to waste segregation and collection

(25) Technological obsolescence

(26) Miscellaneous causes.

Systematic Approach to Waste Reduction

(1) First of all the total waste in the whole system is recognized.

(2) Then the stages at which waste is generated are identified.

(3) Then the sub-stages are identified in which above wastes can be put.

(4) Then waste-reduction programme is implemented at each stage by planning correcting action and eliminating the cause.

Waste Collection System

Wastes affect the environment, the organisation, the public health. Waste collection consists of transporting the waste. It is a major cost element, and if efficiently handled, may reduce the overall cost of WM. Waste collection consumes 80 p.c. of waste reduction programme.

The following factors govern the waste collection:

(1) Separate the waste at source.

(2) Make arrangement to collect it in suitable containers of the right material and right size.

(3) Depending upon the generation rate of waste, make arrangements to collect waste from time to time.

(4) Offer incentives to segregate waste at source

(5) Carry the waste to the salvage industry for ultimate reuse.

(6) Make suitable arrangements to collect both the organic and inorganic wastes.

Recycling of Wastes

The wastes can be recycled/reuses. For this purpose, suitable recycling projects are created. In recycling, the waste is used as input to the same process/system. e.g. recycling of foundry scrap. In reuse, the waste is used as input to some other process/system e.g. sugarcane barrage is used to prepare paper. In reuse of waste, we may generate power or by-products e.g. bio-gas generates electricity/fuel and molasses produces alcohol. In reclamation, the damages, rejected or undesired outputs are converted by repair or processing. Recovery is a general term to indicate gain of resources from wastes.

Waste Disposal System

Waste can be classified by two categories in terms of its disposal

(i) Salvable waste - They have the salvage value e.g. scrap rejected goods, surplus and obsolete items.

(ii) The-salvable waste - They have no salvage value, but need further processing and treatment for disposal.

9.10 USE OF COMPUTERS IN MATERIALS MANAGEMENT

Materials Management is an interactive Material requirement planning and control system. The object of the system is to make it easier to deal with the complexities of operating a manufacturing company by taking into account various aspects of information flow and management. It is primarily designed for manufacturers who build standard product to stock in discrete manufacturing steps fabricators and assemblers.

These companies have a significant investment in inventory, and the system can help them balance their inventory levels with customer demands for timely shipments.

Materials management System consists of ten major modules:

(1) **Master Production Scheduling (MPS):** This is a management planning and production scheduling tool. It is used by the master

scheduler to generate a production schedule for the plant's marketable products. Input to the module includes current customer orders, forecast customer orders, the current production schedule, and the current level of production inventory. The output of the MPS calculations is called the master production schedule. This schedule contains suggested manufacturing orders including quantities and starting dates. The schedule is then input to the Materials Requirement Planning (MRP) module the plan to manufacture and purchase of the required component parts.

(2) **Rough-cut Resource Planning (RRP):** This is a management tool used by a master scheduler to help produce a realistic master schedule by comparing the resources needed to implement the master schedule with the available critical resources. The example of critical resources are labour hours, floor space, investment in work-in-process inventory, and materials supply. The (RRP) reports highlight the capacity constraints and help the user resolve competing demands for critical resources.

(3) **Materials Requirements Planning (MRP):** MRP stimulates the complex flow of material required to manufacture products and generates a material plan. MRP planning starts with up-to-date information about current inventory levels and the planned production requirement. Using part and bill-of-material information the material requirements for each part are calculated. The plan starts with the highest level assemblies and proceeds through the lowest-level parts.

(4) **Parts and Bills of Materials:** This module provides maintenance of engineering, accounting, and planning information about each part and product, and information on how the parts inter-relate to one another to form the product structure (bill-of-material).

(5) **Routings and Work Centers:** The bill-of-material defines the parts and subassemblies that go into a product but does not document how the various components are assembled. The routing and work centers module maintains information that describes the locations where the products are made (work centers) and the proper sequence of manufacturing steps (routings). This information is used to generate cost information the standard product cost module and to help develop detailed production schedules.

(6) **Standard Product Cost (SPC):** SPC provides manufacturers with the capability of accurately calculating the standard cost associated with manufacture of each product. The standard cost of a product is determined by accumulating all relevant materials, labour, and overhead costs for the components of the product as well as the costs associated with the construction of the finished product. These standards can be used to determine product pricing and profitability.

(7) **Material Issues and Receipts:** This module helps control stock room inventory by maintaining timely and accurate records of all actions that affect inventory balances. The data includes receipts of work orders and purchase orders, material issues from stock to a keeping Traffic or C and F.

Store Keeping (Receiving, Storing, Issuing as well as materials handling within the stores). The function of stores is to receive, store and issuing materials.

The stores are divided into:

- Receiving stores
- Tools stores
- General stores
- Raw materials stores
- Finished parts stores and so on.

Receiving stores receives all incoming materials, checks the correctness of quantity received, arranging for inspection, then sends to respective stores along with a report called GIN (or MRT) Goods Inward Note (or Material Receipt Note).

Stores: In the stores, materials are properly stored until drawn by the various departments. Materials are equivalent to Money and great attention must be paid to the proper storage so that they are free from damage and possibility of pilferage. At the same time, the right type of equipment should be used for storage and handling so that material handling expenses are kept to the minimum. Particular work order, filling of a back order, or an unplanned issue.

(8) Inventory Balance Management: The inventory balance management module maintains information about inventory balances and warehouse locations where the inventory is stored.

(9) Work Order Control: a work order is an internal factory organisation to build a specified quantity of a subassembly by a specified date. All work orders require the issue of on-hand inventory for their completion. Prior reservation of on-hand inventory is the best method of preventing shortages at the time of issue. The actual issuing of parts and work orders, and the actual receipt of finished product is accomplished using the material issues and receipts module.

(10) Purchase Order Tracking: A purchase order represents a scheduled receipt for purchase items. Entering a purchase order requires the entry of more information than that required on a work order for example, Vendor information, shipping information, and price information.

9.11 SUMMARY

This section provides a comprehensive approach to material management for managing materials in such a way that the right quality, in right quantity, at the right place, at the right time, and at right price. The chapter enumerates the nature, meaning and importance of materials management. It also discussed issues related to MRP (materials requirement planning), theoretical and practical aspects of inventory management, and use of computer for material management.

9.12 KEY WORDS

Material management: is defined as the integrated function of purchasing and allied activities so as to achieve the maximum coordination and optimum expenditure in the area of materials.

Purchasing: is the acquisition of needed goods and services at min. cost from competent, reliable sources

Inventory carrying cost: Carrying inventory costs money. This is the cost a company has to incur for maintaining stocks to run the works smoothly.

Ordering cost: Every time an order is placed for replenishment, certain costs are involved. The ordering cost involves paperwork expenses, follow-up cost, and cost of transporting the material and its receipt and inspection every time the material is procured.

9.13 SELF ASSESSMENT EXERCISE

1. Define materials management. Explain various objectives of materials management.
2. What do you understand by inventory control? Explain various techniques of inventory control.
3. Write a detailed note on waste management.
4. Give a comprehensive note on store management.
5. Discuss briefly “Use of computer in materials management”.

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Subject: Production and Operations Management

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LESSON: 10 **Quality Control**

Structure

10.0 OBJECTIVES

After going through this lesson, you will be able to:

1. **Meaning and definition of quality control and quality assurance**
2. **Cost aspect of quality control**
3. **Application of statistical tools for quality control**
4. **Use of control charts**

10.1 INTRODUCTION

Generally, it can be said that product is of satisfactory quality, if it satisfies the customer. The customer will buy a product or service, only if it meets his or her minimum needs. He or she may pay more for higher quality to that extent to which its increased utility exceeds the increased cost. Thus customer's satisfaction is the main criteria for determining whether a product possesses the required quality or not. Therefore, customers' wants are first assessed by marketing people and then quality decision is taken on the basis of such information. In order to define quality, therefore, we have to think of it in terms of some use. In industrial context, quality is defined in a much more functional fashion. Thus, we can say that quality means "Fitness for use" whether for a product or a service. It is also considered as the sum total of the attributes or properties that describe the product.

10.2 DEFINITION AND MEANING OF QUALITY

C.D. Lewis had defined quality as "an asset which may be offered to the potential customer of a product or service." The following are the other definitions of quality, which are more explanatory.

(i) Quality means the degree to which a specific product satisfies a particular class of consumers or consumers in general or the degree to which it conforms to a design specification or the distinguishing feature of a product's taste, colour, appearance etc.

(ii) 'Quality means which marks a thing what it is and to make a thing what it is, a number of specifications are given.' When a product is made, it is checked against those specifications, so as to find out its suitability. The significance of 'Suitability' cannot be over emphasized. It does neither mean the highest quality nor the lowest price, but rather the best of each factor in relation to the other.

(iii) Quality is the totality of features and characteristics of a product or service that bear on its ability to satisfy a given need (American Society of Quality Control).

(iv) Quality as a class, kind or grade, is applied in a better sense (C.W. Kennedy).

From the above definitions we can see that prime importance is given to the consumers' satisfaction and for consumers' satisfaction a product or service, which a consumer wants, must possess certain features i.e., properties or attributes, which made the producer or service 'fit for use' or which made the consumers' satisfied. When the properties or attributes are mentioned specifically as the characteristics of a particular product or service, they become specifications for the product or service. As far as possible these characteristics should be expressed in quantitative terms, so that they can be measured or observed objectively. In certain cases, these quality characteristics can be measured easily against some numerical scale e.g., weight of biscuits in each packed in grams, length and width in meters, diameter of ball-bearing in millimeters, speed in kilometers, quantity in numbers etc. Such characteristics are know as variables and decision regarding acceptance or rejection is taken on the basis of tolerances (upper limit, lower limit or both the limits). Products with variances beyond these limits are considered as defective and hence unacceptable. Sometimes it becomes impossible to measure the quality characteristics against some numerical scale. One can say that a product or service is good or bad e.g. a purchaser of a scooter can correctly measure the fuel consumption per kilometer or total kilometers per liter of petrol he or she cannot measure paint finish or the appearance of a scooter. He or she can only say that it is good or bad. Here the measurement or say the assessment of quality becomes more difficult. It depends on the person making a decision. What may be considered good by one may be considered bad by another. This holds good particularly in the case of service industries e.g. a particular radio programmer or TV programmer may be considered best by A, satisfactory by B, fair by C, Very poor or boring by D etc. Quality characteristics of this type are called attributes, the assessment of which is left to the consumers. Attributes are binary (yes or no) conditions. One has to say yes or no, e.g. a candidate appearing at the examination may pass or fail, so far as the assessment of the candidate's performance is concerned.

European Organization for Quality Control (EOQC) has defined quality as "the degree to which a product meets the requirements of customers."

Now to most of the people, quality means high quality. Actually it is not so. Generally, the customers want the best quality they can get for the money they are willing to spend. It does not mean that they want only the very best. They select the very best from the products or services available at the price which they are willing to pay. Therefore, a manufacturer/supplier tries to manufacture/supply the best product he or she can, for the price that the most of his or her potential customers are willing to pay. Product quality is what is perfect from the customer's point of view. There is no point in making chemically pure salt for the consumer market. The commitment made to the customer must be honored. When we say 20 carats, no one expects us to deliver 40 carats. But we must deliver 20 carats consistently. Sometimes, customers are impressed by a higher price and some of them even think that the highly priced products are always better than the lower priced. Usually, the customers pay a higher price for the better quality products or services because they want something better than the very cheap quality. But they will not pay too much for their requirements because customers' purchasing power becomes the upper limit for customers' willingness to pay.

According to Srinivasan of Sundram Clayton quality in the context of total quality control means achieving excellence in everything you do. This is the ultimate definition of quality. According to Oxford Dictionary, the meaning of quality is the degree of excellence. It is the gap between the manufacturer's excellence and customer's requirements.

10.3 DEFINITIONS OF TERMS

Some terms as frequently used in quality engineering. These are:

Inspections the processes by which ascertain the extent to which a manufactured product conforms to design specifications.

Tolerance Permissible variation in dimension, VIZ+/-0.002 cm can mean permissible variation of dimension with 1.998 to 2.002 cm.

Allowance This refers to the differences between parts used in a fit. For example, in the cylinder and piston assembly of engine, if the cylinder has maximum external dimension of say 10.002 cm and the cylinder has a minimum internal diameter to say 10 cm, the minimum allowance=0.002 cm. The maximum allowance will be the difference between internal diameter of cylinder and maximum external diameter of cylinder.

Precision This is the degree of refinement required in a product as perceived by customer and endorsed by the designer in the product specification.

Accuracy This refers to the degree of conformation to standard dimension as per specification attainable by production facilities.

Reliability This is the probability that equipment will work satisfactorily for a given period of time when it is used for the purpose and the manner intended. Quality assurance depends on reliability

Cost it refers to cost of production plus reasonable profit margin and distribution/sales cost.

Cost of production= Materials + Labour cost+ Overhead cost

Cost of product= Cost of product + Selling cost+ Tax/Duties+ profit

Value of a product is created by three elements. Viz. perception, time and place. Perception of society and people conditioned by national sentiments, History and political philosophy. There are four different values, viz. Use Value (utility or function), Esteem Value (resale/snobbish), Cost value (cost of production) and Exchange Value. In our analysis

$$\text{Value} = \frac{\text{Quality}}{\text{Cost}}$$

10.4 COST ECONOMICS AND QUALITY

10.4.1 Optimum Quality

Precision, which is defined as the degree of excellence of a product, can be increased to any higher level subject to only two limitations. Viz. technology and economy. For a given technological level, as quality level increases, the cost of production goes up an increasing rate, whereas the value of the product increases at a decreasing rate. The questions therefore, are what should be the optimum level? (See Fig.10.1)

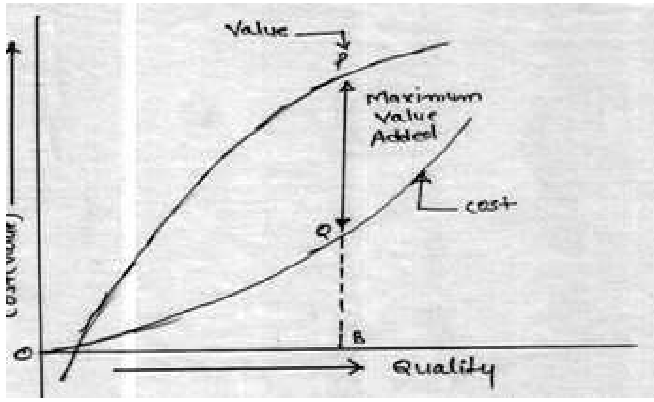


Fig.10.1 Cost and Quality

From the two curves (Value vs. quality) and (cost vs. quality), we find the following:

(a) At very low quality, even through the cost of production is less, its value is so poor that no customer is ready to purchase it. Because of its negative value customers will have to be induced or paid to pick up the item (Region OA).

(b) As quality improves, value also improves at a higher proportion indicating profitable operations (Region AB). Value addition shows positive trend, viz. $\frac{Value}{Cost}$ is higher.

(c) After B, we find that any attempt to increase quality result in escalation of cost of production disproportionate to increase in value of product. Hence, the customer is not attracted to the product even though its quality is higher than those of its competitors because of reduction in the $\left(\frac{Value}{Cost}\right)$ ratio. Here value addition goes down with increasing quality, viz. a negative trend.

There is an optimum level of quality marked as point B, where $\left(\frac{Value}{Cost}\right)$ ratio is the maximum. Here, the tangents to the slopes of both curves are parallel. The maximum value addition at this point is represented by PQ. This is the optimum quality level.

10.4.2 Cost of Inspection vs. Quality

It has been clearly pointed out that quality is a function of design and manufacturer. Once design is completed, the next step is to produce product which conforms to the design parameters. The following two steps are needed to achieve this objective.

- Select suitable process, machine, and plant to produce the item.
- Introduce adequate inspection including measurement and analysis to conform to standards.

By selection of suitable machine, plant, process and tooling, we ensure that products are produced to the desired accuracy. This cannot automatically ensure that all future products would conform to the dimensional standards. This is so because of imperfections in machinery or processes and inadvertent errors on the part of operators due to fatigue, monotony, etc. Therefore, it is essential that each item is again subjected to inspection including measurements and analysis. Inspection again cost money. In an ideal situation, inspection can be minimised, if not eliminated altogether by making process and machinery more accurate by procuring very costly machines, processes and technology. This requires very heavy investment. Even then inspection cannot be altogether eliminated. No doubt, as process cost goes up, quality improves, the number of defects reduces and inspection cost comes down.

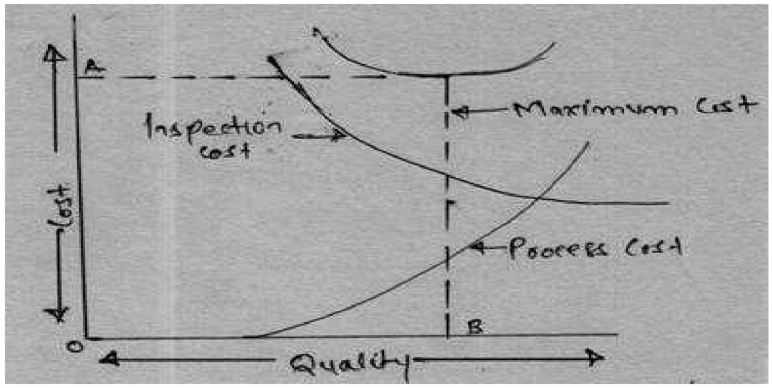


Figure 10.2 Process Cost and Quality

However, we find that as quality increases, the process cost increases at an 'increasing rate' whereas corresponding inspection cost decreases at a 'decreasing rate'. This means there is an optimum level when the two match so that the total cost will be minimum.

Total cost = Process cost + Inspection cost

Inspection cost is defined as cost of inspection which includes costs of measurement and analysis plus cost of rectifying the defects. If incremental cost of improving process more than offsets the decrease in inspection cost, it is better to retain the lesser sophisticated process and continue to incur the inspection cost. This is shown in fig. 10.2. Point B represents minimum total cost. This point also depicts the optimum quality (represented by OB) and optimum cost (viz. OA).

In a practical situation the desired quality level is an economic decision. It is not prudent to go in for ideal conditions and incur heavy investment on process and plants in an attempt to reduce or altogether eliminate the defects due to the following reasons:

- Product changes take place rapidly due to changes in technology and demand pattern.
- Economic considerations dictate retention of old machines/processes.
- Cost of existing process/machines plus cost of additional inspection is less than that of scrapping old and replacing them with new process/machines even if the latter require less or no inspection at all.

10.5 STATISTICAL QUALITY CONTROL

Statistical Quality Control is a technique, which is used for applying statistical theory to industrial mass production for ensuring uniformity in the items as also for facilitating in meeting the specification requirements. In any manufacturing process, some variation in quality, as measured by a parameter or set of parameters, of items is expected as a result of chance. In a manufacturing process, some stable system of chance causes is always present. This chance or random variation is the sum of the effects of the chance causes occurring due to difference among machines, difference among materials, difference among workers and difference among each of these factors over time, etc. These are called the **assignable causes.** A process is said to be under statistical control if it works in the absence of any assignable cause. This is sought to be achieved through the use of Control Charts.

The main feature of the control Chart method is the drawing of conclusions about the production process on the basis of samples drawn from the production process at regular intervals. The sample size five is commonly used in the industry. The logic of selecting the number five is central limit theorem.

There are various types of control charts to control aspects relating to a manufacturing process. These are:

- Control Charts for mean – $\overline{X}$ chart
- Control charts for variation – R chart
- Control charts for proportion of defectives – p chart
- Control charts for number of defects – c chart

10.5.1 Control Chart for Mean – $\overline{X}$ Chart

If the observations (x) about a characteristic like length and life of an item are normally distributed with mean m and standard deviation, the probability that an observation will be in a fixed interval (m – 3 σ to m + 3σ) is 0.9973 of Statistical Distributions. It implies that if a plot such as that in Figure 10.3, given below, is made, on an average only 27 out of 10,000 observations will be outside the interval (m- 3σ, m + 3σ).

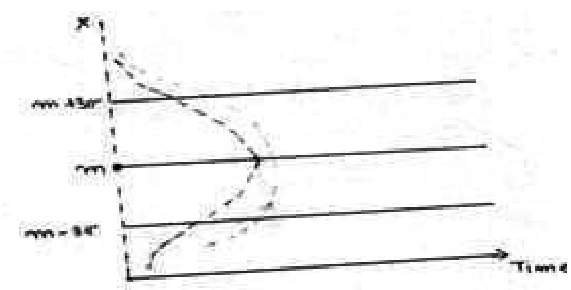


Figure 10.3 Three Sigma Limits

Let the n observations recorded for any characteristic measured by the variable x, of n items be: x_1, x_2, x_3, ..., x_n. Then the average of these n observations is

$$\overline{X} = \frac{x_1 + x_2 + x_3 + ... + x_n}{n}$$

Statistical Distributions that the sampling distribution of such as sample mean is 'normal' with mean m and standard deviation $\frac{\sigma}{\sqrt{n}}$.

Therefore, if averages of samples of n observations, taken at repeated intervals, are plotted, instead of the individual values as it shown in Fig. 10.3, we expect that on an average, only 27 in 10,000 values of these averages will fall outside the interval.

$$m - 3\frac{\sigma}{\sqrt{n}} \text{ to } m + 3\frac{\sigma}{\sqrt{n}}$$

Figure 10.4 given the control chart for x. Here m – 3 $\frac{\sigma}{\sqrt{n}}$ is the lower control limit (LCL) and m + 3 $\frac{\sigma}{\sqrt{n}}$ is the upper control limit (UCL).

The main advantage of the control chart for $\overline{X}$ over the control chart for individual measurement xi is that even if the individual measurement are not normally distributed, their sample mean is always normally distributed.

Estimates of Mean (m) The control limits given in Fig. 10.4 are functions of m and σ. are not know and we have to estimate these parameters. Such estimation is recommended for at lest 25 sample of 5 observations each. Let the averages of the sample be x_1, x_2, x_3,..., x_p. Then, the best estimate of the mean of the sampling distribution of x_i is

$$\overline{\overline{X}} = \frac{\overline{X}_1 + \overline{X}_2 + \overline{X}_3 .... + \overline{X}_n}{p}$$

Incidentally, $\overline{\overline{X}}$ is an unbiased estimator of the mean m.

The unbiased estimate of σ is provided by $\sum(\overline{X}_i - \overline{\overline{X}})^2 / (p - 1)$

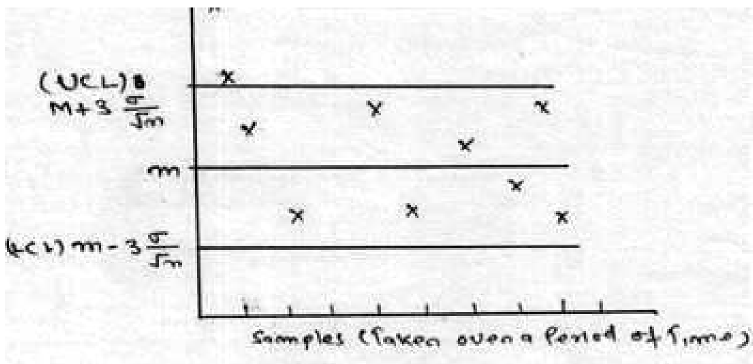


Figure 10.4 Control Chart for $\overline{X}$

Estimations of σ by R (Range) the difference between the largest and the smallest values of a sample of n observations is defined as the 'range'. Let R_i represent the range of the i^{th} sample, then the average range of the p samples is denoted by R and is

$$R = \frac{R_1 + R_2 + R_3 + ... + R_p}{p}$$

$\overline{R}$ /d_2 provides yet another unbiased estimate of σ. The value of d_2 depends on the value of n, and is given in Control Chart Factor Table.

Using $\overline{R}$ /d_2 as an estimate of σ, the lower and upper control limits for $\overline{X}$ are given as:

$$\overline{X} - (3\overline{R} / d_2 \sqrt{n}) \text{ to } \overline{X} + (3\overline{R} / d_2 \sqrt{n})$$

The value of $(3/d_2\sqrt{n})$ are given in Control Chart Factor Table as equal to A2.

Thus, the estimated lower and upper control limits are

$$\bar{\bar{X}} - A_2\,\bar{R} \text{ and } \bar{\bar{X}} + A_2\,\bar{R}\text{, respectively.}$$

It is to be noted that σ can be estimated both by the sample standard deviation as well as sample range. While both provide unbiased estimates of σ but, in Statistical Quality Control, the estimate based on R is used due to simplicity of its calculation even though it is less efficient as compared to the standard deviation. As stated earlier, in the real life production processes, samples of five observations are taken; and $\bar{X}$ & R calculated immediately and the point plotted on the chart. The logic for taking sample size as five is explained in the next section.

10.5.2 Setting up of a Control Chart for $\bar{X}$

As mentioned earlier, a minimum of 25 samples are to be taken for reliable results. Normally, a sample of 5 items is taken for ease in calculation of sample mean. If may be noted that if we are to divide the sum of 5 observations by 5, we may multiply the sum by two and then divide by 10. Division by 10 is obtained without any calculation, just by shifting the decimal place to the left by one point. This is illustrated below:

$$\frac{5.5+5.8+5.6+5.7+5.6}{5}$$

$$= \frac{28.2}{5} = \frac{28.2\times 2}{5\times 2}$$

$$= \frac{56.4}{10} = 5.64$$

The reason for this simplification to find average is due to the reason that the readings are taken and averages calculated by the operators working on the production line.

The trial control limits or the limits to start with, for sample mean, are given by

LCL: $m - 3\frac{\sigma}{\sqrt{n}}$

UCL: $m + 3\frac{\sigma}{\sqrt{n}}$

The value of $3/\sqrt{n}$ are given as 'A', in Table. Thus the control limits can be written as :

LCL $m - A\sigma$

UCL $m + A\sigma$

Now, if the parameters m and σ. are unknown, their estimates x and R/d_2 are used to calculated LCL and UCL as

$\overline{\overline{X}} - A_2\,\overline{R}$ and $\overline{\overline{X}} + A_2\,\overline{R}$

from 25 samples of 5 observations each. These limits are called trial control limits, and plotted as follows:

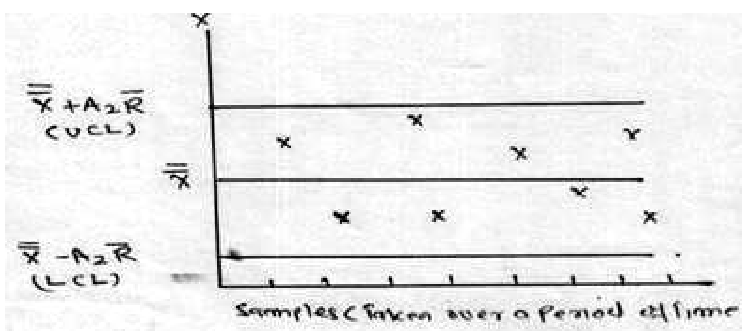


Figure 10.5

These limits are used to determine whether past operations are in control or not. If the entire sample means $\overline{X}_1$ to $\overline{X}_p$ be within these limits, we infer that the process is under control. Of course, there is a chance that a point might be within the above limits but the production process might be out of control. Prudence dictates that it is not worthwhile to waste resources in examining the process. However, if any of the past sample mean (out of 25) is outside the control limits, it is eliminated and the limits are recalculated. This procedure is repeated till all the remaining sample means are within the revised trial limits. It is assumed that those points which fall outside the control limits belong to some other probability distribution and that their presence is due to some assignable causes.

Subsequently, when the production process starts, samples at regular intervals (may be hourly, shift wise, daily, etc.) are taken, and the sample means plotted on the Chart. If any point falls outside the limits, apparently the process is out of control. Even though, there is a little chance that the process is out of control, it is worthwhile examining the process for any factor(s) which might have impacted the process. If nothing is detected, another sample is taken and its mean plotted on the Chart. If this point is also outside the limits, it may be worthwhile to examine the process for any factor which might be causing this.

Even if the points are within control, as in the following cases, the trend shows that the process might go out of control soon:

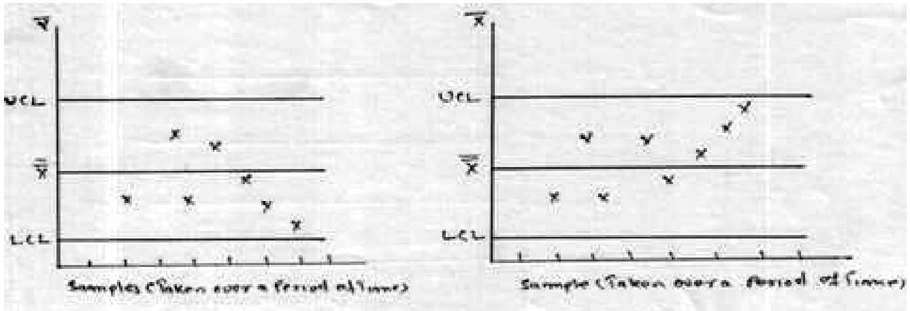


Figure 10.6

The control chart for action on future production may be set up using some desired values of m orσ, to achieve certain pre-assigned goal. In this case, the process may not be under control. But the aimed at values are used when they can be achieved by simply adjusting the production system.

It may be noted that the control limits depend both on mean as well as standard deviation.

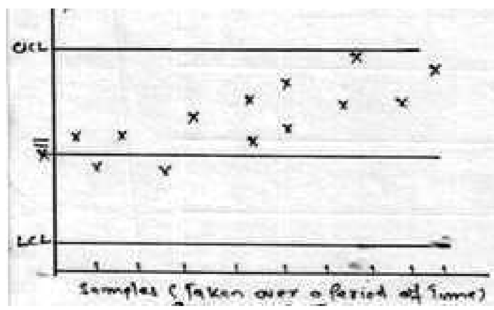
Thus, it is advisable to control both these parameters for the production process. It could happen that the process goes out of control due to shift in the mean.

Similarly, it could happen that while the mean does not change but the variation changes as shown on figure 10.8.

In either of the two cases above, the process could go out of control.

10.5.3 Natural Tolerance Limits

If the distribution is normal, and if m and σ are really equal to the estimates, on an average, only 27 out o 10,000 are expected to he outside the limit m $\pm$ 3 σ. If the natural tolerances are designed in such a manner that the limits contain all but 27 out of 10,000 values, x $\pm$ 3 σ would coincide with the natural tolerance. In the same way, if the natural tolerances are defined in such a way that the all but 1 out of 100 values should be expected to be outside the limits, $\overline{X}$ + 3.29 σ would coincide with the natural tolerance limits. After determining the natural tolerance limits, these are compared with the specification limits.



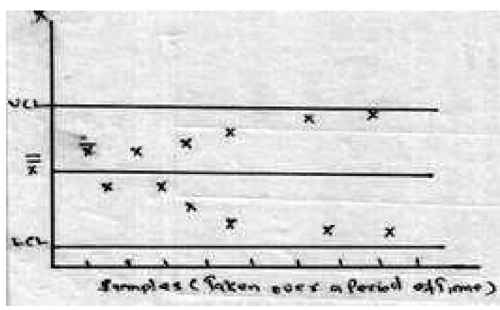


Figure 10.7 Figure 10.8

If the points are under control, there is no need for any action. The search for trouble begins as soon as a point falls outside the control limits. Proper action may be taken to get the system checked. It may be mentioned that even if the process is under control, a point may fall outside the limits as 27 out of 10,000 observations are anyway expected to be outside the control limits. But, even then, it is recommended to look into the process for any change that might have occurred. It is better to check than taking the risk of process going out of control. It may be emphasized that Control Chart is like a smoke detector alarm. Once the alarm is sounded, it is better to look for fire whether it is there or not.

For instance, a shift in the mean (m) results in points falling outside the control limits. It is advisable to check the control limits themselves in addition to examining the whole process when points begin to fall outside control limits.

10.5.4 Control Chart for R

For drawing the control chart for R, we require the value of $\overline{R}$.

We can calculate $\overline{R}$ from the range of each subgroup. The trial upper and lower control limits are D_4 $\overline{R}$ and D_3 $\overline{R}$, respectively. The values of D_4 and D_3 are given in Control Chart Factor Table.

If, we find all points the inside the trial control limits, no modification is recommended. A desired or specified value of $\overline{R}$ may be used to achieve certain desired goal. If the process goes out of control as indicated by points falling outside the control limits, it is advisable to estimate the value of σ. Usually, one method of estimation recommended is to eliminate those points falling outside the control limits (only those points outside above the upper control limit, if points fall above and below the control limits), and compute the control limits using the remaining observations. The procedure may be repeated if more points fall outside the control limits.

10.5.5 Control Chart for Fraction Defective or Proportion of Defectives p-Chart

The $\overline{X}$ and R charts are examples of charts for variables where the quality of an item is assessed with reference to some characteristic which can be measured quantitatively through a continuous variable. Sometimes, however, the quality of an item is observed only through an attribute. In such cases, the item is classified in two categories – e.g. defective and non-defective. It may be recalled that the Binomial Distribution is applicable in situations like this. Here, we cannot use $\overline{X}$ and R Chart. Instead, we use p-Chart-where p stands for proportion of defectives. Thus, if we are given quality of a characteristic observed as attributes even though they may have been measured as variables, we can use p-Chart. This chart has also certain advantages. In terms of cost of getting measurement data on variable, cost of computing (calculation of means, Ranges, etc.), and cost of charting itself. It may be appreciated that it is easier to record an item as defective or non-defective than recording the measurement of characteristic.

Setting up of p-Chart: For drawing up a p-Chart, samples of at least 50 items have to be taken at periodic intervals as an idea of proportion cannot be had unless there are at least 40 observations. This is unlike x chart wherein only 5 observations are taken to calculate sample means. For each sample, the proportion of defectives is defined as follows:

$$p = \frac{Number\ of\ Defectives\ in\ a\ sample}{Number\ of\ items\ inspected\ in\ the\ sample}$$

With reference to the Binomial distribution, the standard deviation of p is given by

$$\sqrt{(pq/n} = \sqrt{\{p\ (1-p)/n}$$

At least 25 samples are recommended for calculating of trial control limits. The overall proportion of defectives in these samples is computed as:

$$\overline{p} = \frac{Total\ number\ of\ defectives\ in\ all\ the\ samples}{Total\ number\ of\ items\ inspected\ in\ all\ the\ samples}$$

For large value of n, say 50 and above, the distribution of p may be taken as normal with mean $\overline{p}$ and SD. $\sqrt{\frac{\overline{p}(1-\overline{p})}{n}}$

Thus, the upper the lower trial control limits are given as:

$$\text{UCLp} = \overline{p} + (\text{standard deviation of } \overline{p})$$

$$= \overline{p} + \sqrt[3]{\frac{\overline{p}(1-\overline{p})}{n}}$$

$$LCPp = \overline{p} - \sqrt[3]{\overline{p}(1-\overline{p})/n}$$

It may be noted that if LCL is less than zero, it is taken as 0, as the value of p (proportion of defectives) is always greater than or equal to zero, and cannot be negative.

Inferences about the process can be drawn in a manner similar to that explained for the $\overline{X}$ and R chart.

However, even if the process is in control and meets the quality level, it can happen that the estimate of p is higher than that can be tolerated. In that case, we have to examine the production process and suitable changes effected.

10.5.6 Control Charts for Number of Defects – c-Chart

An item may have specifications for several of its characteristics like diameter and weight. A characteristic that does not meet the specifications is considered as a defect. If an item contains at least one defect, the item is considered defective. We can define c-Chart as a control chart for defects per item. Actually, the items are examined and the numbers of defects are recorded on the c-chart.

The initial setting up drawing a c-chart and its subsequent revisions are exactly similar to those of the p-chart. The viable c, representing number of defects, follows the Poisson Distribution whose mean and variance are the same theoretical Statistical Distributions. The upper and lower control limits for the c-chart are defined as:

UCLc = $\bar{c}$ + 3 standard deviation of c

LCLc = $\bar{c}$ – 3 standard deviation of c

UCLc = $\bar{c} + 3\sqrt{c}$

LCLc = $\bar{c} - 3\sqrt{c}$

10.6 SAMPLING INSPECTION

Through the use of Statistical Quality Control, described above, a manufacturer attempts to manufacture goods/items according to the specifications of the consumer. The manufacturer keeps on getting the manufacturing process checked at various stages to ensure that the goods/items are of the specified quality. The economical way of doing this, is inspection by sampling. On the other hand, the consumer is always concerned with the quality of the items he receives from the supplier. Of course, the ideal way of doing this is to carry out cent percent inspection of the received items. However, at times, it may not be, possible to carry out cent percent inspection. For example, items like electric bulbs get destroyed it tested for their lives or shells for guns/rocks get destroyed while testing for their functioning. Even if cent percent inspection is feasible, it consumes lot of resources including, money, time, etc. Even then such inspection does not assure of zero defectives in the inspected items because of several practical factors including "human fatigue". Hence, most of the times, inspection through sampling is preferred from practical and economic point of view.

There are two types of sampling inspection. One of Lot-by-Lot sampling and the other is Continuous sampling. In the former, items are grouped into lots, a sample is taken and on the basis of the observed quality of the sample, the entire lot is either accepted or rejected. This type of inspection is known as acceptance sampling.

In continuous sampling inspection, current inspection results are used to decide whether sampling inspection or screening (cent percent) inspection is to be used for the subsequently produced items. Further, sampling inspection can be done both for qualitative and quantitative characters. Thus sampling inspection plans are further classified depending on whether the characteristics are measured and expressed in numbers i.e. variables inspection or whether items are classified as defective or non-defective, i.e. attributes inspection.

The main objective of inspection at the producer's end is to control the quality of the produced items by examining at strategic points. Inspection ensures that the quality of the lot accepted is in accordance with the specifications of the consumer. Thus, the sampling inspection, if properly designed, puts more effective pressure for quality improvement, and, therefore, results in the submission of better quality product for inspection. In fact, even in Statistical Quality Control, samples of items are inspected and results used for controlling the quality of items. Such a procedure, besides ensuring the quality of the product, keeps down the cost of production.

10.6.1 Acceptance Sampling

The first thing, to decide, in acceptance sampling, is to define lots. It is to be ensured that all items in the lot are produced under essentially the same conditions. As far as possible, items manufactured under different conditions should not be mixed into one lot. Attempts should be made to maintain the identity of different lots. Further, it is essential that the sample be drawn from each lot based on which the decision to accept or reject the lot is to be taken. A random sample can be selected by using a table of random numbers or by some method based on chance so as to eliminate any type of bias.

There are three types of such plans:

(i) Single Sampling Plan

(ii) Double Sampling Plan

(iii) Sequential Sampling Plan

10.6.1.1 Single Sampling Plan

A single sampling plan is described as follows:

A sample of n items is drawn from a lot containing N items. The lot is accepted the number of defectives in the sample is less than or equal to the acceptance number ‘c’.

The curve showing the probability of accepting a lot for different proportion of defectives in the lot is called the operating characteristic curve (OC curve) of the plan. The OC curve of a sampling plan shows how the probability of acceptance of a lot varies with the product quality indicated by the proportion of defectives (p), it contains.

It the quality is good, it is desirable to have the probability of acceptance, say L(p) high. If p is zero, the lot contains no defective, and, therefore, will always be accepted. In that case L(p) = 1. On the other hand, if p is 1, the probability of acceptance, L(p) = 0. The shape of the curve is depicted in the following figure 10.9.

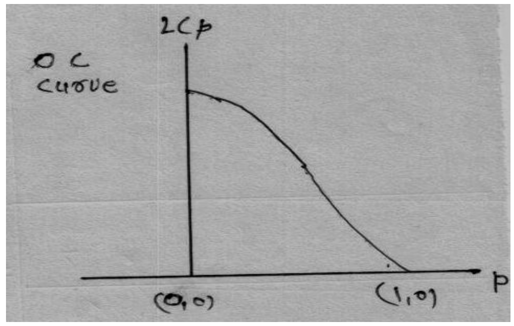


Figure -10.9

When a consumer chooses a sampling plan for a continuous supply of material, he usually does it with reference to what is called an acceptance quality level abbreviated as AQL. This is the quality level of the supplier's production process as also of the individual lots. Hence, he might establish a lot tolerance proportion defective abbreviated as LTPD. It gives the poorest quality he is willing to tolerate in an individual lot.

The two important aspects of a sampling plan are the 'producer's risk and the consumer's risk. If P_a is the probability of acceptance given by an OC curve, then the producer's risk is the probability of rejection or 1 – P_a. It is normally used in the case of rejection of lots from such a process whose average quality equals AQL. The consumer's risk is the probability of acceptance of a lot the quality of which is equal to the lot tolerance proportion defective.

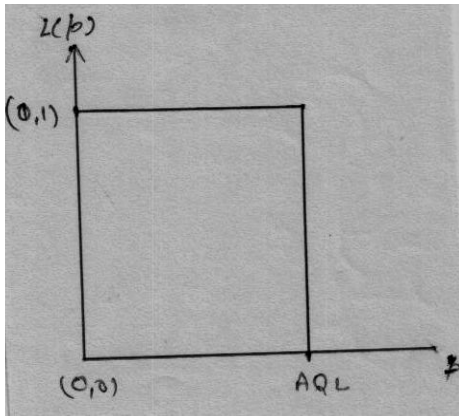


Figure- 10.10

The ideal OC curve should be such that the probability of acceptance is 1.0, if the proportion of defectives in the lot is less than or equal to the AQL, and 0 when the probability of defective in the lot exceeds AQL as shown figure 10.10:

Now, in the case of the single sampling plan, if the lot size 'N' is large as compared to the sample size n, the OC curve is practically independent of the lot size. Hence, a single sampling plan can be defined by the two numbers viz. the sample size n and the acceptance number 'c'. The probability distribution of the proportion of defectives is given by the Binomial Distribution.

Selection of Single Sampling Plan

The consumer has at his disposal the choice of one of many OC curves. He should select one by taking into account the cost of making wrong decisions. By adjusting n and c, he can always find an OC curve which will pass through two pre-assigned values, say, $\{p_1, L(p_1)\}$ and $\{p_2, (L(p_2)\}$. Before choosing sampling inspection, the consumer can select two points p_1 and p_2 such that if quality is submitted better than p_1, he will accept the lot with probability greater than $L(p_1)=1-\alpha$; on the other hand, if the quality is submitted worse than p_2, he will accept the lot with probability less than $L(p_2) = 1-\beta$. Here, alpha is the producer's risk and beta is the consumer's risk. The average of the submitted quality is known as the process average.

The following figure 10.11 depicts the terms associated with single sampling plan.

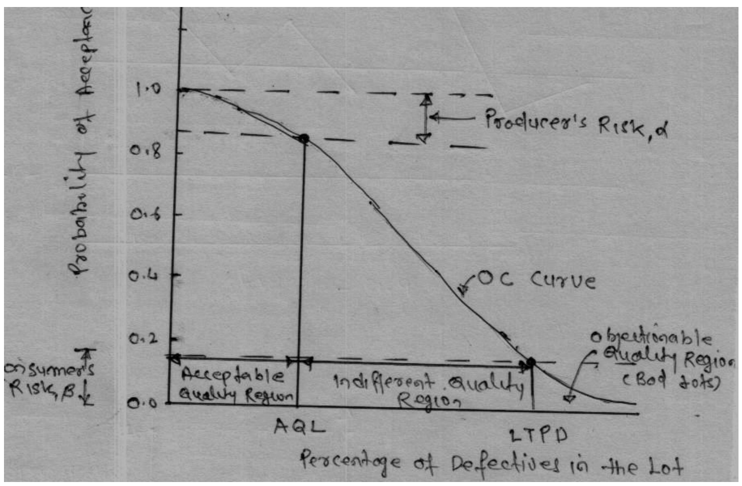


Figure- 10.11

Calculation of OC Curves for Single Sampling Plan

As mentioned earlier, a sampling plan is defined by two numbers viz. n (sample size) and c (acceptance number). So, the lot is accepted if the number of defectives, say d, in a sample of size n is less than or equal to c. If P(i) denotes the probability of i defectives in a sample of n items, then the probability of accepting the lot is given by

$$L(p) = P(0) + P(1) + P(2) + .. + P(c)$$

Example: What is the probability of accepting a lot whose incoming quality, as defined by percentage of defective items, is 5%, the sample size is 20, and the acceptance number c is equal to 1.

Solution: Since the percentage of defectives is 5%. It implies that the fraction or proportion of defectives p is 0.05. The lot will be accepted if the number of defective is either 0 or 1.

The probability of accepting the lot is found by using the Binomial distribution. It is given as:

$$L(0.05) = P(0) + P(1)$$

$$= 20C_0\, p^0\, q^{20} + 20C_1\, p^1\, q^{19}$$

$$= q^{20} + 20(p)\, q^{19}$$

$$= (0.95)^{20} + 20 \times 0.05(0.95)^{19}$$

$$= 0.7358$$

10.6.1.2 Double Sampling Plan

In the single sampling plan, the decision to accept or reject a lot is taken on the basis of one sample drawn from the lot. It could happen that the quality of the sample may not be truely representative of the quality of the lot and the entire lot may be rejected even when the quality might be as per specifications, or the entire lot is accepted even though the quality of the lot is not as per specifications. While, such risk cannot be eliminated, it can be reduced by resorting to taking a second sample from the lot whenever, the first sample does not provide ample evidence of the very good or very bad quality of the lot. A double sampling inspection plan can be described as follows.

A sample of n_i items is drawn from a given lot. The lot is accepted, if the number of defective items in the sample is less than or equal to c_1. If the sample contains more than c_2 defective items (c_2 being greater than c_1), the lot is immediately rejected. But in case, the number of defective items is greater than c_1 but is less than or equal to c_2, a second sample of size n_2 is drawn. The lot is accepted if the number of total defectives in the combined sample of size $n_1 + n_2$ is $\leq c_2$. However, if it is greater than c_2 the lot is rejected. Thus a double sampling plan is described by four numbers n_1, n_2, c_1 and c_2.

Thus, if the incoming quality is very good, the lot is accepted on the basis of the first sample itself and rejected if the quality is very bad. However, if the quality is of an average type, a second sample may be required. Psychologically, a double sampling plan has the advantage that it gives a second chance to lots of doubtful quality. Another advantage of double sampling plan over a single sampling plan is that, for a given amount of risk, it needs lesser items to be inspected, thus reducing the costs involved.

The double sampling plan can be summarised as follows:

- Take a first sample of size n_1

  If the number of defectives (d_1) is $\leq c_1$ – Accept the lot

  If the number of defectives (d_1) is $> c_2$ – Reject the lot
- Take a second sample of size n_2. Let the number of defectives be d_2.

If $d_1 + d_2 \leq c_2$ – Accept the lot

If $d_1 + d_2 > c_2$ – Reject the lot

10.6.1.3 Sequential Sampling Plan

A sequential inspection plan involves examination of a sequence of units (or group of units) of a lot chosen at random and, after inspecting every unit or group of units, making one of the following three decisions:

(i) The lot is accepted

(ii) The lot is rejected

(iii) The evidence is not sufficient for either accepting or rejecting

But whenever the third option is open, an additional unit or a group of units is inspected, and the same three aforesaid decisions are reconsidered on the basis of the basis of the additional information collected. The inspection is continued until the lot is either accepted or rejected.

The main advantage of sequential inspection over any other sampling inspection is that the average number of items to be inspected, under this plan is lesser than Single and Double sampling plans. One of the main disadvantage of this plan is that it requires the inspector to record and calculate after inspection of each item, before proceeding further. However, in a standard inspection procedure, a decision about further inspection is made after inspecting a fixed number of items. On the other hand, in view of the uncertainty regarding the number of items required for eventually accepting or rejecting a lot, the number of items to be kept ready for inspection is much more than actual the number that might be required.

10.7 SIX SIGMA

Six Sigma is now-a-days synonymous with perfection in quality. Before Six-Sigma methodology came in vogue, 3 sigma tolerance levels (for any process) used to be the benchmark for quality measurements.

The Six Sigma method is a management philosophy as well as systematic methodology that uses the relevant data and subsequent statistical analysis to measure and improve operational performance, practices and systems in a company. This is sought to be achieved by identifying and preventing 'defects' in manufacturing and service-related processes for accomplishing perfection. It is driven by an attempt to better understanding of customer needs, judicious use of facts, data and statistical analysis and discrete attention to management. One of the key features of six sigma is anticipating the needs and exceeding expectations of customers.

Even though, commonly perceived as applicable to manufacturing systems, Six Sigma is applicable to any sector like accounts, customer driven services like banking and mail/parcel delivery and marketing. This is because defects can be present even in a service – a defect being defined as deviation from set norms or procedures.

The philosophy behind Six Sigma is that by measuring how many defects are in a process, one can explore the way for systematically eliminating them and getting as near to perfection as possible. For a company to qualify as a Six Sigma company, if cannot produce more than 3.4 defects per million parts or opportunities, abbreviated as DPMO.

10.7.1 Historical Development

Bill Smith, a reliability engineer at Motorola, is widely credited with originating Six Sigma and selling it to Motorola's legendary CEO, Robert Galvin. Smith noted that system failure rates were substantially higher than predicted by final product test. He suggested a number of possible causes for this phenomenon, including a dramatic increase in system complexity and the resulting opportunities for failure and a fundamental flaw in traditional quality thinking. Smith's holistic view of reliability (as measured by mean time to failure) and quality (as measured by process variability and reject rates) was indeed new, as was the Six Sigma quality objective.

Although Six Sigma was started in Motorola in its manufacturing division, it eventually evolved and subsequently used in other companies such as Allied Signal and GE. It is reported that GE saved 10 billion $ by adopting Six Sigma philosophy and methodology, during the first five years of its implementation. Ford, Boeing, Caterpillar, Microsoft, Seagate, Siemens and Merrill Lynch have since used it. Six Sigma is now used in several management initiatives and can be applied to any sector where the control of variation is desired, such as services, call centers, medical and insurance procedures.

10.7.2 Normal Distribution and Six Sigma

It is interesting to know as to why the name six sigma could have been chosen to indicate almost perfect quality. As mentioned above, earlier, the quality was synonymous with 3 sigma (σ). Statistically, it means that when a production process is under statistical control, producing items within $\pm 3\ \sigma$ deviation from the mean, only 27 out of 10,000 items are likely to be defective. It is shown through the figure 10.12

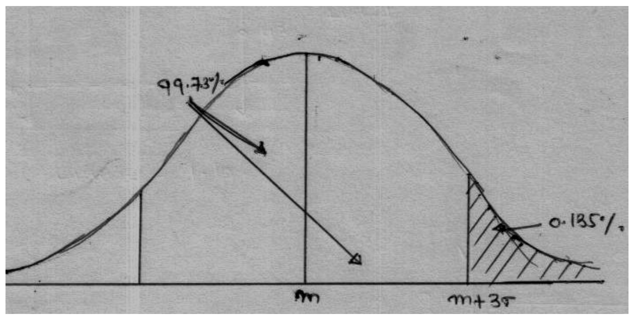


Figure 10.12

If a product is to be labeled as defective, when it exceeds m +3 σ, it implies that there are expected to be 13.5 defects per million items. But Motorola engineers argued that a process can shift 1.5 sigma in regular course, as shown in the figure 10.13

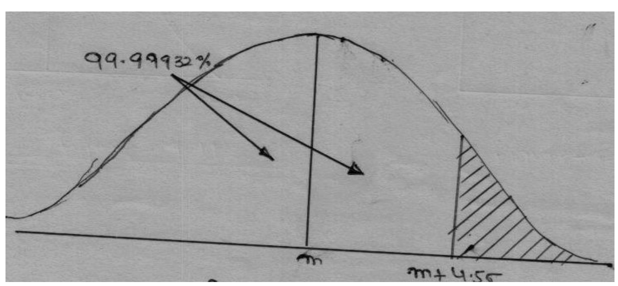


Figure 10.13

Now, to keep the data points within earlier permissible area, with mean shifting by 1.5 sigma, and thus, to accommodate 1.5 sigma shift, they proposed that the tolerance has to be $\pm$4.5 sigma. In six sigma methodology, 99.9996599% (or more) of data lies within $\pm$ six sigma from the mean, thus having only 3.4 defects per million opportunities (DPMO). Now, 99.9996599% value is actually for 4.5 sigma level in Normal curve, but keeping in view the 1.5 sigma process shift, the process sigma level is actually six. While 4.5 sigma is labeled as long term capability or performance, six sigma is referred to as short term capability or performance.

10.8 SUMMARY

The unit focuses on quality as a vehicle for delivering value, real or perceived, to the customer whose needs and expectations are changing over time. It imparts to dimensions to the concept by shifting from quality control to quality assurance. ISO 9000 series of standards provide a comprehensive guideline and industry recognized as a minimum level of acceptable quality. An increasing trend to adopt quality strategies like TQM and quality circle has also been highlighted in the chapter.

10.9 KEY WORDS

Accuracy: This refers to the degree of conformation to standard dimension as per specification attainable by production facilities.

Inspection: The process by which ascertain the extent to which a manufactured product conforms to design specifications.

SQC: Statistical Quality Control is a technique, which is used for applying statistical theory to industrial mass production for ensuring uniformity in the items as also for facilitating in meeting the specification requirements.

SIX Sigma: The Six Sigma method is a management philosophy as well as systematic methodology that uses the relevant data and subsequent statistical analysis to measure and improve operational performance, practices and systems in a company.

Quality assurance: Quality assurance refers to the assurance to customers that the products, parts, components, tools etc. contain specified characteristics and are fit for the intended use.

10.10 SELF ASSESSMENT EXERCISE

1. What do you understand by quality control?
2. What may be key areas to address when improving the cost of quality? Explain.
3. Define Statistical Quality Control. Describe briefly the techniques of SQC used in:
    - (a) Inspection of incoming materials
    - (b) Inspection during process control.
4. Discuss Quality acceptance sampling and explain how the same used for inspection of materials.

10.11 FURTHER READINGS AND SOURCES

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Subject: Production and Operations Management

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Course: MBA Course Code: CP-204

LESSON: 11 Quality Assurance

Structure

11.0 OBJECTIVES

After going through this lesson, you will be able to:

1. **Meaning and definition of quality assurance**
2. **Cost aspect of quality assurance**
3. **Understand concept of TQM**
4. **Quality Standards**

11.1 QUALITY ASSURANCE

11.1.1 Meaning and Importance

Quality assurance refers to the assurance to customers that the products, parts, components, tools etc. contain specified characteristics and are fit for the intended use. Quality assurance is concerned with determining the procedures to be used and frequency to checks or tests to be made within the system so as to ensure that the system is meeting the specification incorporated in the product/service design. In today's competitive industrial world, no business unit can exist for a long time without adhering to the quality. Now, the assurance of quality is not a responsibility of a single person or a department only. Only the inspection department or its personal cannot be held responsible for assurance of quality. It is the responsibility of everybody connected with production-from design and raw materials stage to dispatch and transportation stage i.e. from the designing of the product to the sales and delivery of the finished product-is responsible. Thus design engineering department, purchasing department, inspection department, materials handling department, maintenance and repair department, stores department, production department, sales department etc. are all equally responsible for assuring the quality. They all play an important part for providing a customer a product of acceptable quality. Therefore, everyone has to be alert and everyone should perform one's duty efficiently, because everyone's activity is directly or indirectly related to the quality of a product which their company is manufacturing. Employees of the unit must be made quality conscious. They should be motivated, if the unit wants to get best results from them. This can be done by explaining to them, why the quality is important for themselves as well as for their unit.

11.1.2 Factors affecting employees' morale

Increase in morale results in improvement of quality. If workers are dissatisfied or working conditions are poor, employees' morale will be at a low level and cases of rejections will increase in any unit can be increased only by minimizing the chances of rejection, which in turn results in better quality. Employees may not be able to work or may not work or generally do not work efficiently because of many factors which can be classified as under:

(a) Psychological factors

(i) Monotony and boredom: When a person is required to perform the same type of work a number of times repeatedly over a long time, he gets bored or tired. He works only to spend time without having interest in his work. He gets dissatisfied and a dissatisfied worker cannot discharge his duty efficiently and effectively. This ultimately badly affects the quality of a product, resulting in higher rejections.

(ii) Frustration: Employees get frustrated due to various reasons. They may not find any chance of promotion or scope for self-development. The boss may not be co-operative or may be ill-tempered. Management may not have trust in the employees. Under such circumstances, employees may not work with interest.

(iii) Absence of incentives: Absence of incentives in the form of wags linked with productivity, incentive wage rates, prizes for quality work etc. marks the employees. Employees become careless, thereby affecting badly the quality of a product resulting in higher rate of rejections.

(b) Physiological factors

After working for a certain period continuously, worker experiences stress, which leads to fatigue. If fatigue is severe, it will affect the quality as well as the quantity of production.

(c) Technical factors

(i) Unclear specifications and faulty design: The specifications must be well defined and the design of a product must be faultless because ambiguous specifications and faulty design make the products unfit for use, quality of the products suffers heavily and it results in higher proportion of rejection.

(ii) Improper or unsuitable or substandard tools and equipment: Tools and equipments, which are not proper or suitable or of standard quality, affect the quality badly even if the workers are efficient and sincere.

(iii) Complex or unsystematic operations or processes and improper maintenance and repairs of tools and machines: Operations and processes must be planned and designed systematically. Timely repairs and proper maintenance may result in higher productivity and production of defective products in small number.

(d) Other factors

Working conditions in factory should be satisfactory. Absence of (i) Proper ventilation, (ii) sufficient light, (iii) normal temperature, (iv) Subsidized canteen facilities, (v) Urinals and latrines in sufficient numbers, (vi) Provision of safety gloves, safety glasses, helmets etc. for workers, if found necessary etc. result in decreased efficiency. Possibilities of accidents and absenteeism show upward tendency with the passing of time. Unsatisfactory working conditions bring into existence conflicts between employees and management thereby resulting in decreased productivity and increased number of rejections.

11.1.3 How to motivate the employees

In the preceding section on "Factors affecting employees' morale" we have discussed various factors affecting the efficiency of employees to consider these factors and to take necessary steps as corrective measures. The following are some of the important corrective measure, which may prove to be useful for motivating the employees:

(i) An employee should be moved from one work to another at a regular interval. This type of job rotation reduces monotony and boredom. If a worker is given liberty to work in his own way without affecting quality and productivity, he will work with interest. Job design should be changed, if it is found necessary to simplify the operations or processes. Unnecessary interference by a supervisor, while a worker is performing his job, should be avoided as far as possible.

(ii) Suggestions from employees for improvement of quality should be encouraged and prizes should be awarded for good suggestions. Certain progressive companies run suggestions schemes very successfully.

(iii) Quality campaigns should be initiated and continuously promoted. Moreover, progress against predetermined standards should be examined regularly to find out variances if any. Quality work should be appreciated and incentives in form of prizes, early promotions, higher wage rates etc. should be given for quality work.

(iv) Reasonable wage rates linked with productivity and quality should be implemented to encourage the workers to work sincerely and carefully.

(v) Provision for adequate training to workers should be made for improvement of quality and productivity.

(vi) Promotion policy should be framed in such a way, which can provide an incentive to honest, sincere and hardworking employees in terms of comparatively early promotions at regular intervals. The officers or heads should be co-operative and capable of under each head do feel that the head is their own man and also that he is one important member of the team. The boss should take care of his subordinates. Such practices make the relations between heads and their subordinates cordial and workers work sincerely with full in their superiors.

(vii) After working for a certain number of hours continuously workers get exhausted physically as well as mentally. Therefore, sufficient rest period during working hours should be provided. Now the span of working period after which rest period is to be allowed depends on the type of work. If the work requires comparatively more physical and mental exercise, the rest period to be allowed should be kept comparatively long and it should be allowed after a comparatively short span of working period. Heavy work should be mechanized as far as possible to reduce the strain on body and brain. In large factories, where the materials to be handled are very heavy and in large quantity, latest mechanized materials handling devices i.e. most modern materials handling equipment (conveyor belts, etc.) are used.

(viii) Drawings, designs, operations, methods of production etc. should be simple, well-defined and technically practicable as far as possible. Process sheets should be simple so that operators do not find it difficult to understand the working of a process. Specifications should not be stringent, because no two products coming out of the same process will be identical. There may be slight difference between any two units that have come out of the process. If stringent specifications are to be followed, number of defective/rejections will be too much. Now workers also get frustrated, if they know that the defective or rejections, tolerances (with upper and lower limit) should be prescribed, instead of following the specifications rigidly. Variations in dimension, weight etc. should be permitted up to certain limit (upper or lower), which do not affect the quality.

(ix) Employees should be provided with suitable tools and equipment of standard quality. If this is done, the employees will work with pleasure and quality products will come forth. Proper maintenance and timely repair of the tools and equipment are also important to ensure continuity in production.

(x) Better working conditions encourage the workers to put their best efforts for quality work. Better working conditions generate healthy relations between workers and employers thereby resulting in industrial peace which is a must for increased productivity and better quality work.

11.2 EMPHASIS FROM QUALITY CONTROL TO QUALITY ASSURANCE

"Quality is never by an accident, It is always the result of an intelligent effort".

- John Ruskin

"Quality is never by an accident, It has always to be pre-planned".

- Juran

The quest for efficiency is eternal to mankind. In industrial parlance, efficiency means maximizing production of quality products at optimal cost.

Quality has been defined in different ways by different persons, such as:

- Degree of Excellence
- Life of Product
- Cost of Product
- Fitness for use
- Conformance to requirements
- Customer's satisfaction

These need based definitions represent only certain facets of quality. The achievement of satisfactory quality involves all stage of the quality loop as a whole e.g.,

- Quality due to definition of needs (as defined above)
- Quality due to product design
- Quality due to conformance and product support throughout its life time

Quality Loop

From this it is evident that quality cannot be built into the product during manufacturing alone and instead it has to be built into the product right from the stage of assessing the marketing conditions to design, procurement, manufacturing, sales and distribution and finally after-sales-service to the customer.

The concept has led the industry to shift emphasis from quality Control (QC) to Quality Assurance (QA) and ISO-9000 System is the outcome of quest of the industry to meet challenges of technology up gradation and ever increasing competition in the international market.

11.3 ISO 9000 STANDARDS

ISO stands for International Organization for Standards. ISO-9000 is a series of international standards for quality systems. It is a practical standard for quality applicable both to the manufacturing and service industry.

These standards were first published in India in 1987 and subsequently revised in 1994. These standards have made a dramatic impact on business around the world and have become the regular (a must) for doing business in the world market.

Indian, British and European Equivalent Standards are:

INDIAN	:	IS: 9000
BRITISH	:	BS: 5750
EUROPEAN	:	EN: 29000

ISO-9000 sets out that the company can establish documents and maintain an effective and economic quality system which will demonstrate to the customers that the company is committed to quality and is able to meet their quality needs. These standards answer concisely:

ISO 9000	:	What is Quality management? How to Sum a Quality Assurance System
ISO 9001, 9002, and 9003	:	These systems (9001-9003) decibel about the quality aspects covered and are know as module-1, module-2 & module-3 respectively.
ISO 9004	:	What sort of quality Operations are Appropriate to a Project

These are internationally accepted standards and laid down in an organized way. The standards have been split into 20 Sections (called Elements) to enable users to implement it easily, effectively and efficiently (3e's) they provide an opportunity to have a complete record of all the 20 elements, based on their company standards for use within their own industry. The Standards have been written in general terms with the Product manufacturer in mind but the standards are equally applicable to the service industries such as banking, hospitals, hotels and restaurants, educational institutions etc.

ISO 9000 Quality Management and Quality Assurance Standards Guidelines for Selection and use of modules.

ISO 9004 Quality Management and Quality System Elements-Guidelines for 20 Elements.

ISO 9001-model 1-Model for quality assurance in design/development, production, installation and servicing.

ISO 9002-model 2- Model for quality assurance in Production and Installation.

ISO 9003-mode for quality in Final Inspection and Testing.

ISO 9000 (Quality Management)

- This standard provides the essentials of putting a Management of Quality Assurance Policy action.

- It clarifies the relation between different quality concepts and specifies the rules for using the three models given in ISO 9001, 9002 and 9003.

  ISO: 9004 (Quality Management and Quality System Elements Guidelines)

- Consists of an examination of the quality system elements cross-referenced in ISO 1000 and the system standards. A manufacturer needs to understand an operation in sufficient detail so that only the appropriate elements are selected for each stem of the operation. The object is to minimize cost of the quality project while maximizing the benefits.

Three Quality Assurance Models

Model One (ISO: 9001)

Model one is for use when conformance to specified needs is to be assumed by the manufacturer throughout the whole cycle from design to servicing. Model 1 represents the fullest requirement involving all the quality system element is ISO: 9004 at their most stringent.

Model Two (ISO: 9002)

Model two is more compact. It is for use when the specified requirements for products are started in terms of an already established design or specification. Only the supplier's capabilities in production and installation are to be demonstrated. Here again all the elements of ISO: 9004 are present, but some are treated less stringently.

Model Three (ISO: 9003)

Model three applies to situations where only the suppliers' capabilities for Inspection and Testing can be satisfactorily demonstrated. In this model, only half of the quality system elements of ISO: 9004 are required and at a lower level of stringency that model two.

Salient Features of ISO 9000

ISO 9000 helps in fixing responsibility:

(1) A company adopting ISO 9000 series must identify and assign responsibility for all functions that affect quality. The aim of company shall be to achieve, sustain and improve the reputation for 'quality' at competitive prices in the national and International markets. For achieving this aim, the responsibility and commitment to quality belongs to the management. An executive with necessary authority and ability must be put in charge as 'Management Representative' (MR) and his job would be to co-ordinate so that requirements of ISO 9000 are met. He must accord the buyers' representatives all the facilities listed in the contract and allow him reasonable access to the company records and procedures (Management Responsibility)

(2) The supplier shall establish and maintain a documented quality system as a means of ensuring that product conforms to specified requirements. This shall include:

(i) The preparation of documented quality system, procedures and instructions in accordance with the requirements of the international Standard.

(ii) The effective implementation of the documented quality system procedures and instructions (Quality Policy)

(3) The Supplier shall establish and maintain procedures for contract review.

(4) The supplier shall establish and maintain procedures to control all documents and dates that relate to the requirements of this international Standard. These documents shall be reviewed and approved for adequacy by authorized personal prior to issue (Documents & Data Control).

(5) The supplier shall ensure that purchased product conforms to specified requirements.

(6) The supplier shall establish and maintain procedures for verification, storage and maintenance of purchased supplier product provided for incorporation with the supplies (e.g., Rolling-mill for a mini steel plant project).

(7) Where applicable and appropriate, the supplier shall establish and maintain procedures for identifying the product from applicable drawings, specifications or other

documents, during all stages of production, delivering and installation. (Identification of Product)

(8) The supplier shall ensure that all processes are carried out under controlled Conditions. (Process Control)

The supplier shall ensure that:

(i) The incoming product is not used or processed until

the same has been inspected or otherwise verified (Raw Materials Inspection).

(ii) The product is being inspected and tested as per quality plan during all stages of production (Inspection and Testing).

(iii) The supplier shall carry out all final inspection and testing in accordance with the quality plan or documented procedures (Inspection & Testing).

(9) The supplier shall control, calibrate and maintain inspection, measuring and test equipment, whether owned by the supplier or provided on loan by purchaser. (Inspection Measuring and Test Equipment)

(10) The identification of inspection and test status shall be maintained, as necessary, throughout production and installation to ensure that only the product that has the required inspection and test is dispatched.

(Inspection and Test Status)

(11) The Supplier shall establish and maintain procedures to ensure that product which does not conform to specified requirements is prevented from inadvertent use or installation.

(Control of non-conforming product)

(12) The supplier shall establish, document and maintain procedures for investigating the case of non-conforming product and the corrective action needed to prevent recurrence and also suitable measures to rectify the procedures and processes to prevent recurrence.

(Corrective action)

(13) The supplier shall establish, document and maintain procedures for handling, storage, packaging and delivery of products.

(Handling storage, packaging and delivery).

(14) The supplier shall carry out internal quality audits to verify whether quality activities comply with planned arrangement and to determine the effectiveness of the quality system.

(Quality Records)

(15) The supplier shall carry out internal quality audits to verify whether quality activates comply with planned

arrangement and to determine the effectiveness of the quality system.

(Internal Quality Audits)

(16) The supplier shall establish and maintain procedures for identifying the training needs and provide for the training of all personnel activity affecting quality during production and installation. Appropriate records of training shall be maintained.

(Training)

(17) Where appropriate, the supplier shall establish procedures for identifying statistical techniques required for verifying the acceptability of process capability and product characteristics.

(Statistical Techniques)

ISO 9000 can be summarized as

The ISO 9000 series of standards are basically quality Assurance Standards and not product Standards. The series of standards aims at the following.

(i) Increase customer confidence in the company.

(ii) A Shift from a system of inspection, to one of quality management (QC-QA).

(iii) Gaining management commitment (as quality policy is by top management.)

(iv) Looking quality from cost consciousness point of view.

(v) Giving customers what they need (Contract system).

(vi) Removing the need for multiple assessments of suppliers.

The implementation of ISO 9000 as described above clearly indicates that ISO: 9000 is a step towards TQM (Total Quality Management).

Difference between ISO: 9000 and ISI Marking

ISO: 9000 Is a Quality System Standard and not a product standard i.e. a company having an ISO:9000 certification shall not automatically be qualified for its product standards.

A Customer requiring a product with ISI mark from an ISO company has to be provided with a product with ISI mark as usual conforming to a particular specification and not that the company can escape this responsibility.

A Company can produce variety of products out of which not necessarily all should have ISI mark but for an ISO company they have to adhere to uniform standards (System Standards) as per ISI system for all products.

Further, the ISI mark is by BIS only whereas the certification for ISO standards can be had from any of the authorized agencies in India or abroad. (Today, more than 10 agencies are serving in India itself).

The product standard can be put on the product but not the ISO. The ISO system, however, can be displayed through letter head, paper advertisement, magazines & other media.

How to Obtain License?

Stage I Application and its processing

1) Firms interested in obtaining license for quality system as for IS/ISO 9000 family or standards, should ensure that they are operating quality system in accordance with relevant standard.

2) They should apply on the prescribed proforma in…..(Form III) at nearest regional office of BIS (or any other credited agency) along with prescribed application fee as applicable.

3) The application is to be signed by the proprietor, partner or the Chief Executive Officer (CEO) at the firm or other person authorized to sign any declaration on behalf of the firm. The name and designation of the person signing the application must be recorded legibly in a space set apart for the purpose in the application form.

4) Each application must be accompanied by a supplementary questionnaire (Form IV) duly filled in along with the, Documented Quality System the requisite of the relevant quality system standard.

If the application is rejected by BIS

Reasons shall be given therein:

1) Application Fee not accompanying the application

2) Application Form III or IV is incomplete.

3) Annexures to the application are not clear.

BIS will acknowledge the receipt of application/application fee. Every applicant will be given a serial number to be known as "Application Number".

In all future correspondence, reference of Application Number is a must.

Stage II : Adequacy Audit

1) After the application has been accepted, the Documented Quality System (Quality Manual/Quality Plan etc.) shall be examined by the BIS for verifying the conformance to relevant standard (001/002/003).

2) Any significant omission or deviation from the prescribed requirements situated by BIS will have to be corrected by the applicant.

Stage III Preliminary Visit & Assessment

BIS official (S) may make a visit to the premises of the applicant to acquaint himself/themselves of the size, nature of operation & firm's readiness for the audit. The assessment will comprise the following sequence:

a) **Opening Meeting:** The meeting will be conducted by the leader of the audit team in which the CEO of the company, MR (Managerial Representative) and Heads of all departments being audited are expected to be present.

During this meeting, the leader will explain the scope and extant of the audit and the important terms used in the audit.

b) **Conduct of Assessment:** Each auditor should be accompanied by a guide who is conversant with the activities of the deptt(s).

Observations recorded by the auditors must be signed by the guide as a token of acceptance.

c) **Closing Meeting and Report**

1) All the members present in the opening meeting should preferably be present in the closing meeting as well, when the audit team will present their findings to the firm.

2) The Non-conformities (as……..to established system) observed by the audit team will be handed over to the firm at the end of each day for necessary corrective action.

3) These frames for the corrective action (S) will be decided by the firm.

4) The Non-conformity report will be signed by the Managerial Representative who is the manager, agent or representative for the Quality Implementation System as a token of acceptance.

11.4 TOTAL QUALITY MANAGEMENT (TQM)

TQM is a quality-focused customer-oriented integrative management method that emphasizes continuing and cumulative gains in quality, productivity and cost reduction. These gains are achieved through continuous improvement in product design. Reduction in operating costs, reduction in operating losses. Avoidance of wastage of time, effort and material in any form, removal of production-line deficiencies, up gradation of skills and empowerment of employees to detect and correct errors, among other measures. TQM involves the participation of every department, every section, every activity, continuous improvement effort. Its central integrative focus is the concept of total customer satisfaction with the quality and performance of the company's products or service.

The structure of TQM may be seen to consist of the following main elements:

- Design Standardization
- Taguchi Methods (Control of Variability)
- Quality Function Deployment
- Performance measurement and Statistical Quality Control
- Employee Involvement
- Small-Group Activities

The nature of each of these elements may be outlined briefly:

(i) Design standardization: Denotes that the design of components and their assembly in a product has been rationalized, tested rigorously and proven in manufacture. It is a powerful means for improving the flow of new products through the product and process design function. It also has major implications for simplifying the factory floor environment and the entire product service task in the field. A proven standard design serves to eliminate various 'bugs' from the production process. It makes possible the optimization of the production process and its error-free operation.

(ii) Taguchi methods: Provide a powerful mean for isolating critical product design parameters that need to be controlled in the manufacturing process. They also enable losses. Taguchi's quality loss function enables management to think of quality in terms of money rather than merely in terms of the implications of various statistical distributions, standard deviations, variability and so on. The importance of Taguchi methods lies in their demonstration of how the cost of variability. The cost of quality to the company and to society can be calculated through Taguchi's quality loss function. The function, for example enables a company to evaluate the significance of 50 per cent reduction in product variability in terms of monetary gains. The company can then analyse whether the methods by which it can achieve that 50 per cent reduction in variability are worth the reduced quality monetary losses.

(iii) Quality Function Deployment (QFD): Represents a comprehensive analytic schema or framework for quality. The purpose of this schema is to enable a company to translate any customer preference or desire about products into what has to be done in design, manufacturing or distribution and to product and the process, to satisfy the customer.

Quality function deployment provides structure to the product development cycle. The foundation of this structure is customer requirements. QFD proceeds in a systematic manner for design concepts to manufacturing process of manufactured product. It ensures at each step that quality assurance is built into both process and product. QFD also implies that the company has documented its quality police that is understood, implemented and maintained at all levels in the organization and that responsibility and authority are clearly defined.

(iv) Performance measurement and statistical quality Control: Are applicable of both the factory of enterprise and its vendors or suppliers. The latter are enjoined upon and expected to supply materials, components and inputs of required standards and specifications of quality. Without a proper frame of measurement, a company cannot assess and evaluate the success or effectiveness of its efforts towards improving the cost and quality of its operations and outputs.

(v) The concept of employee involvement: Is essentially concerned with extending decision-making to the lowest possible hierarchies level of the company, it also denotes a high level of workers' motivation and morale and their identification with the goals of the organization. A high level of employee involvement, i.e. their motivation, commitment and empowerment towards productivity, innovation and problem-solving, depends on the strength of an organization's culture, i.e., its system of shared values, beliefs, norms and vision.

(vi) The concept of small-group activities: Is closely aligned with employee involvement. Small voluntary groups of workers known as quality circles or productivity teams represent a mechanism for evoking, sustaining and utilizing employee involvement. Small-group activates represent of powerful way of improving productivity, quality and work performance in the organization in a continuing manner.

11.4.1 Six Sigma or Zero Defects in TQM

Six sigma is major part of the TQM programme. It is defined as 3 to 4 defects per million. It stresses that the goal of zero defects is achievable. The concept and method of six sigma is applicable to everyone and to all functions, i.e., manufacturing, engineering, marketing, personal, etc. As a concept, it aims at reducing process variation and reducing and finally eliminating all defects. As a method, it aims at the output of work, the customers of that output, customers' critical requirements, suppliers and the firm's critical requirements of them, the processes used by the firm and the tools and approaches for continuously improving the firm's processes. Six sigma, in essence, is a measure of variation.

The Methodology of Six Sigma: The application of six sigma as concept and a method involves the following six steps.

1. Specify clearly the products or service, i.e., the Output, from your processes that the customer receives from you and which incorporate you value-added element.
2. Specify the customers of the output and determine what they consider important.
3. Identify your suppliers and specify your critical requirements of them. Your ability to satisfy your customers depends on the ability of your suppliers to meet your critical requirements.
4. Delineate the process for doing your work. Map key sub-processes or activities and identify tasks, decision-points, storage points, wait points or queues, workflow and items of rework.
5. Examine each link or step in the process with a view to assess whether or not it adds value to the product or service to satisfy the customer. Improve the process in the light of such an examination.
6. Continue the improvement process by measuring and analyzing defects or deficiencies and then proceed towards removing them in a planned manner.

11.4.2 The Integrative Focus of TQM

The TQM system is integrated around the central concept of Total Customer Satisfaction. The concept is not restricted to the manufacture of zero-defect products. It extends to and encompasses continuing changes or improvements in the product based on feedback from the customers regarding their preferences and expectations regarding the performance of the product. This aspect is also known as the practice of 'experience or design looping' in Japanese firms. It essentially implies continuing improvements in products' design and manufacture in the light of periodic surveys of customer experience, opinions and preferences.

Key facets of TQM's integrative focus are the four Pls:

- People Involvement
- Product Process Innovation
- Problem Investigation
- Perpetual Improvement

The keynote of these four PIs is teamwork or cooperation. In TQM however, the concept of teamwork is larger and more inclusive. It implies that (a) employees are viewed as assets: (b) suppliers are viewed as partners: and (c) customers are viewed as guides. Involving all three of them intimately in the company's manufacturing policies.

The underlying assumptions or key premises of TQM may be briefly summarized:

- Quality cannot be improved by investment in high technology alone.
- Quality depends on and comes from, people.
- Quality is the result of attitudes and values: it is the result of viewing quality as 'way of life'

11.5 QUALITY CIRCLES

In manufacturing, the Japanese practice is that the responsibility for quality rests with the manufacturer of the part rather than "the quality department acting as a staff function i.e. here the responsibility is of the production department itself'. The workers are organized into teams (3 to 25 members per team) who themselves take the decision on solutions to quality problems.

Even if one item produced is of sub-standard & it is likely to effect the subsequent process, then the process shall be stopped immediately and the process and then restart the production. This helps in bettering quality and reducing rejections motivating workers as they feel proud of being a part of the decision process. This helps as an over-all achieving higher productivity, lowering was trinity and reducing cost of production per unit.

11.6 SUMMARY

The unit focuses on quality as a vehicle for delivering value, real or perceived, to the customer whose needs and expectations are changing over time. It imparts to dimensions to the concept by shifting from quality control to quality assurance. ISO 9000 series of standards provide a comprehensive guideline and industry recognized as a minimum level of acceptable quality. An increasing trend to adopt quality strategies like TQM and quality circle has also been highlighted in the chapter.

11.7 KEY WORDS

SIX Sigma: The Six Sigma method is a management philosophy as well as systematic methodology that uses the relevant data and subsequent statistical analysis to measure and improve operational performance, practices and systems in a company.

Quality assurance: Quality assurance refers to the assurance to customers that the products, parts, components, tools etc. contain specified characteristics and are fit for the intended use.

ISO-9000 Standards: ISO stands for International Organization for Standards. ISO-9000 is a series of international standards for quality systems. It is a practical standard for quality applicable both to the manufacturing and service industry.

Total Quality Management: TQM is a quality-focused customer-oriented integrative management method that emphasizes continuing and cumulative gains in quality, productivity and cost reduction.

Quality Circle: In manufacturing, the Japanese practice is that the responsibility for quality rests with the manufacturer of the part rather than "the quality department acting as a staff function i.e. here the responsibility is of the production department itself'. The workers are organized into teams (3 to 25 members per team) who themselves take the decision on solutions to quality problems.

11.8 SELF ASSESSMENT EXERCISE

1. What is quality assurance? How it is different from quality control?
2. Give a detailed note on ISO: 9000 Quality standards.

3. What is Total Quality Management (TQM). How it ensure zero defects in the production?

11.9 FURTHER READINGS AND SOURCES

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Course: MBA Course Code: CP-204

LESSON: 12

Industrial Safety and Safety Management

Structure

12.0 OBJECTIVES

After going through this lesson, you will be able to:

- **Understand the concept of industrial accidents and safety at work**
- **Analyse the cost of industrial accidents**
- **Methods and principles of accidents prevention**
- **Understand the meaning and concepts of safety management**
- **Analysis the various techniques to evaluate safety measures**

12.1 INTRODUCTION

It is responsibility of every management to ensure workers' safety while they are at work. Industrial safety and efficiency are directly correlated to a great extent. Safety measures not only result in reduction in industrial accidents but also hoist industrial productively. Industrial measures include precautionary steps to be taken by the management of an enterprise in order to prevent accidents and healthy work environment. Accident prevention should become an integral part of management policy for, "an accident prevented is a benefaction; an injury compensated, an apology".

What is an Accident?

An accident is an event which was unexpected or the cause of which was unforeseen. An accident is an occurrence that interrupts or interferes with the orderly progress of the activity in question.

Accidents have three main types of causes.

- Unsafe acts, about 88%
- Unsafe conditions, about 10% (preventable)
- Natural calamities, about 2%

Accidents are always caused. They do not happen.

12.2 INDUSTRIAL ACCIDENTS

An industrial accident is an unexpected occurrence in an industrial establishment causing bodily injury to one or more persons. Under the Factory Act, 1948, an industrial accident has been defined as "in an industrial establishment causing bodily injury to a person which makes him unfit to resume his duties in the next 48 hours"

When oil is spilt on the floor and a worker places his leg unknowingly over the spilt oil, it is likely that he may fall down due to the slipperiness and break his leg hand or head or any other part of body depending on the nature of fall. A fall of bolt and nut, a plate, a pipe bit or a tool from overhead on a person may cause injury to his head or body ranging from a mere scratch to a deep wound depending on the height of fall and weight of the object. Some persons carrying a pipeline may hit other person at some other job.

In the first circumstance, good housekeeping is the requirement to prevent accidents. In the second instance, good maintenance and safer manual handling are the needs to prevent the accident. In the third and fourth instances the need for proper manual handling is needed to prevent the accident.

The causes of industrial accidents may be any one of the following: Improper mechanical handling, electric systems without adequate protection, moving machinery without guarding, explosion, toxicity, corrosion, and radioactivity etc.

- The leakage of methyl isocyanate from giant storage vessels at union carbide factory, which caused death of thousand's of given proper consideration.
- At Nypro works, England, in 1974 , a massive amount of Cyclohexane vapors escaped and ignited giving rise to a major explosion and killed 28 men and injured 36 men at site and another 53 men off the site.
- Recently in Jaipur, there was an explosion of tanks of Indian oil depot – causing a lot of damage to the health, property, and wealth. The fog and smoke hit up to 40 km. range.

12.2.1 Classification of Accidents

Accident can be classified generally due to

1. *Failure of equipments or machines*

Equipments are usually designed for safe operations. At times due to continuous working or overworking, it may suddenly fail and cause an accident. Preventive and periodical maintenance of the equipment will avert this type of accident.

2. *Unsafe operation/ unsafe act/ unsafe conditions of machines.*

Operating a machine without authority, entering dangerous zones without authority, operating at more than rated speed, unsafe mixing, loading, working on moving equipments, and failure to use safety and protective devices.

3. *Employee behaviorist cause,*

   Improper attitude of the worker, deliberate disobedience of safety rules, lack of knowledge and skill, physical or mental defect.

4. *Environmental cause*

   Improper guarding, defective parts, improper illumination, improper ventilation, and unsafe housekeeping.

5. *Calamity due to natural causes.*

Floods, storms, earthquakes, lightning. and external military bomb operations.

6. *Due to fire -electrical failure.*

   Due to improper housekeeping, negligence, storing of unwanted materials, smoking, improper storage of fuels, sparks due to friction.

7. *Due to chemicals/explosive nature.*

   Chemicals are in general poisonous and corrosive, They cause extreme damage if safety precautions are not obeyed properly. They give rise to fumes and vapors which may cause fires and explosion on mixing with air or oxygen. Also they leak in pipelines and corrode entire equipments and areas causing deep wounds and slippage on coming into contact with them. So they require careful storage and handling.

12.3 COSTS OF ACCIDENTS

Accidents interrupt the flow of work and very costly, cots of accidents can be classified under to broad categories as:

(A) Costs involved in accident preventions.

(B) Costs resulting from an accident.

The ratio between the two is the good measure of the interest of top management taken in safety management- it varies from 1:4 to 1:10.

12.3.1 Costs Involved in Accident Preventions.

These include:

- Cost of direct staff employed in safety work.
- Cost of safety training of employees at all levels.
- Increased cost of plant and equipments owing to safer design.
- Cost of safety devices and equipments.
- Cost of insurance etc.

12.3.2 Costs resulting from an accident.

It can be divided into two types

(1). Direct costs

(2). Indirect costs.

Direct costs will involve compensation payment to the workers and medical expenses. Indirect costs involve lose happened due to the accidents. Usually it is found that indirect costs are nearly four times the direct costs.

The indirect costs can be

1. The cost of time lost by the injured employee.
2. Cost of time lost by other employees who stop their work out of curiosity, sympathy or to assist the injured employee.
3. Cost of time lost by supervisors, engineers and other executives during the time of assisting the injured employee or investigating the accident or arranging a new person for the job.
4. The cost of time spent by first aid attendants and hospital persons when the amount is not paid by the insurance.
5. Cost due to damage to machines, tools, equipments or other properties.
6. Incidental cost due to interference with production failure to fill orders in time and payment of forfeits.
7. Cost to employee under welfare and benefit systems.
8. Cost of employer to the injured employee, even after his return he may not be fully fit for particular time.
9. Cost due to the loss on idle machines.

12.4 SAFETY MANAGEMENT

Rapid industrialization has brought in many changes. Positive changes are on increase in gross domestic Products, overall improvement in quality of life etc. It has also brought in some negative effects such as the serious consequences due to industrial accidents. From factories to offices, construction sites to local authorities, health and safety is more than just a legal requirement. It is a good business sense. A safer, healthier workforce leads to higher morale and can lead to improved productivity and reduces risk.

The field of industrial health and safety has undergone significant change over the past two decades. There are many reasons for this. Some of the prominent include the following:

- Technological changes that have introduced new hazards in the work place.
- Proliferation of health and safety legislations.
- Increased pressure from assertive regulatory agencies.
- Realization by industrial executives that a safe and healthy work place is typically a more productive work place
- Skyrocketing health care and workers compensation costs
- Increased pressure from environmental groups and the public
- A growing interest in ethics and corporate responsibility
- Professionalisation of health and safety occupations
- Increased pressure from the labour organizations and employees in general
- Rapidly mounting costs associated with product safety and other types of litigation

All of these factors, when taken together, have made the safety management as more challenging and more important than it has ever been for the industries. Safety management in industry consists of the following key elements:

Visible management commitment to safety: The management of safety has been seen as an essential part of management's daily responsibilities, along with others such as quality, production, cost control, profitability and morale. Management can show commitment to safety by:

- Applying a high priority to safety in the planning and evaluation of all projects and operations.
- Taking a personal interest in accidents, their investigation and follow up and in the welfare of the people concerned.
- Staffing safety department with experienced and competent personnel.
- Setting a good example by adopting safety standards.
- Management participation in safety inspections and safety meetings
- Promoting safety in public, during company meetings and in publications
- Always including safety instructions when issuing day to day instructions

- Including safety as a priority item on the agenda at staff and management meetings
- Safety should feature prominently in business plans and performance re- ports
- It is management's responsibility to ensure that all employees are properly equipped and trained and to motivate them so that all employees want to work safely.

12.4.1 SAFETY POLICY

An effective safety policy will be concise, easily understood and available to every one. Each company has to develop its own policy to meet its own particular requirements and should be based on the following philosophy:

- Acceptance of the principle that all injuries can and should be prevented
- Management at all levels is responsible for preventing accidents
- Safety should have equal status along with other primary business objectives
- The need to provide properly engineered facilities and safe procedures
- All operational exposures which may result in injury should be safe guarded
- It is necessary to train all personnel to work safely

- A safe operation is usually an efficient operation

The policy should be distributed to all personnel as well as displayed on notice boards, and published in house journals.

12.4.2 SAFETY TO BE A LINE MANAGEMENT RESPONSIBILITY

In some companies the belief may still exist that the responsibility for safety lies mainly with the safety department, or the safety officer. This is quite wrong. The safety department has a vital role to play as a specialist adviser but it can be neither responsible, nor accountable for safety policy or performance. This responsibility lies with the line management from chief executive to every level of supervisor.

- All responsibilities and accountabilities for safety in the line must be clearly defined in job descriptions.
- The organization must encourage a two way flow of information and ideas. So that all personnel understand that their input is necessary.
- Each manager and supervisor must demonstrate personal commitment to the safety program by good example and by reacting promptly and effectively to:
    - Poor safety performance
    - Excellent safety performance.
    - Lack of standards of safety practices
    - Lack of adequate safety programme, plans and objectives

- Safety reports and their recommendations
- Unsafe working conditions and practices
- Inadequate training or instruction
- Accident and incident reports and the action needed to prevent recurrence.
- Ideas and suggestion for improving safety.

It follows that staff appraisal procedures should include, in a meaningful and incisive manner, consideration of each manager's and supervisor's safety attitudes and performance. All personnel should be involved in the safety effort and must be made aware of their role in the safety organization and what their own responsibilities are.

12.4.3 SAFETY OFFICERS

Too often, managers have left safety matters to the safety department. However, no safety department can in any way be responsible or accountable for what happens under someone else's management. Its role can only be to advise, coordinate and monitor. To do so effectively, it must contain adequate expertise and be freely available to management at all levels. It has to be kept sufficiently aware of the company's commercial and technical objectives to allow it to:

- Guide management on safety policy, audits and accidents reporting and investigation.
- Provide technical safety information and experience.

- Give guidance on, and participate in preparation of instructions, training and exercises.
- Coordinate the monitoring and appraisal of safety performance
- Guide management on contractor safety management

The credibility of safety staff is of extreme importance and is a key factor in the Safety Management Programme.

12.4.4 SAFETY STANDARDS

Safety can be separated into two components: firstly in design, equipment and procedures and secondly, people's attitude and their behaviour towards safety. Key factors in establishing these standards, which can be operating procedures, safety rules and regulations and standards of house keeping are:

- They should be written so that they can be easily understood.
- They must be accessible to all personnel
- Standards and procedures must be practicable and reasonable.
- Standards will be more acceptable to people
- Standards should be adequate to cover changing circumstances taking into account relevant safety experiences both of the company itself and of other companies.

The success of standards depends upon the extent to which people abide by them. If standards are breached without correction, the credibility of that standard is in doubt.

12.4.5 TECHNIQUES TO MEASURE SAFETY PERFORMANCE

The lost time accident (LTA) frequency rate is one measure of safety performance. The method is similar to that used by many other industries, and enables direct comparisons to be made. However, the relevance and usefulness of LTA frequency rate is reduced as the total number of LTAs becomes very small, or if the operation is small and the number of LTAs are close to or zero. In such situations it cannot be relied upon as an indicator of safety performance and a more sensitive tool is needed. Many companies already record non- LTAs and plan to move towards recording near misses and unsafe practices. This will indicate the relationship between the seriousness of the injury and the unsafe practices that caused the incident. By aiming our efforts at unsafe practices, one is working directly on preventing accidents ever happening. This is a powerful tool for every one to use, bearing in mind that the main purpose of any measurement technique is to improve performance by eliminating accidents.

12.4.6 SAFETY TARGETS AND OBJECTIVES

A steady annual reduction should be achievable proving the established policies are kept alive, and people remain committed to safety. The setting of targets that are seen to be both reasonable and achievable is essential. Typically a certain percentage annual reduction in frequency rate can be a target, while the long term objective is to achieve an accident free performance.

Management should develop plans to achieve the long term safety objectives. Each department should develop its own safety plans and targets with a written schedule. The details of these programmes can form a useful basis for discussion at safety meetings.

Targets should be quantified wherever possible and could include the following:

- Instructions, rules, procedures or documents to be written or received with a completion schedule.
- Frequency and number of safety committee meetings and other safety meetings
- Frequency and number of inspection and audits of the different types
- Frequency of contingency plan rehearsals involving company and external resources

Staff reports include safety related targets or tasks against which performance can be measured. Performance improvements should not be demanded without giving individuals the tools to do the job, such as training and proper equipment.

12.4.7 AUDITS OF SAFETY STANDARDS AND PRACTICES

Most companies already have safety inspection and audit programmes, usually concentrating on equipment and procedures, where supervisors, managers, representatives from the safety department and sometimes outsiders audit to a fixed schedule, often with months, if not years, between audits. Efforts should be made to increase the effectiveness of auditing by structuring the content, coverage and participation of each audit and by the adoption of procedures to monitor timely implementation of audit recommendations.

In addition, there should be auditing for unsafe acts and conditions. This can be undertaken whenever a manager or supervisor enters a work area. It involves looking at people, what they do, how they do it, what they wear; and at tools, equipment and the general work area. It is potentially a very powerful tool because correction of unsafe acts and conditions at frequent intervals will prevent accidents and recording them will be a sensitive yardstick of safety performance.

12.4.8 SAFETY TRAINING

A safety programme requires a concentrated effort to ensure staff is made fully aware of the programme and of the philosophy behind it. Achieving acceptance of the philosophy down the line is the biggest challenge for management and a major programme of presentations, work shops and discussions will be needed. Dissemination throughout the company can be achieved rapidly by these means, but informal discussion and briefing between the supervisor and subordinate is equally necessary. Consistency of approach is essential so that everybody gets the same message. Senior management should participate in these presentations thus demonstrating their commitment. The emphasis must be on changing people's attitudes to safety and demonstrating how personnel behaviour is the most important factor in preventing accidents. Existing technical training should of course be continued and specific safety aspects incorporate into the programme. Management should plan and monitor progress through the established training programmes for each individual thus ensuring the person is fully equipped to do his job.

12.4.9 INVESTIGATION AND FOLLOW UP OF INJURIES AND INCIDENTS

Incident investigation procedures are already well established in many companies but too often the main objective of the investigation, to prevent it happening again, is sacrificed in the search for the person responsible for the accident. Thus people become defensive and it becomes difficult to establish the facts. The responsibility for incident investigation lies with line management. One should be aware that the questions what caused the accident? And who is responsible, should not be confused. Even though it may be established as a matter of fact that a certain accident was directly caused by an individual, it is often too easy to simply put the blame on the individual concerned. The matter should rather be viewed in the context of the wider sphere of management's own responsibilities. For instance, the individual concerned may have been inadequately placed, instructed, supervised or trained; he may have been unfamiliar with the procedures, or the procedures may have been unsuited to the job in hand.

There are a number of guidelines for accident investigation:

- Investigate promptly
- Involve those who have a real knowledge of the work situation
- Collect and record facts, including organizational relationship, similar occurrences and other relevant background information.
- Have as the objective 'to prevent a similar incident happening again
- Identify all causes
- Recommend corrective actions

All recommendations should be followed up and any lessons learned should be communicated as widely as possible.

12.4.10 MOTIVATION AND COMMUNICATION

The success of a safety programme depends on people - how they are motivated and how they communicate with each other. One of the major keys to success lies in establishing communication with people at all levels. Methods may include written circulars, reports, news sheets, promotional activities, incentive and / or reward schemes, personal contact and, most successful of all, structured safety meetings at the work place level where every one can become involved . Safety meetings will be more productive and motivating if a member of a group under the guidance of management is asked to lead the meeting, having first been given the framework of the subjects for discussion and what the discussion hopes to achieve. Where contractors are part of the work group they should also be included. Conclusions and concerns should be written down and acted upon. The active participation of all staff in safety meetings should be regarded as a long term objective. The main objectives of safety meetings are to:

- Seek ways to eliminate unsafe practices
- Convey safety information to all employees
- Obtain contributions from employees
- Get participation in and commitment to the safety programme
- Encourage communication and debate
- Resolve any concerns or problems that emerge.

Feedback should be given as soon as possible so that open action items do not accumulate. In addition to structured safety meetings, supervisors, when considering forthcoming jobs with their subordinates, need to discuss all the relevant safety aspects by means of a toolbox talk or pre job meeting.

A major management objective at both safety committees and safety meetings should be to find out how people at all levels perceive the safety effort and whether safety information and messages are understood in the way they are meant. Feed back must be encouraged if people are to remain motivated. What is a Safety and

Health Management Program and where does it fit into management system?

Management leadership and employee involvement are complementary. Management leadership provides the motivating force and the resources for organizing and controlling activities within the organization. In an effective program, management regards worker safety and health as a fundamental value. Employer involvement provides the means through which workers express their own commitment to safety and health, for themselves and their fellow workers.

If one wants to reduce incidents and their related costs, everyone must place as much emphasis on safety and health issues as they place on other core management issues, such as production, sales, and quality control. To be most effective, safety and health must be balanced with, and incorporated into, the other core business processes. There is a certain amount safety ″culture″ and components of an effective safety and health program that must exist to accomplish this task.

″Safety is # 1″, or ″Safety First″ may sound good, but in reality, safety can not be considered separately from other aspects of the business. Rather, it must become a basic value and not a priority for your company. One should consider changing "Safety is #1″ and " Safety First″ to "Safe production is our only standard.″ Or something similar. The point is that we are trying to create a safety culture that will be valued by all employees. This emphasizes the idea that it's fine to produce as hard and as fast as possible, which in most instances is the case, as long as it can be done safely without taking short cuts.

To get an idea of where safety and health system fits into the workplace, answer the questions below:

Safety and health are an integral part of our operations. Yes, No, Don't know

Teamwork is apparent in all parts of the organization. Yes, No, Don't know

Managers and supervisors are out on the floor frequently and always observe the company safety and health rules. Yes, No, Don't know

Employees are encouraged to identify safety and health hazards and correct them on their own. Yes, No, Don't know

Employees have full and open access to all the tools and equipment they need to do their job safely. Yes, No, Don't know

If you were able to answer YES to each question, you may be on your way to developing a safety. If you answered any question with No or Don't know, you need research and understand the opportunity for improvements in your safety management system.

12.5 SUMMARY

It is responsibility of every management to ensure workers' safety while they are at work. Industrial safety and efficiency are directly correlated to a great extent. Safety measures not only result in reduction in industrial accidents but also hoist industrial productivity. An accident is an event which was unexpected or the cause of which was unforeseen. An accident is an occurrence that interrupts or interferes with the orderly progress of the activity in question. Accidents interrupt the flow of work and very costly.

The management of safety has been seen as an essential part of management's daily responsibilities, along with others such as quality, production, cost control, profitability and morale. An effective safety policy will be concise, easily understood and available to every one. Each company has to develop its own policy to meet its own particular requirements. A steady annual reduction should be achievable proving the established policies are kept alive, and people remain committed to safety. The setting of targets that are seen to be both reasonable and achievable is essential. The success of a safety programme depends on people - how they are motivated and how they communicate with each other. One of the major keys to success lies in establishing communication with people at all levels.

Safety is # 1", or "Safety First" may sound good, but in reality, safety can not be considered separately from other aspects of the business. Rather, it must become a basic value and not a priority for your company. One should consider changing "Safety is #1" and "Safety First" to" Safe production is our only standard".

12.6 KEY WORDS

Accident: An accident is an event which was unexpected or the cause of which was unforeseen. An accident is an occurrence that interrupts or interferes with the orderly progress of the activity in question.

Industrial Accident: An industrial accident is an unexpected occurrence in an industrial establishment causing bodily injury to one or more persons. Under the Factory Act, 1948, an industrial accident has been defined as "in an industrial establishment causing bodily injury to a person which makes him unfit to resume his duties in the next 48 hours"

12.7 SELF ASSESSMENT EXERCISE

1. Elaborate the meaning and type of Industrial accidents
2. "Prevention is better than cure". Explain the statement in light of Cost of Accidents.
3. Write a detailed note on safety management and safety policy.

12.8 FURTHER READINGS AND SOURCES

- Management Systems for Safety, Jeremy Stranks, 1994, Pitman Publishing
- Industrial Safety and Health Management, C. Ray Asfahl, Third Edition, 1995, Prentice Hall
- Safety Engineering, James CoVan, 1995, John Wiley & Sons, Inc.
- Safety Auditing - A Management Tool, Donald W. Kase/Kay J. Wiese, 1990, Van Nostrand Reinhold
- Safety Management Systems, Alan Waring, 1996, Chapman & Hall
- Analyzing Safety System Effectiveness, Dan Petersen, Third Edition, 1996, Van Nostrand Reinhold