PONDICHERRY UNIVERSITY

DIRECTORATE OF DISTANCE EDUCATION

Production and Operations Management

MBA – OPERATIONS & SUPPLY CHAIN MANAGEMENT

SEMESTER III

MBSC3001

Production and Operations Management

MBA – OPERATIONS & SUPPLY CHAIN MANAGEMENT

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Introduction

Production and operations management has lately been generating a lot of interest and has emerged as an exciting area of study. This is mainly because of rapid developments in the fields of computer science and Information Technology (IT), and continuous improvements in the area of production and operations management in organisations. Production and operations management deals with the production of products and services using various resources, which include men, materials, and machines. In recent years, the scope of production and operation management has broadened. Earlier, it was confined to the manufacturing of products and determining the methods of performing activities in production plant effectively. Now, it encompasses a number of activities, such as production planning, scheduling, product designing and development, inventory management, quality management, and capacity management.

Production and operations management applies basic concepts, principles, and practices of management to those areas of an organisation that are linked with the production of goods and services. Thus, production and operations management plays a key role in the growth of an organisation. Efficient management of production and operations in an organisation generates revenue and profit as the organisation is able to sell high-quality products and services at low cost to customers. An organisation's growth depends on how well its products and services are selling in the market. Therefore, to survive and thrive in the competitive business environment, an organisation has to manage all the activities related to production and operations effectively.

The book Production and Operations Management helps students understand different aspects of production and operations management. They are made aware of the concept of product, service, process design, plant location, facility layout, and capacity management. The book also discusses the significance of production planning and control in operations management. Moreover, it describes aggregate planning and its different methods and techniques. Students are also made familiar with the concept of total quality management and quality control. Towards the end, the book discusses the different ways of enhancing the productivity of a plant with various productivity improvement techniques, maintenance management, and the just-in-time system.

Syllabus

MBA (Operations & Supply Chain Management) – III Semester

PAPER - XI

PRODUCTION AND OPERATIONS MANAGEMENT

Paper Code: MBSC3001

Objectives

- To understand the concepts and principles of Production and Operations
- To appreciate the importance of quality in Production Management
- To apply the productivity improvement techniques

UNIT I

Transformation process model: Inputs, Process and outputs; Classification of operations; Responsibilities of Operations Manager; New Product Development, Selection and Design of Product / Services.

UNIT II

Process types in manufacturing: Project, jobbing, batch, line, mass, continuous; Process types in services: professional services, services shops, mass services; Plant location; Layout planning.

UNIT III

Production Planning & Control: Production planning techniques for various process choices, Techniques of production control, Aggregate planning techniques,

UNIT IV

Quality management: Introduction; Meaning; Quality characteristics of goods and services; Tools and techniques for quality improvement: check sheet, histogram, scatter diagram, cause and effect diagram, Pareto chart, process diagram, statistical process control chart; Quality assurance; Total quality management (TQM) model; Service quality, concept of Six Sigma and its application.

UNIT V

Productivity Improvement Techniques: Work study; Method study; Work measurement: time study: stop watch time study; Work sampling. Maintenance: maintenance policies for facilities and equipment; Time of failure; Preventive versus breakdown maintenance; Procedure for maintenance, total productive maintenance (TPM)

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UNIT-I: Introduction to Production and Operations Management

UNIT-II: Process Design and Plant Location and Layout Decisions

CHAPTER

1 Production and Operations Management

Structure

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Learning Objectives

After studying this chapter, you will be able to:

- explain the basic principle behind ITO model
- explain the concept of production and operations management
- list the various types of operations involved in POM
- describe the roles and responsibilities of production and operations manager
- explain the recent trends in production and operations management

1.1 Introduction

Have you ever thought how a chair is obtained from a piece of wood? Wood is transformed into a chair by using some tools and human efforts. This conversion process of wood from raw materials into chair as finished goods is known as production. Sometimes, the raw material or input used in production process is intangible, for instance, ideas, knowledge, skills and information. These intangible inputs are known as services, which are taken by the customer. For example, banks help customers to make them financially stable. Services are of various kinds. These may include accounting, consultancy, training, insurance, transportation and so on.

Production involves conversion of raw materials into goods and services, while operations include all the activities that are required to produce and deliver a product or a service, as studied in the course OM0010, Operations Management.

Production and Operations Management (POM) helps an organisation to produce in the right quantity, at the right time and cost; thereby, fulfilling the needs of customers and increasing organisational efficiency and effectiveness. POM encompasses a number of activities such as the selection of location for an organisation's facilities, plant layout and material handling, product design, production planning and control, quality control and materials management.

In this chapter, you will study about the significance of Input-Transformation-Output (ITO) model. The chapter also explains the concept and evolution of POM. The chapter will familiarise you with the elements, objectives, scope, and advantages of POM. Further, you will also study about the various types of operations involved in POM. After this, you will study about the roles and responsibilities of POM. Towards the end of the chapter, you will study about the recent trends in POM.

1.2 Transformation Process Model: Inputs, Process and Outputs

Operations management as part of production and services transforms inputs into outputs. In other words, operations can be referred to the processes that use a set of input resources (labour, capital, equipment, land, buildings, materials and information) to convert it into outputs (products and services). This process is basically known as Input-Transformation-Output (ITO) process.

The transformation process can either be a very simple; one similar to making furniture from wood, or very complex one such as changing a customer's dissatisfaction over poor service to delight by resolving the complaint with courtesy.

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Fig. 1.1 shows the basic ITO model for manufacturing and services:

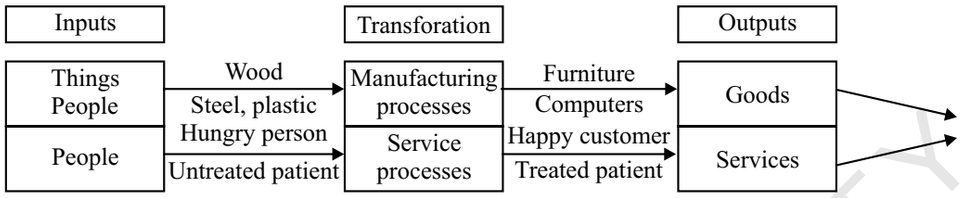

Fig. 1.1: Basic ITO Model for Manufacturing and Services

Transformation processes include modification in the:

- Materials' or clients' physical properties
- Materials, information, or clients' locations
- Physical or digital possession of data or items
- Facilities for storing or accommodating goods, data, or clients
- Objective or data format
- Mental and physiological health of consumers

In any transformation process, inputs can be both, things and people. The two major categories of inputs are:

- **Transformed resources:** These are the resources that are transformed in the production process. Three major types of transformed resources are:
  - **Materials:** It includes transforming the resources either physically (for example, through manufacturing), by location (for example, through transportation), by ownership (for example, from wholesaler to retailer), or by storage (for example warehousing).
  - **Information:** Location, possession (as in market research), storage (as in libraries), or property (as in accountants) can all play a role in this transformation (for example, telecommunications).
  - **Customers:** They can undergo physical changes (at salons, for instance), storage changes (in hotels, for instance), geographical changes (on buses, for instance), physiological changes (in hospitals, for instance), or mental changes (for example by entertainment).
- **Transforming resources:** These resources help in carrying out the transformation process. The two major types of transforming resources are:
  - **Facilities:** It includes buildings, equipment, and plants involved in the operations process.
  - **Staff:** It includes all the human resource involved in the operations process.

An output of one ITO model often becomes input to another ITO model. In a general operations system, there are several ITO models linked together. As inputs are often the output from another part of the system, they can also be both, tangible and intangible. For example, iron ore is an output from a mining operation, but an input for producing steel.

Notes

Self-Assessment Questions

1. Define the term operations.
2. Transformation processes does not include modification in the:
   a. Mental characteristics of customers
   b. Location of materials, information or customers
   c. Ownership of materials or information
   d. Storage or accommodation of materials, information or customers
3. In any transformation process, inputs can be both, things and people. (True/False)
4. _____resources help in carrying out the transformation process.

1.3 Concept of Production and Operations Management

POM is a process that is associated with the conversion of available inputs into the desired output. In other words, POM is a process that integrates and transforms resources used in an organisation into value-added products or services with the requisite quality level. For example, a hospital uses doctors, nurses, medical equipment, and diagnosis and surgical procedures as inputs to produce the desired health care for people as an output. For a better understanding, let us discuss the concept of production and operations management separately.

Production management comprises a set of interconnected management activities that are involved in the manufacturing of products. When this set of interconnected management activities are involved in the delivery of a product or service, it is called operations management. Table 1.1 differentiates between production management and operations management:

Table 1.1: Difference between Production Management and Operations Management

Production Management	Operations Management
Production management involves a system in which inputs are transformed into tangible goods. The term production management is used in manufacturing organisations, such as textile factories, motor manufacturing organisations, household appliance manufacturing organisations etc.	Operations management involves a system in which inputs are transformed into intangible goods. The term operations management is used in service organisations such as banks, airlines, educational institutions, and police stations.
Production management focuses on the efficient utilisation of inputs to achieve the desired output.	Operations management is all about planning and executing activities for the production of services.

Today, POM has in a way expanded to more than one interconnected activity. Now, production management comprises a number of interrelated services. For instance, an automobile organisation uses motor parts, men, and capital as inputs to produce vehicles. The production of vehicles involves a number of services, such as welding, assembling, cutting, and finishing. Apart from these activities, the organisation needs to promote its vehicles through marketing activities also. Therefore, instead of using the two terms production management and

operations management separately, nowadays, a consolidated term production and operations management is being used. The main objective of POM is to ensure whether the products/ services are produced with the desired quality and are delivered to customers on time.

1.3.1 Evolution of production and operations management

For over two centuries, POM has been recognised as a crucial factor for the economic growth of a nation. The importance of production management was first recognised in the 18th century by Adam Smith, the father of economics. At that time, production management was known as manufacturing management. Adam Smith drew attention to the concept of division of labour wherein the production process is broken into a sequence of tasks and each task is assigned to specific labour. The application of this concept led to a significant increase in the skills and efficiency of labour. In the early 20th century, F. W. Taylor implemented the theories and concepts given by Adam Smith. Till 1930, a number of techniques were developed pertaining to manufacturing management. Table 1.2 shows contributions to the field of manufacturing management from time to time:

Table 1.2: Techniques and Other Contribution Management

Date (Approx.)	Contribution	Contributor
1776	Specialisation of labour in manufacturing	Adam Smith
1799	Interchangeable parts, cost accounting	Eli Whitney
1832	Division of labour by skill; assignment of jobs by skill; basics of time study	Charles Babbage
19 00	Scientific management; time study and work study developed; dividing planning and doing of work	Frederick W. Taylor
1900	Motion study of jobs	Frank B. Gilbreth
1901	Scheduling Techniques for employees, machines, and jobs in manufacturing	Henry L. Gantt
1915	Economic lot sizes for inventory control	F. W. Harris
1927	Human relation; the Hawthorne studies	Elton Mayo
1931	Statistical inference applied to quality control charts	Walter A. Shewhart
1935	Statistical sampling applied to quality control; inspection sampling plans	H. G. Roming
1940	Operation research applications in World War II	P. M. S. Blacket
1946	Digital computer	John Mauchly and J. P. Eckert
1947	Linear programming	Gorge B. Dantzig, William Orchard-Hays, and others
1950	Mathematical programming, non-linear and stochastic processes	A. Charnes, W. W. Cooper, H. Raiffa, and others

Notes

Table 1.2: Techniques and Other Contribution Management		
Date (Approx.)	**Contribution**	**Contributor**
1951	Commercial digital computer; large-scale computations available	Sperry Univac
1960	Organisational behaviour; continued study of people at work	L. Porter
1970	Integrating operations into overall strategy and policy	W. Skinner
1970	Computer applications to manufacturing, scheduling, control, and material requirement planning	J. Orlicky and O. Wright
1980	Quality and productivity applications from Japan; robotics, computer-aided design, and manufacturing	W. E. Deming and J. Juran

(**Source:** *Production and Operations Management by S. Anil Kumar by New Age International Publishers)*

Production management became an acceptable term in the 1930s when F. W. Taylor performed a research on workers to prevent wasteful efforts and achieve greater efficiency in manufacturing. At the same time, several psychologists and scientists started studying human behaviour in a work environment. In the 1970s, the service sector became more prominent; thus, a new term was introduced called production and operations management.

1.3.2 Elements of production and operations management

The conversion of inputs into output comprises three main elements, which are shown in Fig. 1.3:

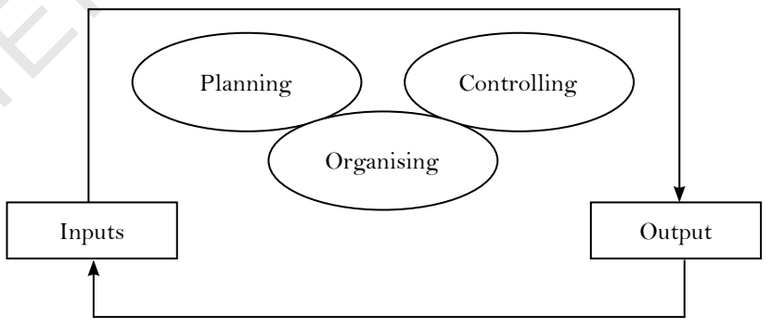

Fig. 1.3: Elements of POM

- **Planning:** This involves determining the goals and objectives that an organisation aspires to achieve within a given time period. Planning also involves developing alternatives and selecting the best course of action among the available alternatives to accomplish the set objectives. Moreover, it is concerned with the optimal use of available resources.
- **Organising:** This involves arranging work processes, authority, and resources in such a manner, so that all production activities can be performed in a defined and sequenced manner.

- **Controlling:** This involves establishing performance standards, measuring the actual performance, determining gaps between desired and actual performance, and taking corrective measures.

1.3.3 Objectives of production and operations management

The main objective of POM is to produce goods and services in the right quantity at the right time and at the right cost. The following are the some of the important objectives of POM:

- **Producing high quality output in the right quantity at the right time and cost:** This objective refers to one of the most important objective of producing the output at the right time. It is the important parameter to judge the effectiveness of an organisation. Similarly, producing the output in right quantity and at minimised cost leads to an increase in the profitability of an organisation.
- **Providing excellent customer service:** This objective refers is about how organisations should strive to produce a product that satisfies the needs of customers in terms of the quality, cost, and timely delivery of the product. This helps an organisation to achieve a high level of customer satisfaction.
- **Making an efficient use of available resources**: This objective implies that POM helps an organisation to make efficient utilisation of resources by preventing the wastage of resources and allocating them appropriately.

1.3.4 Scope of production and operations management

In modern times, the scope of POM is indeed vast from what it was in the past. Nowadays, POM encompasses a number of activities, such as selection of location, acquisition of land, installation of machinery, procurement of raw material, and conversion of raw material into finished goods. Apart from this, it also covers activities, such as quality management, production planning and control, and work simplification. POM also aims to satisfy the customers while meeting the organisational objectives of effectiveness, efficiency and adoptability. Fig. 1.4 shows the scope of POM:

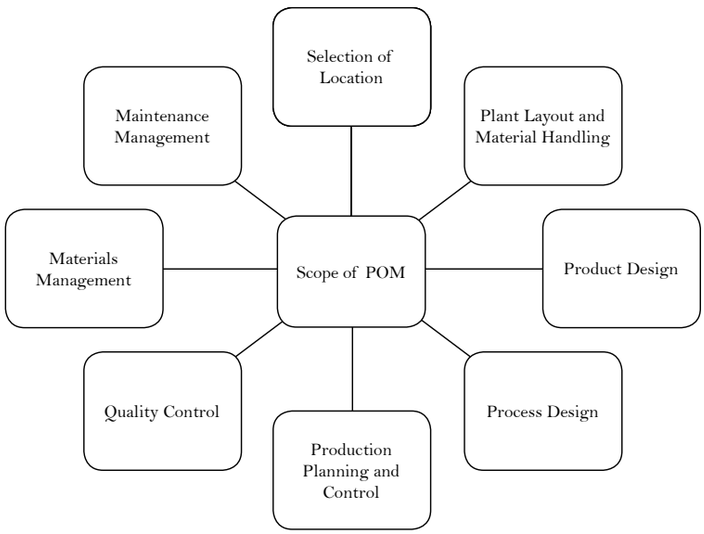

Fig. 1.4: Scope of POM

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- **Selection of Location:** It refers to a geographic factor that affects the overall profitability of an organisation to a large extent. The acquisition of location requires a large investment of an organisation. Therefore, an organisation needs to be careful while selecting a location for its facilities as any wrong decision may incur a heavy loss for the organisation. While selecting a location for its manufacturing plant, warehouses, and stores, an organisation needs to take into account various factors, such as proximity to market and raw material, availability of labour, and transportation costs. Moreover, an organisation should make decisions related to the selection of location based on its future expansion and diversification plans.
- **Plant Layout and Material Handling:** This relates to the production activities of an organisation. Plant layout is associated with the arrangement of facilities such as departments, work centres and equipment in such a manner the desired output can be produced in an economical manner. According to James Moore, *"Plant layout is a plan of an optimum arrangement of facilities including personnel, operating equipment, storage space, material handling equipment and all other supporting services along with the design of best structure to contain all these facilities."* On the other hand, material handling is all about the movement and storage of materials at minimum cost by using proper methods and equipment. It helps in increasing the output, improving product quality and decreasing the cost of production of an organisation. Thus, plant layout and material handling are the prime activities for a successful production process.
- **Product Design:** This activity plays a significant role in increasing the sales of an organisation. To survive in today's competitive market scenario, every organisation strives to design innovative products and introduce them in the market as early as possible. An effective design differentiates a product of an organisation from that of its competitors. Product design includes decisions related to the shape, size, colour, appearance and quality of a product.
- **Process Design:** This activity involves the decisions related to the selection of a process and technology for manufacturing products. Process design also involves analysing the workflow and identifying the implementation requirements for a particular process. To identify such requirements, a number of tools are used such as flowcharts, process simulation software, and scale models.
- **Production Planning and Control:** This refers to one of the most important aspects of POM. After taking decisions pertaining to product and process design, the next step is to plan and control production activities. Production planning involves determining necessary jobs and creating work orders required to be performed to manufacture products. It also involves determining the duration for manufacturing products and following up the progress of products. The following are some of the major activities involved in production planning and control:
- **Planning:** This involves the decision of what to produce, how much to produce, when to produce, and how to produce. Planning also involves scheduling production activities in advance.
- **Routing:** This refers to the selection of a route by which raw materials are passed for processing. Routing determines the most profitable path to be followed till raw materials are processed into final products.

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- **Scheduling:** It involves deciding the date and time for each production activity.
- **Dispatching:** This involves the movement of raw materials from one location to other, (from stores to manufacturing plants) to carry out production operations. It also involves giving necessary authority for starting a particular work that is planned under routing and scheduling activities.
- **Quality Control:** It refers to a system that is used for maintaining a desired level of product quality. Quality control involves the prevention of defects, effective feedback system and corrective action procedures. The following are the objectives of quality control:
  - Achieving a high level of customer satisfaction by providing high quality products at nominal prices
  - Reducing the total cost by minimising defects
  - Building brand image and goodwill of the organisation
- **Materials Management:** It involves the acquisition, control, and efficient use of materials required for manufacturing products. The main objectives of materials management are as follows:
  - Minimising material cost through standardisation, value analysis, and import substitution
  - Purchasing, transporting and storing materials efficiently
  - Developing cordial relations with suppliers to ensure continuous supply of raw materials
- **Maintenance Management:** It involves maintaining plant and machinery to carry out day-to-day operations smoothly. The following are the main objectives of maintenance management:
- Keeping the plant and machinery in good working condition at the lowest possible cost
- Ensuring the availability of machines whenever required

1.3.5 Advantages of production and operations management

As discussed in the previous section, POM is helpful for an organisation in many ways. The following are some of the main advantages of POM:

- **Competitive Advantage:** It refers to one of the main advantages of POM. Nowadays, organisations are using various advanced methods to increase the efficiency of their production process. Some of these techniques are Total Quality Management (TQM), Business Process Re-engineering (BPR), Flexible Manufacturing Systems (FMS), Computer Integrated Manufacturing (CIM), and Customer Relationship Management (CRM).
- **Service Orientation:** This refers to a major advantage of POM. Nowadays, organisations not only focus on manufacturing quality products, but also on providing excellent customer service, such as after sales service, timely delivery, and credit facilities.

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- **Environment Friendliness:** It implies that POM abides by various environmental laws. The enactment of these laws has resulted in the disappearance of industrial units that have an adverse effect on environment.

Self-Assessment Questions

5. Manufacturing is a part and parcel of _____ management.

a. Operations

b. Finance

c. Production and operations

d. Quality control

6. _____ is defined as a system that is used to maintain a desired level of precision/standards in a given product or service.

7. _____ involves the design of an overall process route for converting the raw material into finished goods.

a. Process design

b. Product design

c. Planning

d. Dispatching

8. _____ is the task of determining the activities required to achieve targets and maintain a line of authority and responsibility.

9. _____ management focusses upon administration, planning, and execution of activities involved in production of goods and services.

Activity

Suppose you are the production and operations manager of an organisation. There are some issues related to poor quality of the product, such as delivery of defective products, expiry dated products, etc. Which are the areas of POM that should be evaluated in order to overcome this problem? Also discuss how the production manager can solve this problem.

1.4 Classification of Operations

Operations management starts with high-level business plans and strategies, made for both short term and long term. These plans and strategies are based on strong demand forecasting for products or services. Operating plans are then translated into schedules that form the production and purchasing plans. While executing the production and purchasing plans, the production planning and material control department works together with the manufacturing department. On the basis of various kinds of processes, operations management can be divided into five broad categories as shown in Fig. 1.5:

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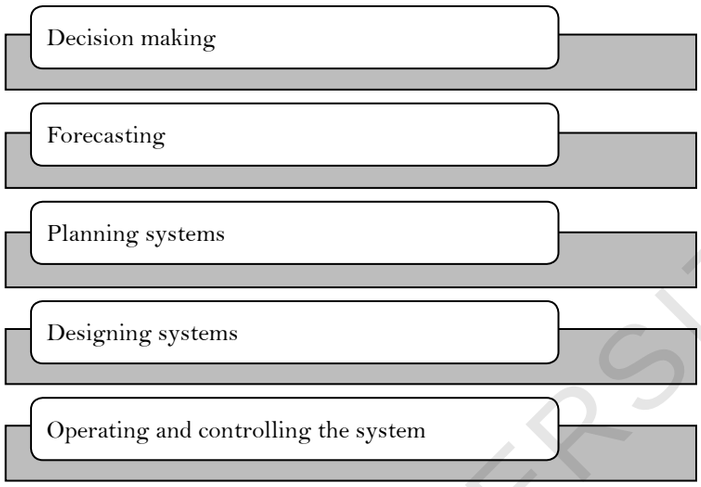

Fig. 1.5: Classification of Operations Management

- **Decision making:** Operations managers are decision makers. They need to make various decisions while making choices among available alternatives. Making accurate decisions is very important as it may affect the entire organisation. An operations manager may require to make the following decisions:
  - **What:** It is one of the most important decisions that an operations manager needs to make while deciding on what resources will be needed to accomplish an operation, and in what amount.
  - **When:** An operations manager is also required to make decisions on when will each resource be needed, when should the work be scheduled, when should materials and other supplies be ordered, and when is corrective action needed.
  - **Where:** An operations manager is also required to make decisions regarding where will the work be done.
  - **How:** These decisions are related with how will the product or service be designed, how will the work be done, how will resources be allocated, etc.
  - **Who:** An operations manager is also required to make decisions regarding who will do the work.
- **Forecasting:** In general, forecasting can be defined as a process of predicting the events or conditions that may take place in an organisation. It involves estimating the future events by evaluating the past information. These events can be pertaining to the demand and sales of a product, production capacity, materials required and number of employees. Apart from this, forecasting in an organisation enables to plan its operations. Forecasting also enables managers to answer the following questions:
  - How much profit will the organisation earn?
  - What will be the demand for the organisation's product or service?
  - What will be the total cost of the organisation to produce products or deliver services?
  - What will be the total amount of funds that need to be raised by the organisation?

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- **Planning and scheduling system:** The planning and scheduling system involves processes of making a detailed plan of the day-to-day production operations in an organisation. This plan clearly mentions the time allocated to each operation to complete the production process on time. Moreover, this plan provides the information related to resources to be used for completing the production operations. An effective planning and scheduling system helps an organisation to answer the following questions:
  - What type of work centre should be allotted for each job?
  - What should be the duration for completing an operation?
  - What should be the amount of resources to be employed for production?
  - What should be the sequence for performing the different jobs?
- **Designing systems:** It consists of product designing, facilities layout, and designing of work systems. All the products have their own designated functions and their characteristics primarily depend on these designated functions. Every product is created with an aim to perform its designated function efficiently in order to satisfy the needs of the customers. Therefore, product designing is a critical process for an organisation, as the success or failure of the product directly affects the organisation's business, market share and reputation. In addition, production efficiency is very much dependent on the plant layout. The machinery, equipment, and other facilities should be located appropriately in a plant to ensure the smooth and rapid movement of materials throughout all the production processes. Hence, we can say that a facility should be properly laid out. Designing of work systems is also an important component in operations management. It helps in explaining the significance of work design and how jobs are performed.
- **Operating and controlling the system:** Accurate execution and control are the key ingredients for the success of any organisation. It is a tool that helps an organisation to achieve its pre-determined objectives. The main objective of operating and controlling the system is to ensure the availability of the right quantity and quality of inputs for the processes. In addition, it involves identifying deviation between the actual production and planned production and taking corrective actions for the same. An effective system ensures the optimum utilisation of production capacity. Moreover, it helps an organisation in maintaining an adequate level of inventory as well as a balanced and uninterrupted production flow. This further helps in conforming to delivery commitments and making adjustments in production as per the changes in demand. The various activities that help in accurate operating and controlling of system, involve inventory management, material requirement planning, Just-in-Time (JIT), operational scheduling, quality assurance, etc.

Self-Assessment Questions

10. _____ can be defined as a process of predicting the events or conditions that may take place in an organisation.

11. Define planning and scheduling system as a part of operations management.

12. What are the major elements of designing system?

13. _____helps in explaining the significance of work design and how jobs are performed.

NOTES

1.5 Role and Responsibilities of an Operations Manager

In an organisation, the production and operations manager is responsible for planning, organising, directing, and controlling the activities that are involved in converting inputs into the desired output. He/she also needs to procure resources at minimum cost and make the best utilisation of these resources. Moreover, he/she is responsible for producing the right products at the right time. Apart from this, the following are some of the main responsibilities of a production and operations manager:

- Producing products and services as per the desired specifications
- Acquiring raw material at minimum prices
- Selecting the best location for facilities, such as factories, warehouses, and stores
- Purchasing the efficient equipment of production
- Establishing work standards
- Selecting an efficient production technique
- Planning capacities of plant and machinery
- Planning and controlling production activities
- Managing and controlling inventory
- Measuring and monitoring productivity
- Maintaining industrial relations
- Ensuring the health and safety of employees
- Planning budget and other financial resources
- Participating in strategic decision making
- Automating production processes
- Enhancing research and development efforts
- Ensuring the timely delivery of products and services
- Abiding by environmental rules and regulations
- Maintaining long-term relationship with suppliers and various other third parties

Apart from this, a production and operations manager is responsible for making various decisions. Fig. 1.6 shows the decisions made by a production and operations manager:

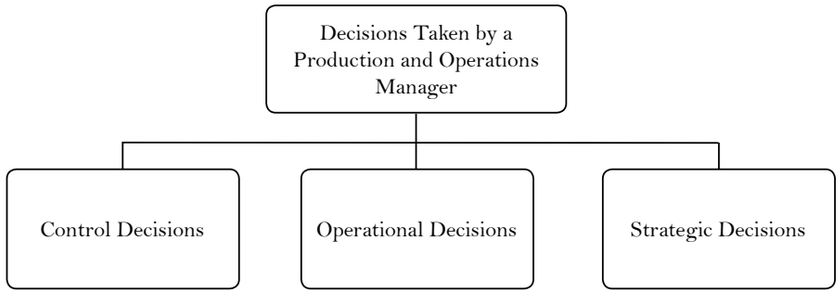

Fig. 1.6: POM Decisions

Notes

- **Strategic Decisions**: These involve decisions related to production planning, technology, facility layout, and allocation of resources. These decisions also include:
  - Developing long-term production plans
  - Selecting and maintaining production facilities
  - Making an optimal allocation of resources
- **Operational Decisions**: These involve decisions related to demand inventory systems, materials management, and shop floor planning. Moreover, operational decisions also include:
  - Scheduling production activities
  - Planning and controlling the inventory of finished goods
  - Deciding what to produce and when to produce
  - Planning the requirements of materials
  - Deciding the capacity requirements
- **Control Decisions**: Involve decisions related to total quality control, project planning, and maintenance management. These decisions also include:
  - Controlling the quality of products and services
  - Maintaining machines and plants
  - Planning and controlling projects

Self-Assessment Questions

14. In an organisation, what is the production and operations manager responsible for?

i. Planning of activities
ii. Organising of activities
iii. Revising of activities
iv. Directing of activities

a. i,ii,iii
b. i,ii,iv
c. ii,iii,iv
d. all of the above

15. The production and operations manager should acquire raw material at minimum prices. (True/False)

16. Strategic decisions involve decisions related to production planning, technology, facility layout and _____.

17. Decisions related to maintenance of machines and plants come under _____.

18. Developing long-term production plans falls under the category of operational decisions. (True/False)

19. List any three responsibilities of production and operations managers.

Notes

Activity

Give an example in which the production and operations manager is responsible for planning the activities that are involved in converting the inputs into outputs.

1.6 Recent Trends in Production and Operations Management

As discussed earlier, POM is all about producing goods and services as per the needs and expectations of customers. With the recent developments in the business environment and technologies, there are a number of new trends that have emerged in the field of POM. The following are some of the recent trends in POM:

- **Globalisation:** It involves the integration of different economies, societies, and cultures through cross-border communication and trades. The reduction in trade barriers and ever increasing competition has encouraged organisations to enter into global business. Globalisation has provided organisations with enormous opportunities of growth and expansion in the international market. To survive in the global market, an organisation needs to design innovative products and use efficient production techniques.
- **Total Quality Management (TQM):** It aims at minimising errors occurred at the time of producing goods and providing services. The concept of TQM focuses on the strengths, systems, work culture, policies, and the cost effectiveness of an organisation so as to deliver quality products and services to customers. Moreover, it is concerned with the active participation of employees in continuous improvement in the quality of products and services.
- **Agile Manufacturing:** It refers to an approach to manufacturing that is concerned with fulfilling the needs of customers while maintaining the high standards of quality and controlling the overall costs involved in manufacturing of a particular product.
- **Customer Relationship Management (CRM):** It is a method for running a company that helps them meet the demands of their clients by giving them what they want—great goods and services. Customer relationship management (CRM) also seeks to enhance customer service and attain a high degree of client satisfaction, leading to a notable uptick in customer loyalty and retention. It includes a plethora of technologies that simplify communication with clients, which aids in discovering, acquiring, and keeping customers.
- **Just-In-Time (JIT) production:** Earlier, mass production methods were used to manufacture products. In this method, products were produced in batches and these products were sold at mass scale so that economies of scale could be obtained. However, nowadays the JIT method is used for production processes. JIT means ordering and receiving inventory for sales and production purposes, only when it is needed and not before. The JIT approach helps an organisation in reducing its ordering and carrying costs.
- **Supply Chain Management (SCM):** Earlier, organisations chose a supplier based on of bids provided by them for a particular order. The lowest one was chosen. Organisations did not focus much on suppliers. However, nowadays the supplier is considered one of the major entities in the supply chain. Thus, focus has been shifted to SCM with an increased focus on quality and quantity. Supply chain involves everything starting from production to product development and also the information system required to direct these activities.

Notes

- **Product development:** Earlier, product life cycle was long. After the launch of a product in the market, it continued to be long. However, now, due to use of advanced technology, product life cycle has become shorter. It has resulted in quick replacement of the older product. Product development generally involves formation of products with new and distinct characteristics.
- **Customised production:** Earlier, production was carried out on a large scale to gain economies of scale. However, now, due to increased flexibility and competition, organisations customise their products according to the customer's requirement. Companies deploy mass customisation techniques to achieve maximum customer satisfaction.
- **Employee empowerment:** Earlier, organisations were not concerned about the workers and their well-being. However, with the development of human resource management, employees are given their due significance. Now, they are considered valuable resources for the organisation because they provide a competitive edge to the organisation. Thus, organisations make due provisions to ensure empowerment to their employees. Employee empowerment refers to an environment created by organisations, wherein employees have the authority to take decisions related to their work. Organisations also empower employees by boosting their morale, by motivating them through rewards and recognition, by encouraging a transparent work culture, etc.
- **Green production:** Earlier, the main focus of production was to obtain the resources at the lowest possible cost and minimise the manufacturing cost by ignoring the environmental concerns. Nowadays, organisations are more concerned about the environment and they have adopted green production and green marketing strategies. Green marketing involves production and use of eco-friendly products. This marketing strategy helps in creating awareness about the environment. Organisations are also taking initiatives to save natural resources by taking care of forests and wild life. Some of the Indian companies that adopted green marketing are ITC Limited, Tata Metaliks Limited (TML), Tamil Nadu Newsprint and Papers Limited (TNPL), HCL Technologies, Oil and Natural Gas Company (ONGC), IndusInd Bank, IDEA Cellular, and Hero Honda Motors.
- **Business Process Re-engineering (BPR):** BPR involves re-designing the workflow pattern and processes of an organisation. Earlier, organisations did not have options to improve the efficiency of their production process. However, now, many techniques have been evolved. Organisations are using various advanced methods to increase the efficiency of their production process. BPR is one of those techniques. It helps in identifying the loopholes in the existing processes and re-designing the process and thus, helps in increasing the efficiency.
- **New technology:** Earlier, organisations did not have options to improve the efficiency of their production process. However, now many advanced techniques are there so that the efficiency of the production process can be improved. These techniques are BPR, SCM, lean system, and implementation of Six Sigma.
- **Lean systems:** Earlier, there was no proper system to eliminate wastes. Nowadays, organisations are implementing lean system to their production and operations activities to improve the efficiency of their production processes by eliminating the wastes and non-value added activities. A lean system helps in identifying and eliminating wastes and non-value added activities.

Notes

Self-Assessment Questions

20. _____is concerned with the active participation of employees in continuous improvement in the quality of products and services.

21. _____refers to an approach to manufacturing that is concerned with fulfilling the needs of customers while maintaining the high standards of quality and controlling the overall costs involved in manufacturing of a particular product.

22. Define CRM as a recent trend in production and operations management.

23. _____involves re-designing the workflow pattern and processes of an organisation.

Activity

Give some examples to explain the significance of SCM in a manufacturing organisation.

1.7 Summary

- The process of transforming a set of input resources, such as labour, capital, equipment, land, buildings, materials and information into outputs, such as products and services is known as Input-Transformation-Output (ITO) process.
- POM is the process of using resources of an organisation to produce requisite goods and services in accordance with the policies of the organisation.
- Manufacturing is the process of producing only tangible goods, whereas production includes production of both tangible goods as well as intangible services.
- Operations management is the process, whereby resources or inputs are converted into services. The term 'production management' is generally used for production of tangible goods, whereas 'operations management' is typically used when the output is a tangible product or an intangible service.
- Adam Smith first addressed the significance of production management in the 18th century.
- Controlling entails governing of the activities in such a way that the actual performance goes in accordance with the planned performance.
- The objective of POM is the optimal utilisation of available resources such as manpower, capital, and material.
- Location of facilities refers to the place, where the production or service facility is or is to be established.
- The basic idea of a plant layout is to arrange the facilities to meet the required output according to the quality standards.
- Material handling involves the physical movement of materials from inventory to the machines and from one machine to another.
- Product design is associated with the decisions related to the shape, size, colour, appearance, and quality of a product.

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- The process design is associated with the selection of process, choice of a certain technology, and process flow analysis.
- Production planning involves determining necessary jobs and creating work orders that need to be performed to manufacture products.
- Quality control is a system used for maintaining a desired level of product quality or conformance to customer specifications. On the basis of various kinds of processes, operations management can be divided into five broad categories
  - Decision making
  - Forecasting
  - Planning and scheduling system
  - Designing systems
  - Operating and controlling the system

1.8 Glossary

- **Capacity:** It is the ability to produce particular number of units at a given time.
- **Controlling:** It refers to activities that ensure actual performance is in accordance with planned performance.
- **Just-in-Time:** It is a manufacturing system whose goal is to optimise process and procedures by continuously pursuing waste reduction.
- **Planning:** It is an activity, which helps the production and operations manager in making future decisions.
- **Production:** It involves conversion of raw materials into finished goods and services by using human effort and other equipment.
- **Operations management:** It involves a system in which inputs are transformed into tangible and intangible goods.
- **Organising:** It entails proper allocation of work to the employees according to their skills and efficiency. It also entails performing the allotted activities that are needed to achieve organisational goals.

1.9 Terminal Questions

1. Write a short note on ITO model.
2. Differentiate between the concept of production management and operations management.
3. Give a brief note about the scope of POM.
4. Write a short note on the historical evolution of POM.
5. Discuss the various categories of operations involved in POM.
6. List and explain any five responsibilities of production and operations manager.
7. Summarise the recent developments that have taken place in the area of POM.

Notes

1.10 Answers

Q.	Self Assessment Questions
1.	Operations can be referred to the processes that use a set of input resources to convert it into outputs.
2.	a. Mental characteristics of customers
3.	True
4.	Transforming
5.	c. Production and operations
6.	Quality control
7.	a. Process design
8.	Organising
9.	Operations
10.	Forecasting
11.	The planning and scheduling system involves processes of making a detailed plan of the day-to-day production operations in an organisation.
12.	Designing systems consist of product designing, facilities layout, and designing of work systems.
13.	Designing of work systems
14.	b. i,ii,iv
15.	True
16.	Allocation of resources
17.	Control decisions
18.	False
19.	Responsibilities of a production and operations manager are as follows: • Producing products and services as per the desired specifications • Acquiring raw material at minimum prices • Selecting the best location for facilities such as factories, warehouses, and stores
20.	Total Quality Management (TQM)
21.	Agile Manufacturing

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22.	CRM is a business strategy that aims to improve customer service and achieve a high level of customer satisfaction.
23.	Business Process Reengineering (BPR)
Q.	**Terminal Questions**
1.	The process of transforming a set of input resources, such as labour, capital, equipment, land, buildings, materials and information into outputs, such as products and services is known as Input-Transformation-Output (ITO) process. Refer to section **1.2 Transformation process model:** Inputs, Process and outputs.
2.	The term "production management" is used in manufacturing organisations, whereas "operations management" is used in service organisations. Refer to section **1.3 Concept of Production and Operations Management.**
3.	The scope of POM includes many activities such as selection of location, product design, process design, quality control, material management, etc. Refer to section **1.3 Concept of Production and Operations Management.**
4.	The different stages in the evolution of POM are the industrial revolution, post-civil war period, scientific management, human relation movement, operations research, and the service revolution. Refer to section **1.3 Concept of Production and Operations Management.**
5.	The various categories of operations involved in POM, consists of decision making, forecasting, planning and scheduling system, designing systems, and operating and controlling the system. Refer to section **1.4 Classification of Operations.**
6.	A production and operations manager has many responsibilities and he/she plays an important role in production and operations activities. Refer to section **1.5 Role and Responsibilities of an Operations Manager.**
7.	Recent developments in POM are JIT production, SCM, BPR, lean system, and service operation management. Refer to section**1.6 Recent Trends in Production and Operations Management.**

1.11 Case Study: Production and Operations Management in XYZ Pvt. Ltd.

XYZ Pvt. Ltd. was a prominent player in India's valve manufacturing industry. Gaining maximum efficiency in the manufacturing process was the organisation's top priority. Sales of the company's goods were seen to be progressively falling over time. Consequently, the company invested in research to determine the root causes of the ongoing sales slump. It was determined that the organisation's lack of service orientation was the primary cause of this deterioration. Customers were dissatisfied with the goods and began buying from competitors as a result.

Another finding was that XYZ was relying solely on output to stay ahead in the market. Total Quality Management (TQM), Business Process Reengineering (BPR), Forecast Management

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System (FMS), Computer Integrated Manufacturing (CIM), and Customer Relationship Management (CRM) were some of the cutting-edge strategies used by the organization's rivals to get an edge in the market. The production manager was informed about XYZ's ongoing difficulty and chose to reorganise the entire manufacturing process of the organisation.

Discussion Questions

1. What should be the objectives of XYZ after restructuring its production process?

   (**Hint:** One of the objectives of XYZ is to produce right kind of products.)

2. If you are the production manager of the organisation, what should be your responsibilities?

   (**Hint:** One of the responsibilities of the production manager is to produce products and services as per the desired specifications.)

1.12 References and Suggested Readings

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CHAPTER

2

Product and Service Analysis

Structure

Notes

Learning Objectives

After completing this chapter, you will be able to:

- discuss the concept of product and its characteristics
- explain product differentiation
- explain the concept of product selection
- elaborate on the concept of product design
- elucidate the concept of product development

2.1 Introduction

As discussed in the last chapter, Production and Operations Management (POM) is a process of combining inputs and converting them into final products. Products are an offering that are produced by an organisation to satisfy the needs and expectations of the customers. It can include goods, services, information, and ideas. Before producing a product, an organisation needs to take into consideration the processing, economic, and aesthetic aspects of the product. Product analysis is a systematic assessment of products with the aforementioned parameters. Product analysis is a process of an organisation that involves three sub-processes, namely product selection, product design, and product development.

Product selection is a process in which an organisation selects a product that is can possibly satisfy the needs and expectations of its customers. The selection of the right product helps an organisation to maximise its profit and minimise the costs. An organisation uses different methods for selecting its products, such as consumer surveys, opinion polls, brainstorming, and panel discussions. Product design is a process of defining product characteristics, such as the colour, size, shape, and functionality. While designing its product, an organisation needs to consider three main aspects, such as needs and expectations of customers, cost of design, and time factor. Product development is all about developing systematic methods to get a product to the market. It may involve modifying the existing product of an organisation or developing an entirely new product that would meet the needs of a new set of customers.

The chapter begins by explaining the concept of product and its characteristics. Next, it discusses the concept of product selection. Further, the chapter lays emphasis on the concept of product design. It also explains the factors to be considered by an organisation while designing its product. Toward the end, the chapter sheds light on the concept of product development, its process, and advantages.

2.2 Concept of Product and its Characteristics

Any service or good that meets the requirements and exceeds the expectations of consumers is considered a product. Businesses sell products and services in the market to satisfy consumer demand and make a profit. A company's product is its most valuable asset and the foundation of its marketing strategy.

According to Peter Drucker, "Suppliers and especially manufacturers have market power because they have information about a product or a service that the customer does not and cannot have, and does not need if he can trust the brand. This explains the profitability of brands."

A company's success hinges on its ability to anticipate and meet consumer demands. For example, some consumers only use their cell phones for conversing, while others utilise them for both personal and professional purpose, such as teleconferencing. Needs of the customers depend on

their purchasing power; for example, a customer whose basic need is surfing over the Internet may opt for a simple computer; whereas, a software engineer may need a high configuration computer. Consequently, the quantity of goods also increases proportionally as the amount of necessity does.

Now, let us discuss the different levels of a product in the next section.

2.2.1 Levels of product

Customers need better items that can meet their existing needs as their economy grows. Companies meet the diverse demands of their clients by offering multiple versions of the same product. With each tier, a product gains access to more and more useful features. Mobile phones, for instance, cater to a wide range of tastes by offering a variety of features and functionalities. It is possible to purchase extremely basic mobile phones for customers who merely want to use them for communication. On the other hand, customers can opt to get mobile phones with extra functions if they want to use them for communication, business, and pleasure. Figure 2.1 displays the various product levels:

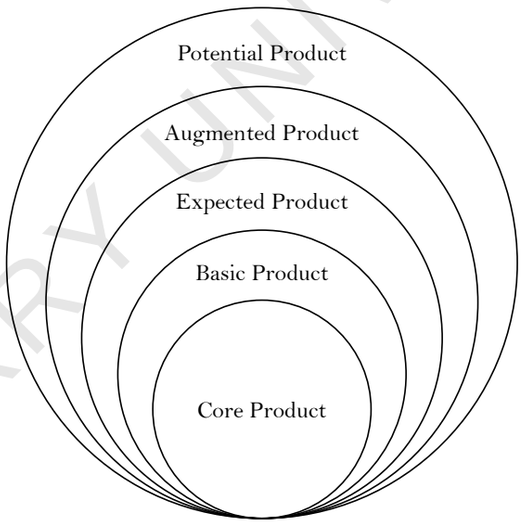

Fig.2.1: Product Levels

Now, let us discuss the different levels of a product (as shown in Fig.2.1) in brief:

- **Core product:** It sets the stage for subsequent tiers of product offerings and contains the product's most important features. Consider the automobile: its primary function is transportation. Thus, a basic product is a compact vehicle that does not have any extra features.
- **Basic product:** It encompasses not only the essential element of a product but also its supplementary advantages. One example of a basic product is a car that is both clean and spacious..
- **Expected product:** A product that is highly sought after by consumers is what it means. Other factors, such as socioeconomic status, influence this variable from person to person. A consumer purchasing a vehicle, for instance, may anticipate the inclusion of a climate control system and audio system.
- **Augmented product:** It covers more features of a product in comparison to competing products. Customers that are reasonable are more satisfied with the value they receive

from the added perks. An automobile, for instance, might be equipped with an LCD TV and a refrigerator.

- **Potential product**: This product category evaluates the present product in relation to the future benefit it will provide. It goes above and beyond what clients expect in terms of value creation. A high-tech gadget automobile that combines pleasant interior design with abundant seating is one example of a possible product.

Activity

Differentiate various levels of a product by taking an example of a motorbike of a particular band and its variants.

2.2.2 Product classification

The tangibility, durability, and utility of a thing are the three main criteria for categorising it. A company's policies on distribution, pricing, placement, and advertising are all impacted by how a product is classified. Fig.2.2 displays multiple product classification schemes:

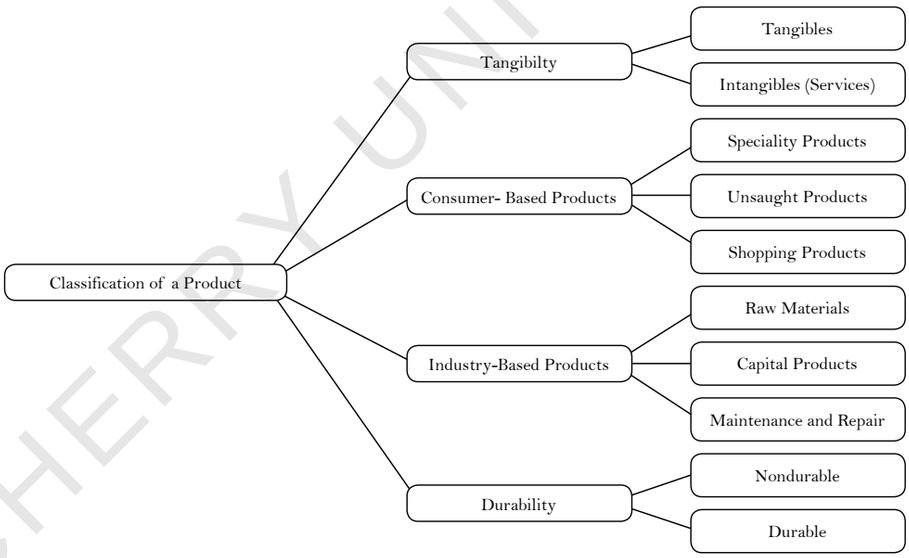

Fig.2.2: Classification of Products

Now, let us discuss the various methods to classify a product (as shown in Fig.2.2) in brief:

- **Tangibility:** There are the two categories into which products are categorised using this method:
  - **Tangible Product:** It describes things that are tactile, meaning they can be felt and handled. Consider the following: mug, bed, brush, bottle.
  - **Intangible Products:** It describes things that are tactile but not touchable. Expenses like health insurance and doctor visits are examples of intangible services.
- **Consumer-based Products:** Consumer goods are those that are bought and used by people rather than being resold. The following are the three main categories into which consumer goods fall:
  - **Specialty Products:** Certain types of consumers are drawn to certain products because of their interests, hobbies, occupations, or personal preferences. A consumer

is only happy with a product that meets their exact specifications when they have a unique demand. The buyer in this situation is unyielding and refuses to go to any farther lengths to locate the desired item. For instance, no one will buy a competing product if they desire a Canon camera with 15 megapixels and Electro-Optical System (EOS) technology.

- **Unsought Products:** These are items that are not widely recognised by consumers. Customers have a lot of doubts about purchasing those items. The companies sell these products and attract additional customers using aggressive marketing strategies. Take LED TVs as an example; they were relatively unknown to Indian consumers in the past. To further promote this product, the companies have appointed a number of well-known Bollywood actors and actresses to serve as brand ambassadors.
- **Shopping Products:** Customers purchase these items after carefully weighing their pros and cons, as well as the products' costs and packaging. Customers often consult with friends, family, and local businesses before making large purchases, such as washers and dryers. He or she will choose the most appropriate washing machine from the available possibilities after doing study.

- **Industry-based Products:** Products that meet the needs of a specific industry are known as industry-based products. These are the inputs that businesses need to manufacture and ship their final goods to consumers. There is further categorisation of these:
  - **Raw Materials:** In this context, "materials" means everything that goes into making a product. Tobacco, iron ore, gold, and lumber are the four main ingredients of cigarette, furniture, jewellery, and building materials, respectively.
  - **Capital Products:** Products that are essential to the manufacturing and processing of other goods fall under this category. The infrastructure and after-sale services needed for this product type are massive. Organisations often make use of forklifts as a means of transporting raw goods.
  - **Maintenance and Repair Supplies:** These are the items needed to process and create a final product. When it comes to fixing and maintaining most industrial equipment, for instance, lubricants and tools are necessities.
- **Durability:** How long a product lasts is what this term describes. Longevity of benefit is an advantage of durable products. Products that do not have a long shelf life are bought with the intention of using them right away. Consumables and drinks are examples of perishable goods, while appliances, clothing, and electronics are examples of durable goods.

2.2.3 Product differentiation and its basis

In order to meet the needs of consumers, the market offers a wide range of items. In order to acquire a competitive advantage in the market, organisations strive to make their products stand out from the competition. The Indian market, for instance, offers a dizzying array of mobile phone models. In order to entice buyers, cell phone manufacturers include a variety of features in their products. You can differentiate your product based on these features:

- **Design:** This function is great for making a product stand out visually. When a company wants to make a new and improved product, they invest a lot of money in R&D. Counterfeiting and piracy are common problems that businesses encounter.

Notes

Exhibit

Counterfeiting and Piracy in India

Counterfeiting and piracy always deteriorate the condition of the nation's economy. India, Europe, and the US have lost billions of dollars through counterfeiting of products. An original Rolex watch costs thousands of rupees; however, it can be bought in a grey market (a market where product is distributed unofficially and without the permission of the manufacturer) for few hundred rupees. India is a hub for such high-design low-quality counterfeit products. Due to availability of these counterfeit products, the Indian government loses tax revenue that creates hindrance in the economic development of the country. As per the study conducted by AC Nielson and Federation of Indian Chambers of Commerce & Industry (FICCI) in 2005, the Indian government bears the loss of 238 billion per annum due to counterfeit products. In India, the software and automobile industries are highly affected by counterfeit products. For example, an original Windows 7 CD costs around Rs. 10,500; whereas, the same CD can be bought from a local CD seller at a nominal rate of Rs. 100 to 150. Similarly, one can buy duplicate auto components at very low prices. Sometimes, it becomes very difficult for customers to distinguish between the original and counterfeit products as both are similar in design. The manufacturers of counterfeit products usually keep the names similar to the original products. This process diminishes the brand value and image of the original product. As a result, the customers start losing interest in the brand and gradually stop using the product. The customers develop preference for counterfeit products and feel that original brand does not provide them value for money. The Indian music industry has also lost a large sum of money as music piracy is difficult to control. An individual can download all the latest songs without paying a single penny. India is among the top 10 countries affected by piracy. The Indian government has taken several initiatives to curb counterfeiting and piracy of products. These initiatives cannot prove effective until customers take responsibility to stop using such products.

- **Features:** Both the features and the way a product works fall into this category. Adding or removing features allows a company to differentiate its products. Two companies that have recently introduced new features—Spice Mobiles and Micromax—include dual SIM functionality. However, in order to make the product more valuable to customers, some companies eliminate unnecessary features. In Windows 7, for instance, Microsoft has included a number of new and improved features while removing some older ones, like InkBall and Windows Mail, from Windows Vista.
- **Quality:** What this term describes is a product feature that allows it to consistently perform according to predetermined standards throughout time. For any product, there is an underlying set of norms and requirements held by the consumers. Clients may be willing to shell out more cash for superior goods. Take Tata Steel as an example; their performance and delivery have consistently been top-notch. This company made history by becoming the first in India to earn the Six Sigma Black Belt certification.
- **Durability:** The ability of a product to maintain its degree of satisfaction throughout its use is what this term alludes to. To provide just one example, Asian Paints invests much in R&D to produce high-quality products like ACE Exterior Emulsion.

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Exhibit

Service Differentiation and its Basis

It is very important to have a brief idea about service differentiation along with product differentiation. The bases of service differentiation are:

- **Ordering:** It refers to a service that simplifies the order placing process. For example, several organisations started providing online information and order placement services.
- **Delivery:** It refers to the process of bringing products to customers. A supplier takes care of the speed and accuracy of delivery of a product. For example, Dell makes fast and accurate delivery of computers to its customers.
- **Installation:** It refers to the setting up of a new product at customer's place to make it operational. For example, heavy machineries require good installation services.
- **Customer Training:** It refers to a process of educating the customers regarding the usage of the product. For example, the complex machineries such a fully automated washing machine with several features are difficult to operate; therefore, a proper training is required to make customers use the product efficiently.
- **Customer Consulting:** It refers to the instructions given in the form of a booklet, data, and advice to customers. For example, booklets are given at the time of purachase of TVs, mobile phones, and pressure cookers.
- **Maintenance and Repair:** This activity takes place when a machine starts malfunctioning due to wrong or over use. In such cases, an organisation provides maintenance and repair services through online help tools or by sending a person to fix the problem.

Activity

Classify the products of three major industries on the basis of tangibility and durability.

2.2.4 Product line analysis

An inventory of items that share common features and functions is one component of a product line analysis. Based on consumer tastes, a business sorts its wares into several categories. By comparing and contrasting different goods in a company's line, product line analysis reveals how best to manufacture and market a product. In most cases, a business will undertake market research for each of its product lines that it sells. In the product line analysis, there are four main decisions:

- **Build:** This is the procedure for making a new range of products. Introducing a new product line involves a substantial financial commitment from the company.
- **Maintain:** It refers to managing and balancing the product line in a competitive market.
- **Harvest:** It refers to getting your hands on the good stuff that comes from the product line.
- **Divest:** It refers to a company getting out of a losing product line before it turns a loss.

Notes

It is very important for an organisation to find out the return on investment from different product lines. This can be done with the help of sales and profit analysis of different product lines. Let us demonstrate the sales and profit analysis of ABC Limited by understanding its different product lines, which is shown in Fig.2.3:

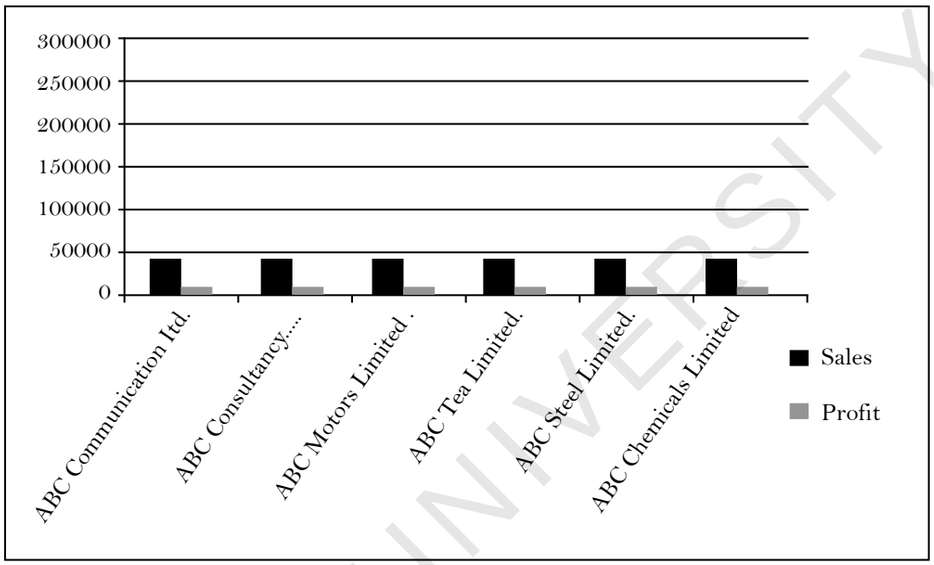

Fig.2.3: Sales and Profit Analysis of Different Product Lines of ABC Limited

As shown in Fig. 2.3, you can see that ABC Steel Limited is the most profitable product line of ABC Limited. ABC Limited can focus on its other product lines where profit is not good in comparison to sales. ABC Motors Limited needs strategic planning to increase its profit percentage.

A product can be categorised into four major types based on its sales volume and profit. The four categories of the products are:

- **Core:** It describes items that get a lot of attention from marketers yet don't make much money. Consider the low-priced mobile phones: they sell a lot yet don't make much money.
- **Staples:** These are items that do not receive extensive advertising. Profit margins are significant despite the modest sales volume of these products. A good illustration would be the relatively low sales volume but high profit margin of IBM servers.
- **Specialties:** Products with low profit margins, limited sales volume, and minimal promotional needs fall under this category. One example is the low profit and sales volume of high-resolution digital Single-Lens Reflex (SLR) cameras.
- **Convenience Items:** Products in this category tend to generate a lot of money with little advertising. Software and sound cards are two such examples.

2.2.5 Product Mix Analysis

Product mix, also known as product assortment, refers to the combination of a company's product lines. The term "product mix" refers to the assortment of goods and services offered by a company. In a product mix, there could be a single line of products or multiple lines. Figure 2.4 displays Hindustan Unilever Limited's product mix:

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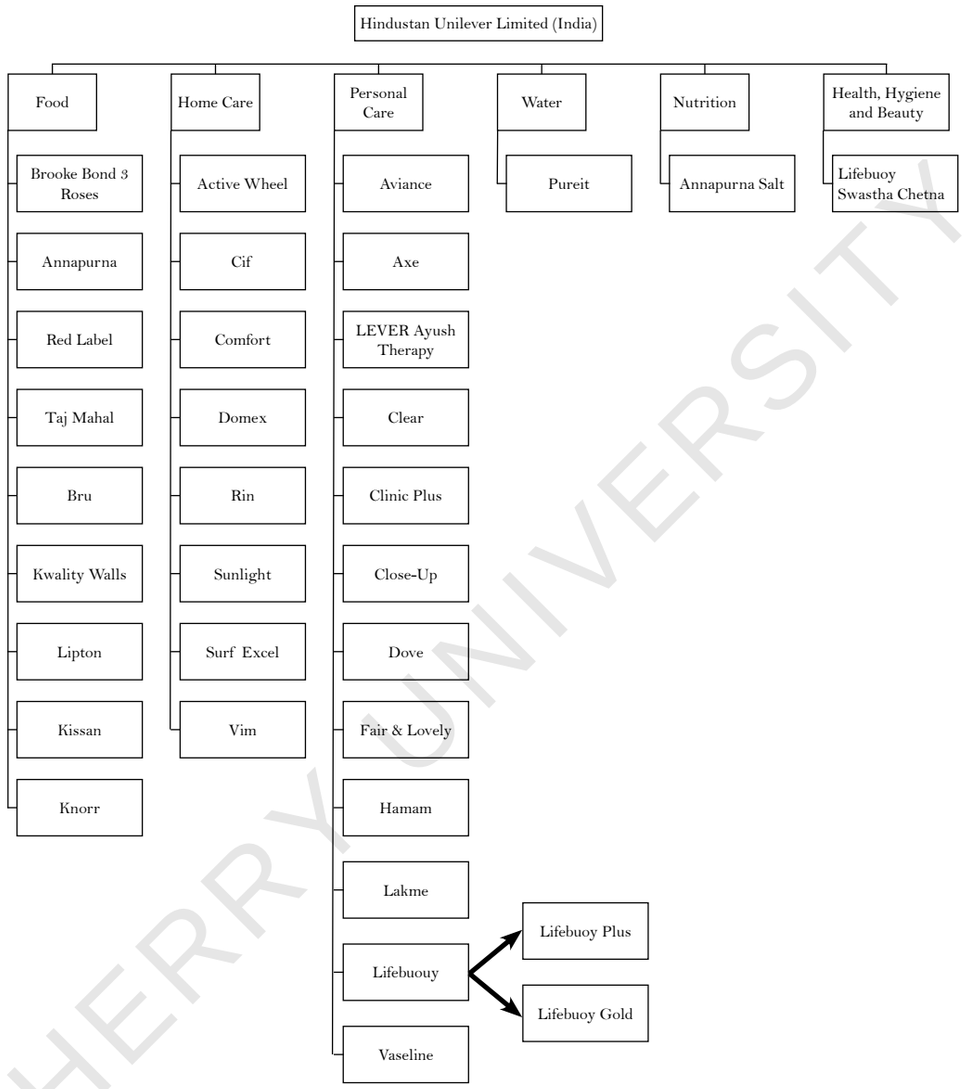

Fig. 2.4: Product Mix of Hindustan Unilever

Consistency, breadth, depth, and length make up an organization's product mix. Products in a mix consist of:

- **Width:** This metric measures the overall number of product lines offered by a company. Figure-2.4 shows the six product lines that make up the width of the product mix: food, home care, personal care, water, nutrition, and beauty products.
- **Length:** In a product mix, this is the sum of all the offered items. Hindustan Unilever Limited's product mix is 34 lengths long, as seen in Figure 2.4.
- **Depth:** A product line's entire number of items is what this term refers to. Figure 2.4 shows that there are thirteen different items in the personal care product line.
- **Consistency:** The degree to which an organisation's product lines are interdependent is quantified by this factor. When a company makes hair care products like shampoos, oils, and conditioners, for instance, it makes sure that each line is consistent with the others.

Notes

Self-Assessment Questions

1. Which of the following is not a basis for product differentiation?
   a. Design, Physical Structure or Size
   b. Features
   c. Quality
   d. Delivery Time
2. _____ includes additional attributes of a product as compared to products offered by competitors.
3. The durable products provide benefits for a longer period of time. (True/ False)
4. _____includes the list of some specific products with similar attributes and functions.
5. What is product mix?

2.3 Product Selection

Product selection is a process wherein an organisation selects an appropriate product by considering a number of factors. It is an important strategic decision for an organisation. It should select the right product to be produced as many other decisions are interrelated. The decisions that depend on the selection of a product by an organisation are as follows:

- The type of technology used for producing products
- The capacity of the production system
- The location of production facilities
- The planning and controlling systems

While selecting its product, an organisation should ensure that the selected product meets the needs and expectations of customers. Product selection requires a thoughtful consideration and supervision. This is because the overall profitability and competitiveness of the business depends on the type of product selected. Therefore, it is essential to select the right product to get the desired revenue. Organisations use different methods to select its product, which are as follows:

- Consumer and dealer surveys
- Opinion polls
- Pure or applied research
- Brainstorming
- Panel discussions
- Scenario building

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An organisation needs to consider various physiological and psychological factors while selecting a product, which are shown in Table-1:

Table 1: Factors to be considered for Product Selection

Physiological Factors	Psychological Factors
• Plant location and layout	• Overall organisational objective
• Availability of funds	• Market potential
• Time frame	• Management competence
• Environmental Conditions	• Government policies and regulations
• Ownership character	• Socio-economic objectives

Self-Assessment Questions

6. _____is a process wherein an organisation selects an appropriate product by considering a number of factors.

7. Name some physiological factors that are considered for product selection.

2.4 Product Design

Product design is the next step immediately after the organisation selects the product to be produced. It is a critical process for an organisation as the success or failure of the product directly affects the business, market share, and reputation. Apart from this, the design of a product also affects its quality as well as its ability to satisfy the needs of customers. The following are the three main aspects that an organisation needs to take into consideration while designing its product:

- **Needs and Expectations of Customers:** It refers to one of the most important factors that need to be taken into account while designing its product. It involves the designing of a product as per the needs of its customers. A poorly designed product may not be able to fulfil customer's requirements, which, in turn, makes customers switch to other brands.
- **Cost of Design:** It implies that an organisation should design its product within the given budget. If the design of a product incurs heavy cost, it may lead to a high price of the product. In such a case, customers may prefer to go for substitute products that are available at lower prices.
- **Time Factor:** The product design process of an organisation should not take much time. This is because if the designing of the product is unnecessarily delayed and requires a number of revisions, the competitors may capture the market.

The product design process of an organisation undergoes seven steps, which are shown in Fig.2.5:

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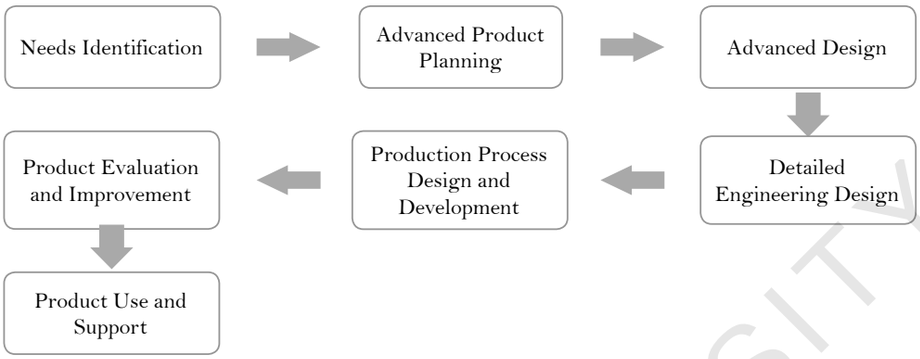

Fig.2.5: Process of Product Design

Generally, in large-scale organisations, a separate department is established for product designing. The main objective of this department is to identify and design the product that needs to be produced. In addition, the product designing department is responsible for providing the technical specification and the blue print of the product to be produced. It works in coordination with different departments of the company, such as production department and sales department, while designing the product.

2.4.1 Factors to be considered for product design

As discussed earlier, product design is a critical process. Any mistake made at the product design stage may adversely affect the business and goodwill. Therefore, an organisation needs to consider a number of factors while designing its products. These factors are shown in Fig.2.6:

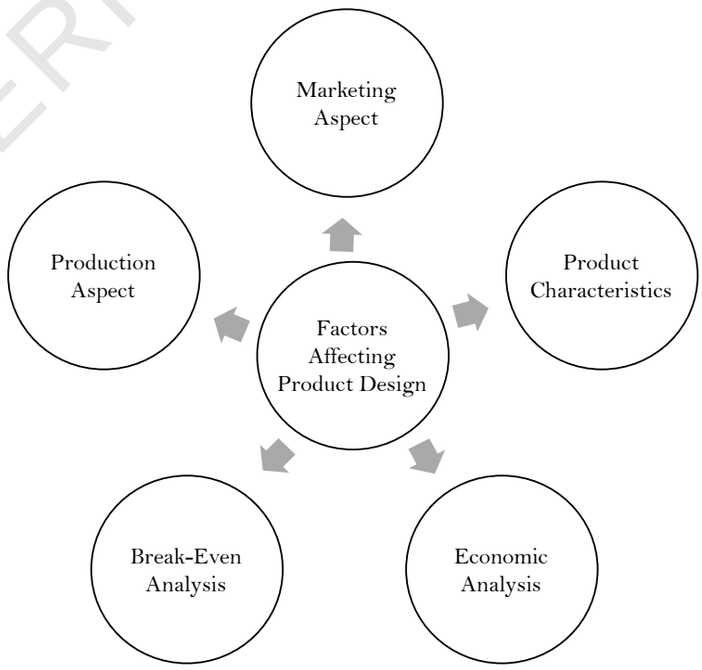

Fig.2.6: Factors Affecting Product Design

Let us discuss the factors affecting product design (as shown in Fig.2.6) in detail.

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Marketing Aspect

Before designing its product, an organisation needs to perform a deep analysis of the market to know the prevailing market trends and conditions. This helps the organisation in estimating the demand for its products in the market. In the case of new product, the demand can be determined based on the demand of related products. For example, the demand for tires can be determined from the demand for cars in the market. Apart from this, the demand for a new product can be created by modifying the design or usage of the existing product. For example, Horlicks has changed the design of its container to raise the demand. The glass container has been replaced with the plastic jars which are easy to handle. The new look is designed for keeping the brand young.

Product Characteristics

As discussed earlier, an organisation needs to design a product that can satisfy the needs of customers with respect to the quality, durability, packaging, and functionality. Therefore, need to ensure that the product should contain the following characteristics:

- **Functionality: It r**efers to one of the important characteristics of a product. A product should have a clearly defined objective, which states its functional scope or usage. For example, the main objective of a washing machine is to wash clothes. Therefore, a customer should purchase a washing machine with the predefined expectation that it would wash clothes. Apart from the main objective, the manufacturer should also provide other specifications to customers, such as how the machine works, how to dry clothes, and how to set timing for washing clothes. The design and cost of the product is decided on the basis of its functions.
- **Operational Aspect:** This implies that a product should be easy to handle and simple to operate. In some cases, a product is customised according to the customer's requirements. With the increased customisation, the designing of a product has become a challenge. This is because it involves assembling of different parts to form a customised product, which increases product complexity.

  Therefore, an organisation needs to design user-friendly products that can be easily operated by all customers.
- **Durability and Dependability:** It refers to the two important characteristics of a product. Durability refers to the life of a product in favourable conditions. It is not only associated with the selection of good quality raw material, but also depends on various other factors, such as the nature of the product. For example, the durability of crackers and matchsticks is very less. In such a case, it does not imply that the raw material used in crackers and matchsticks is of low quality. On the other hand, dependability is the ability of a product to work effectively.
- **Aesthetic Aspect:** It refers to the physical appearance of the product. The aesthetic aspect of a product is concerned with a final shape to the basic product. For example, the main parts of an ordinary passenger bus and a luxury bus are same; however, the design of both the buses is completely different.

Economic Analysis

Economic analysis is another important factor that needs to be taken into consideration while making product design decisions. The economic analysis of a product is performed after a

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detailed study of its marketing, functional, operational, and quality aspects. It involves the following activities in a sequence:

1. Determining the capital expenditure involved in the production of a product
2. Determining the expected production cost
3. Determining the expected profit margin of the product
4. Identifying whether the price of the product is competitive in the market
5. Determining the expected sales of the product

An organisation needs to take into account the following aspects while performing the economic analysis of a product:

- **Specialisation:** It refers to one of the most important aspects that an organisation should consider while performing the economic analysis of a product. Specialisation is a method of production wherein an organisation focuses on the production of a specific product with limited and defined variations. This would help in gaining expertise in manufacturing a particular type of product. It helps in reducing costs incurred on research and development activities and the modification of products. In addition, it helps an organisation in reducing the training cost of employees.
- **Standardisation:** It refers to one of the important aspects of the economic analysis of a product. Standardisation is all about establishing standards for product quality and functionality. It is associated with technology, industry, and production process. It is important in the case of mass production of a product. The main objectives of standardisation are as follows:
  - Attaining economies of scale with respect to cost, effort, and conservation of scarce resources
  - Providing the best possible solutions for problems related to economies of scale
  - Maintaining the expected level of productivity
- **Simplification:** It involves reducing diversity among the different products of an organisation with respect to their colour, size, and shape. Simplification helps in the following ways:
  - Reducing the production of useless products
  - Reducing changes in machine setups, idle time of equipment, inventories, and clerical overload
  - Generating continuous employment instead of temporary employment
  - Delivering products to customers on time
  - Reducing the obsolescence of materials and machinery

Break-Even Analysis

After performing the economic analysis of a product, the profitability of the product needs to be determined. Profitability can be determined with the help of break-even analysis of a product. Before, understanding the break-even analysis, it is necessary to understand the cost structure of a product. The total cost of a product is categorised into two types, which are explained as follows:

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- **Fixed Costs:** It refers to costs that do not vary with an increase or decrease in the quantity of products to be produced. For example, rent, interest, factory power cost, and salary of managers.
- **Variable Costs:** It refers to costs that vary with an increase or decrease in the quantity of products to be produced. For example, direct labour cost, material cost, and fuel cost required for running the machines.

For varying degrees of production, most businesses utilise break-even analysis to figure out how much money they will make. It is useful for finding the production point where income is equal to costs. Analyzing the profit contribution is another name for break-even analysis. Here are a few common ways that break-even analysis is defined:

According to **Matz, Curry** and **Frank**, *"a break-even analysis indicates at what level, cost and revenue are in equilibrium."*

According to **Keller** and **Ferrara**, *"the break-even point of a unit of a company is the level of sales income which will equal the sum of its fixed costs and its variable costs."*

According to **Charles T. Homogreen**, *"the break-even point of activity (sales volume) is where total revenue and total expenses are equal. It is the point of zero profit and zero loss."*

The important aspect of understanding break-even analysis is the break-even point at which there is no net loss or gain of an organisation as expenses equals revenue. The break-even analysis is done under two conditions, which are as follows:

- Relationship between income and linear costs
- Revenue-cost connection that is non-linear

Several approaches to break-even analysis can be derived from these two conditions. Figure 2.7 illustrates a few of these methods:

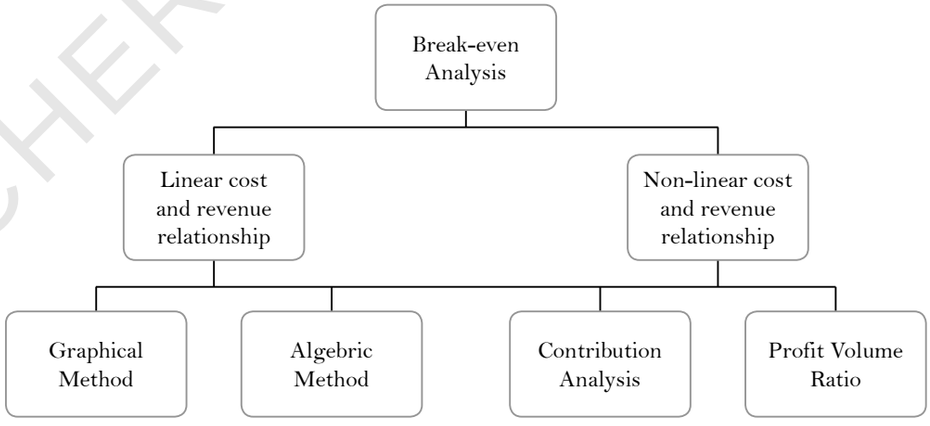

Fig. 2.7: Methods of Break-Even Analysis

Figure 2.7 indicates the methods of break-even analysis:

- **Graphical Method:** A break-even analysis that is linear is displayed. If the price of a product stays the same and the company increases production, then the relationship between output and total revenue is linear.

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Let us learn this method through Fig. 2.8:

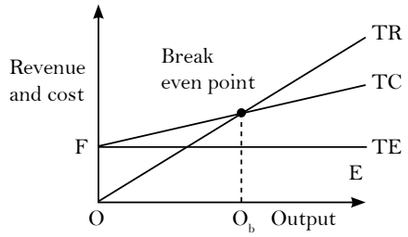

Fig. 2.8: Graphical Method of Break-Even Analysis

As shown in Fig.2.8, TFC is equals to FE, which is a fixed cost line. The vertical distance between TC and TFC line equals TVC. As quantity of output increases, the vertical distance between TC and TFC increases. This implies that TVC increases with change in TC and TFC. Until Qb of the quantity is produced, total cost exceeds the total revenue, which implies that an organisation will suffer losses if it produces less than Qb. At Qb output level, total revenue equals total cost. At this point, an organisation neither makes profit nor loss implying that it is a break-even point. Thus, Qb is a break-even level of output. Producing more than Qb will be profitable as TR is greater than TC.

- **Algebraic Method:** This method helps in decision making problems of the organisation. We know that profit is equal to difference between total revenue and total cost.

  π= TR - TC

  TR=P*Q

  TC= TVC+TFC

  TC= AVC*Q + TFC (TVC is the variable cost per unit multiplied by the output produced and sold)

  Let Qb is the break-even quantity at which TR=TC.

  TR=TC

  P.Qb = TFC +AVC.Qb

  P.Qb – AVC.Qb = TFC

  (P – AVC)Qb = TFC

  Qb = TFC/ (P – AVC)

Thus, from the above equation, it can be said that the break-even quantity of output is determined by TFC, price and variable cost per unit of output.

Production Aspect

After deciding all the aspects, it is essential to take into account the production aspect. While designing a product, it is also necessary to ensure whether the available production facilities are able to produce the required quantity. The production aspect encompasses a number of factors, which are as follows:

- **Selection of Processes:** Implies that the organisation should verify whether the selected production process is suitable for producing a product. The selection of a production process helps an organisation in the following ways:
  - Identifying the processes that become highly expensive after a certain level of production

- Making the production process suitable for the existing manufacturing tools and machinery
- Determining the sequence of operations and assembly methods

- **Selection of Materials and Components**: It involves the following:
  - Specifications for reducing the waste
  - Methods for reducing wastage
  - Standard components and assemblies
- **Selection of Manpower:** It involves selecting the manpower with the required skills and competencies. The manpower should be able to meet the quality requirements of the product.

2.4.2 Design for Manufacture and Assembly (DFMA)

DFMA is a design that is established to minimise the cost and time of production. Moreover, it aims at producing goods and services without major issues. DFMA integrates the product design with the process design. The following are the main objectives of DFMA:

- Reducing the cost and time of production by simplifying the product design.
- Increasing reliability of the production process. This is because when the product design is simplified, there are fewer chances of errors.
- Increasing the quality of a product.
- Providing a framework for the production of product.
- Achieving a high level of customer satisfaction by delivering high-quality products.

DFMA is established with the help of software, such as Computer Aided Design (CAD). Apart from this, there is some other software that can check the validity of product design and suggest materials for its various components

2.4.3 Different techniques used for product design

The advent of computers and Information Technology (IT) has made the designing of a product easier and effective. Apart from this, the advancement in technology has made a large contribution in shortening the product lifecycle and bringing product innovation. Some of the most commonly used technologies for designing products are as follows:

- **Computer Aided Design (CAD):** It refers to software that makes use of computer graphics for creating, modifying, and analysing product design. CAD helps in preparing 2-D and 3-D images of the product on the basis of plan and elevation views. These images can be easily rotated for analysing the product from every angle. The image of the product can be modified as per the requirement of the organisation. CAD also suggests materials that can be used and colour scheme of a particular product to be designed.
- **Computer Aided Engineering (CAE):** It refers to the use of computer softwares for improving the product designs. CAE is able to evaluate the finalised product design for its engineering strengths and weaknesses. In CAE, the components of product design are analysed and verified by using different tests on computer.

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- **Computer Aided Manufacture (CAM):** It refers to software used to control the tools and machinery for the manufacturing of products with the help of computers.

Self-Assessment Questions

8. CAD stands for _____.
9. A product should have a clearly defined objective, which states its functional scope or usage. (True/ False)
10. Break-even analysis is also called as_____-.

2.5 Concept of Product Development

Product development is a process of searching the best possible alternative for producing a product. As discussed earlier, it may involve modifying the existing product by adding some new features to it or developing an entirely new product that would meet the needs of a new set of customers. Some of the popular definitions of product development are as follows:

According to **William J. Stanton**, *"Product development encompasses the technical activities of product research, engineering and design."*

According to **Limpson** and **Darling**, *"Product development involves the adding, dropping, and modification of item specifications in the product line for a given period of time, usually one year."*

Some management scholars are of a viewpoint that product development involves changing the size, design, characteristics, colour, and packing of the existing product. The following are three major objectives of product development:

- **Enhancing the market position: It i**mplies that the development of new products helps an organisation to increase its market share by creating barriers to entry for competitors and establishing a market image by wider product lines.
- **Making efficient utilisation of resources:** It refers to one of the most important objective of product development. While developing new products, an organisation makes use of those resources that were lying idle earlier.
- **Improving organisational capabilities:** It implies that product development requires creativity and innovation, which, in turn, enhances the capabilities of an organisation.

Apart from this, the following are some other objectives of product development:

- Checking the feasibility of the production of a product
- Developing the qualities and characteristics of the product
- Developing different models and designs of the product
- Selecting the best model and design
- Deciding the packaging of the product
- Expanding and contracting the product mix
- Discontinuing the production of unprofitable products
- Improving product quality

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2.5.1 Advantages of product development

Nowadays, product development has become an indispensible part of every organisation. It provides many advantages. The following are some important advantages of product development:

- Helps in producing high quality products
- Helps in achieving a high level of customer satisfaction
- Helps in expanding the market for products
- Maintains a stable demand for products
- Minimises the chances of product obsolescence
- Helps in handling competition more effectively
- Increases the goodwill of an organisation
- Increases profit earning possibilities of an organisation

2.5.2 Process of developing the existing product

Product development is a chronological sequence of activities involved in producing products. Fig. 2.9 shows the steps involved in the process of product development:

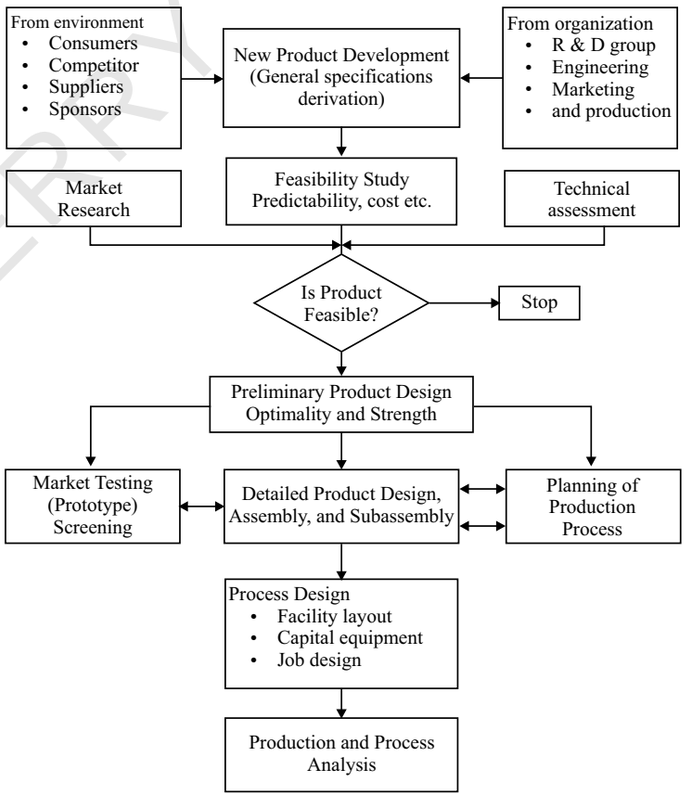

Fig. 2.9 : Process of Product Development

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The steps involved in the process of production development are as follows:

1. Determining the technological and functional specifications of a product to be produced
2. Conducting the feasibility analysis of the product with respect to its physical reliability, economic worth, and financial viability
3. Preparing a preliminary product design for ensuring the strength, compatibility, and stability of the product
4. Conducting market analysis to determine whether the product design is acceptable to customers
5. Developing a detailed design of the product to convert it into the working drawings of parts, subassembly, and assembly
6. Planning the production process
7. Designing the production process
8. Making a prototype of the product
9. Producing the product at a large scale

2.5.3 New product development process

Any company's future prosperity hinges on the introduction of new products. Nonetheless, introducing a brand-new product to consumers is no easy feat. Before releasing a product to consumers, marketers must adhere to certain protocols. Failure to adequately plan and conduct market research can lead to a product's failure in the marketplace. For the successful launching of a product, an organisation should follow the process of new product development, which is shown in Fig.2.10:

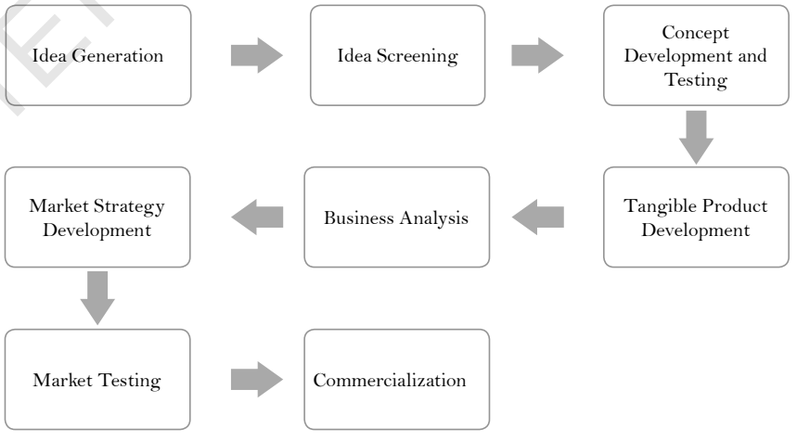

Fig. 2.10: New Product Development Process

The explanation of the process of new product development is as follows:

Idea Generation

The process of coming up with fresh product ideas entails investigating potential concepts. A creative thought process is required, but it can be accomplished through brainstorming sessions.

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The following sources can be used to develop ideas:

- **Brainstorming:** The process is defined as an attempt to generate a set of ideas by applying four overarching principles. Avoiding criticism, concentrating on quantity, being creative, and merging ideas to reach a complete answer are the rules of brainstorming. Ten to twelve persons will practise this method together.
- **Focus Group:** What this term describes is the process by which entrepreneurs join groups to brainstorm potential company ideas with the assistance of experts in the sector. Groups of eight to twelve people are assembled in focus groups and given a subject to talk about. They have been briefed about the purpose of the discussion and the topics that will be discussed.
- **Surveys:** This is the approach that an entrepreneur takes when trying to learn about people's wants and requirements. The entrepreneur can use this information to better understand current market conditions and potential opportunities for new business ventures. In this approach, the entrepreneur typically creates a preliminary version that includes multiple-choice questions about frequent issues that individuals encounter in their daily lives. The business owner invites people to participate in the survey by having them fill out the form. Businesses can reach out to customers in two ways: by sending out emails or by going door-to-door. Also, the business owner can make a survey that people can fill out online.
- **Interacting with People:** It helps to generate ideas for new product development. An organisation consults scientists, engineers, customers, marketers, employees, channel members, and competitors to get new ideas. The requirements of customers generate maximum number of ideas. However, some management experts believe that customers do not help in developing a new product. According to **Henry Ford**, "If I had asked people what they wanted, they would have said a faster horse."
- **Creativity Techniques:** This helps in generating creative ideas. Some of the creative techniques are:
- **Attribute Listing:** This type of technique lists and modifies each feature of a product. For example, reducing the size of the mobile phones and adding new features, such as radio, camera, data card, and Microsoft Office.
- **Forced Relationship: This h**elps to build a relationship among all the ideas of a list. For example, sofa and bed are two pieces of furniture that can be combined to make a sofa-bed.
- **Morphological Analysis: It** refers to generating the idea by combining different modes of doing the work. For example, a courier organisation can use various modes of transportation to reach national and international destinations. A new idea of transportation can be generated by combining the different modes of transportation, such as air, water, and rail.
- **Reverse Assumption Analysis:** It refers to reversing the normal list of products and services of a particular industry. For example, if we reverse the normal list of services provided by a school, then we will conclude that there is no teacher in the school, students do not pay fees for learning, rather they pay for hours spent in the school, and students have full freedom to come to school according to their willingness. This analysis helps an organisation to generate some creative ideas.
- **New Context:** This refers to putting a familiar process into a new context, such as helping a dog in trouble instead of helping a child in trouble.
- **Mind Mapping:** This lists a thought on a paper and consequently associates it with the next thought. For example, a thought starts with a motorbike; list it on the paper, and then the next thought comes into the mind (Hero Honda). Link all the bike-related

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Idea Screening

Idea screening refers to selecting the ideas that help in achieving the objectives of an organisation. Ideas are analytically assessed by the personnel to separate the most eye-catching options. Screening depends upon the number of ideas; thus it may be done in rounds involving executives who judge the viability of ideas. The consecutive rounds may apply more advanced research techniques. Rough estimates are made of the potential of any idea, as the ideas are sculpted down to a few striking options, in terms of sales, manufacturing costs, profit possibilities, and rivals' response. Satisfactory ideas transfer on to the next step.

While screening the ideas, an organisation should take care of two kinds of errors: drop-error and go-error. A drop-error occurs when an organisation dismisses any idea that would have been better if accepted. For example, an organisation has an idea of making shampoo, oil, and soap but it drops the idea of making shampoo and oil. The organisation selects to make soap; therefore, dropping the idea of making shampoo and oil that could have been better is called drop-error. A go-error occurs when an organisation adopts a poor idea for development and commercialisation. In this case, the organisation can suffer a huge loss and eventually the failure of the product too. In the preceding example, making soap can be a wrong idea for the organisation and can result into a go-error. Therefore, the purpose of screening the ideas is to select the most profitable idea.

Concept Development and Testing

The marketer, with a few ideas in hand, tries to find initial response from customers, distributors and its workforces. Focus groups are assembled, where the ideas are presented often in the form of presentations to a group. For example, sheet displaying drawings of a product idea or an advertisement of the product may be shown to the customer. In some circumstances, focus groups may be presented with some mock-up of the ideas, which are corporeal but impractical versions of the product idea. The marketers gather information, from the focus group on various aspects, which reveal whether the customer would like or dislike the concept; what would be the level of curiosity in purchasing the product; what would be the average frequency of purchase; and what should be the pricing on which customers may show their willingness to spend on the product.

Concept development and testing refers to technically developing an idea on the paper. In concept development and testing step, the organisation takes the decision whether the idea should be developed into the final product or not. The idea development includes several concepts, such as usage, segment, and primary benefits of a product. Concept testing helps to predict the profitability of a new product before its launch in the market.

Market Strategy Development

After successful concept testing, a marketer develops an initial three part plan of the strategy that is meant for presenting new product into the market.

The first part describes the concepts related with the size of the target market, its structure and behaviour; predetermined product positioning and sales, market share, and profit objectives, which an organisation desires to find out in the first few years. For example an organisation that wishes to bring an instant breakfast drink into the market, is required to find out the target market which might be families with children who want something new and a convenient and nutritious form of breakfast. They may position the product at a higher or a lower price, at a higher category, and in the instant breakfast drink category. And may

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also decide how much growth it will aim to gain in first year of launch and in the succeeding years, thereafter.

The second part describes the pricing strategy, distribution strategy, and the marketing budget for the first year of the launch of the product. We can understand this with the help of the above mentioned case. After working on the decisions related to the target market, positioning and growth issues, the organisation may decide on the various flavours in which it can launch its instant breakfast drink. It may decide various prices for different packaging sizes. It may also decide on various coupons, free samples, or allowances on a certain amount of purchase. The organisation may focus on the budget for advertising that is to be done on a national and local level. The advertising emphasis is also decided in the form of nutrition and convenience benefits. The budget necessary for conducting R&D, obtaining data related with retail audit, market reaction, and buying rates, can also be decided at this stage.

The third part describes the marketing strategy plan related to long term sales and profit goals. In this part, decisions on marketing mix are also taken.

Business Analysis

At this stage, the marketer has almost reduced a hypothetically large number of ideas down to one or two options. Now, the process depends mainly on the market research. Efforts are made to examine the feasibility of the product ideas. The important objective at this stage happens to be obtaining valuable forecasts of operational cost, market size, and financial estimates. Apart from this, it also requires deciding on whether the product will be acceptable within the overall mission and strategy of the organisation. Internal research is very much needed at this stage, and this includes discussions with production and purchasing staff. Apart from this, external marketing research which includes surveys related to customers and distributors, secondary research, and rival's analysis is also very important.

An idea's potential for becoming a marketable product can be assessed through business analysis. Estimating the manufacturing cost, operational costs, sales volume, and profit margin are ways to estimate the feasibility. In addition to considering the product from a marketing and financial perspective, a company should check if it fits in with its overall goals and objectives.

Tangible Product Development

Serious consideration is given to ideas that pass through business analysis for development. Organisations direct their research and development departments to build an initial prototype of the idea. They also focus on constructing marketing plans for the product. Once the sample is ready, the marketer tries to gather customer's opinion. Here, the customer gets a real experience of the product as well as other features of the marketing mix, that include pricing, distribution, and promotion options. Encouraging customer reaction helps in introducing the product and also helps in gaining other valued information such as projected purchase rates and the probable use of product by the customers. Poor reaction suggests that a few more adjustments are necessary to be made to the marketing mix elements. Once the adjustments are made, the marketer may again put the product for customer test. Not only does it help in gaining customer feedback, but also helps in evaluating the viability of production for manufacturing products at a large-scale and in a cost effective way.

In product development, the concept is transformed into a tangible good. A company will first commission R&D to create a working model of the concept. Just as it is about to make the prototype, it needs feedback from clients on things like size, price, and product design.

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Advertising, pricing, and distribution are all parts of the marketing mix that consumers encounter during product development. They also get a first look at the actual product.

Market Testing

Products that come to this category are arranged to be tested as real products. Sometimes marketers skip market testing, and accept the product idea as it comes from concept testing, to launch the idea in a developed form of product. But a few organisations, before going in for commercialisation, desire to gain more input from the bigger market group. Market testing makes the availability of the product to a selective minor segment of the target market such as one city, with full market effort and in the similar way it desires to present the product for purchase in the whole target market. Sometimes when consumer products are sold at retail stores, marketers have to work harder, to bring the product into the test market and convincing the distributers to purchase products and give it place on their store shelves. Distributors may also get some fees if they approve to give place in their stores to the product for testing the customer's shopping response, which helps the organisation in measuring the product interest. A few other high-tech methods such as virtual reality and computer simulations also help in effective market testing. Customers are exposed to computer-projected virtual reality settings and tests and are asked to trace and choose products. Computer simulations do not directly involve customers. As a substitute, definite variables are entered into computer programs to calculate the response of the target market.

By providing free samples to consumers and collecting their opinion, market testing determines whether the product is suitable for the market. Some companies may go straight to releasing the product to the public without going through this process. On the other hand, before releasing a product to the public, some companies run tests in the market to gauge consumer sentiment and behaviour.

Commercialisation

Commercialisation refers to the act of launching the product in the market. An organisation decides how, when, where, and to whom the product should be distributed.

The 'how' part deals with the decisions related to introductory market strategies. Any organisation is required to develop an action plan for presenting the product into the market. Introducing new products may take more time and money for their establishment in the market, thus it is very important to decide on the how aspect. The 'when' aspect deals with the timing of the commercialisation of a new product in the market. It states when the organisation wants to enter into the market with its product. It makes a decision regarding whether it wants to make the first entry, or wants to enter into the market with its competitors and make a parallel entry, or it wants to delay its launch and wait for its competitors to launch their products first and by this way, wants a late entry. Sometimes organisations go in for a late entry if they are presenting the new product as a replacement for the older product. In such cases, the organisation wants to wait until the old stock ends. The 'where' aspect deals with strategies related to geographical areas; the organisation must decide where it wants to launch its new product, whether it wants to launch it in the national market or the international market, whether it should be in a single locality or in many regions. Most organisations develop the products to sell them basically in the domestic market. If the product performs well, then the organisation might consider introducing it in nearby countries or into the world market as well. The 'to whom' aspect deals with the target market prospects. The organisation must be

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clear about whom it wants to sell its product to. It includes complete knowledge about the target market, initial distribution and promotion, to attract the desired prospective groups.

If positive results come through market testing, it is the signal that the product is ready to be announced to the extensive market.

Self-Assessment Questions

11. _____refers to the act of launching the product in the market.

12. At which of the following stage, the marketer almost reduces a hypothetically large number of ideas down to one or two options?

a. Business Analysis

b. Product Development

c. Market Testing

d. Commercialisation

13. Concept testing helps to predict the profitability of a new product before its launch in the market. (True/ False)

2.6 Design for Services

Services are performances, such as transportation, utilities, and media, and have varying characteristics from physical products. Services are intangible products, such as accounting, banking, insurance, consultancy, education, medical treatment, and transportation. Services are sold without transfer of possession or ownership from manufacturer to the customers. Sometimes services are not easily identifiable because they are closely associated with a physical good. For example, the class room teaching is a combination service, such as lecture and tangibles, including class room and laboratory.

Services are multifaceted economic activities that do not directly involve with the manufacturing of goods, mining or agriculture. Service typically associates labour, managerial skill, training, and advice to add value. It includes visits to the doctor, enjoying a dinner at a restaurant, travelling in an airplane, and attending a concert. The difference between goods and services are narrowing down due to technological advancements. Information and Communication Technology (ICT) enables people to participate in service-related activities without being physically present. With the help of ICT, movies can be copied on the memory cards for future use. Software can be stored like any other manufactured product. Technology helps providers to produce a single service that is capable of being mass-consumed, for example, online Internet dictionary.

Some definitions of service are:

"A service is an activity or series of activities of more or less intangible nature that normally, but not necessarily, take place in interactions between the customer and the service employee and/or physical resources or goods and/or systems of the service provider, which are provided as solutions to customer problems." **(Gronroos 1990)**

"A service is any act or performance that one party can offer to another that is essentially intangible and does not result in ownership of anything. Its production may or may not be linked to a physical product." **(Kotler)**

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There are four characteristics of services. They are as follows:

- **Intangibility:** It refers to the non-receptive characteristic of products by sensory organs. This is the most basic distinctive characteristic of a service. Services are deeds, actions, and performances which cannot be seen, felt, touched, or tasted as we can do with the physical products. For example, medical services are performance of providers actions, such as diagnosis, surgery, and treatment directed towards the patients. The patients cannot see and touch the services in the process of service delivery. The patients can only see and touch the tangible products, such as equipment and infrastructure of the hospital. Intangibility of services causes lack of confidence on the part of the customer as they find it difficult to measure the value, price and quality of service.

  The core value of a tangible product is processed in a factory; whereas, the core value of intangible product is produced in the buyer-seller interaction. Customers tend to look for evidence of quality and other attributes to overcome the uncertainties about the services. For example, customers look at the surroundings of the beauty salon, and at the qualifications and professional standing of the hair-dresser. Services do not have a physical dimension. There is no industry that offers only tangible goods; some kind of service is always attached with it. The product offerings have been categorised into four types. They are as follows:

- **Purely Tangible Goods:** These refer to buildings and land.
- **Tangible Goods with Accompanying Services:** These include such goods as cars, refrigerators, and air conditioners.
  - **Major Service with some Accompanying Goods:** These include restaurants, fast food centres, hotels and hospitals.
  - **Pure Services:** These refer to consulting and legal advices.

  There are the following key implications derived from the intangible characteristics of services:
  - Difficult for customers to evaluate.
  - Difficult to advertise and display prices.
  - Difficult to determine the actual cost of per unit of service.
- **Inseparability:** It refers to the characteristic of simultaneous production and consumption of the services. Services cannot be stored to be distributed later. It implies that the service provider is an integral part of the service at the time of its sale. The tangible goods, such as Tata Nano car manufactured at Sanand in Gujarat can be consumed after a period of time. On the other hand, the teacher in the classroom and the doctor in the hospital are inseparable parts of the service offering of teaching and treatment. In the sale of products, ownership transfers from manufacturer; whereas, sale of services does not transfer the ownership. Customers often interact with the different employees who can affect their experience. For example, a businessman travelling in the executive class in an airplane avoids seating with a family travelling with children. The physical presence of a customer is essential in service offerings. For example, to use the services of an airline, hotel, and hospital, a customer must be physically present.

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- The key implications derived from the inseparable characteristics of service are as follows:
- Service providers are critical.
- Training of service provider is necessary to ensure quality.
- Customer behaviour and competence can help or hinder productivity.
- Location and opening hours of service outlets must be convenient for customers.
- Behaviour of other customers affects customer satisfaction.
- Waiting time should be minimised by self-service or expanding service hours.

- **Heterogeneity:** It refers to the characteristic of differentiation in service quality. In most of the cases, services are performed by the human beings and likely to differ in quality as per their readiness to provide services. The service quality can change from day to day or even hour to hour. For example, services performed by the airhostess in the first hour of her service can be different from the service performed at consecutive hours. Service is produced and consumed simultaneously. The service delivered by the host varies in the warmth of affection with different guests. Heterogeneity gives rise to concerns about the uniformity of service quality. Service personnel training and careful monitoring of customer satisfaction are required to maintain service standards.

  The key implications derived from the heterogeneity characteristics of service are as follows:

  - Achieving consistency is difficult.
  - Customising service is done as per the expectations of individual customers.
  - Replacing employees with machine may reduce variability in service.

- **Perishability:** Services are perishable in nature and cannot be stored. For example, an empty seat in an airplane is the lost opportunity of the provider forever, an unoccupied hospital bed or hotel room, or an hour without a patient in the day of a physician are the lost opportunities of the service providers. Perishability of offerings does not pose much of a problem if demand for a service is steady. On the other hand, at the times of unusually high or low demand of service, organisations can have severe difficulties due to its perishability. Organisations can recover wrong service delivery. For example, a bad haircut cannot be returned but it can be recovered by the hairdresser by improving the hair cut.

The key implications which can be derived from this characteristic of services are as follows:

- It cannot be inventoried.
- Demand is very time sensitive.
- High price during peak demand, low price during off peak demand.
- Make use of technology to improve efficiency.
- It can be recovered.

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The service design process involves a number of steps, which are shown in Fig.2.11:

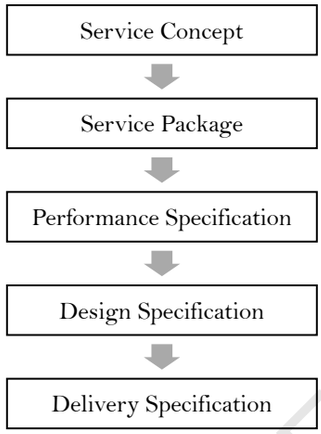

Fig.2.11: Process of Service Design

The steps involved in the process of service design are explained as follows:

1. Service Concept: It refers to the first step in the process of service design. Service concept includes details, such as the type of service delivered by an organisation, the target market, and features of service. Establishing service concept helps to identify potential customers and their needs and expectations. Moreover, the service concept enables to analyse how the newly developed service would help in gaining a competitive advantage in the market. For example, Domino's Pizza follows the concept of delivering pizzas within 30 minutes.

2. Service Package: It includes physical and psychological benefits that a customer would attain after receiving a service. Let us understand service package with the help of an example. In the case of services provided by a management institute, physical attributes include air-conditioned classrooms, comfortable furniture, latest training aids, well-stocked library, and a cafeteria.. The psychological benefits are the brand name and a stringent screening system for admission. Other benefits include highly qualified and experienced faculty.

3. Performance Specification: It describes the customer requirements and expectations from the service to be designed. For example, when a customer purchases a broadband network, he/she expects good network coverage and high speed of the Internet.

4. Design Specification: It defines the cost and time involved in designing the service. Moreover, in this step, the details related to the service facility, such as layout and location, are also defined.

5. Delivery Specification: It involves deciding work schedule, service deliverables, and the place where the service is designed.

Self-Assessment Questions

14. Write down the steps of process of service design.

15. _____are multifaceted economic activities that do not directly involve with the manufacturing of goods, mining or agriculture.

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2.7 Summary

- Products are offered in the market for earning revenue and meeting the requirements of customers. The different levels of products include core product, basic product, expected product, augmented product and potential product.
- Products are classified in to different ways such as tangibility, durability and usage that determine the pricing, promotion and distribution policies of organisation.
- Products are differentiated on the basis of design, features, quality, and durability.
- Product selection is based on decisions related to technology for producing products, capacity of production system, location of production facilities and planning and controlling system.
- Customers' expectations, cost and time are the three main aspects related to product design.
- Product development aims at enhancing the market position, making efficient utilisation of resources and improving organisational capabilities.
- The process of new product development includes idea generation, idea screening, concept development and testing, tangible product development, business analysis, market strategy development, market testing and commercialisation.
- Intangibility, inseparability, heterogeneity and perishability are the characteristics of services.
- Process of service design includes service concept, service package, performance specification, design specification and delivery specification.

2.8 Glossary

- **Augmented Product:** It includes some nonphysical parts, such as warranty and guarantee to the product for which customers may or may not pay premium
- **Basic Product:** It adds some other benefits to the core product
- **Core Benefit:** It refers to the main reason of buying any product
- **Expected Product:** It delivers the value as per the expectation of the customers
- **Marketing Mix:** It refers to the mix of all the controllable, such as product, price, place, and promotion
- **Potential Product:** It provides something beyond the expectations of customers
- **Product Life Cycle:** It defines the various stages of a product and industry
- **Shopping Product:** It refers to a product that is bought by a customer after analysing its merits and demerits
- **Unsought Product:** It refers to the product that is not completely known by customers; therefore, they feel hesitant in using that product

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2.9 Terminal Questions

1. Discuss the concept of product and its characteristics.
2. Elaborate on the concept of product selection.
3. Define product design.
4. Write a short note on service design.
5. Explain the concept of product development.
6. Discuss the new product development process.

2.10 Answers

Q.	Self Assessment Questions
1.	d Delivery time
2.	Augmented product
3.	True
4.	Product line analysis
5.	The combination of product lines of an organisation is called product mix.
6.	Product selection
7.	Plant location and layout, availability of funds and environmental conditions
8.	Computer Aided Design
9.	True
10.	Profit contribution analysis
11.	Commercialisation
12.	a Business Analysis
13.	True
14.	The steps of service design are as follows: 1. Service Concept 2. Service Package 3. Performance Specification 4. Design Specification 5. Delivery Specification
15.	Services

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Q.	Terminal questions
1.	Product refers to a good or service that satisfies the needs and expectations of customers. Refer to section **2.2 Concept of Product and its Characteristics.**
2.	Product selection is based on decisions related to technology for producing products, capacity of production system, location of production facilities and planning and controlling system. Refer to section **2.3 Product Selection.**
3.	Product design is a process of creating a product. Refer to section **2.4 Product Design.**
4.	Process of service design includes service concept, service package, performance specification, design specification and delivery specification. Refer to section **2.6 Design for Services.**
5.	Product development is a process of searching the best possible alternative for producing a product. Refer to section **2.5 Concept of Product Development.**
6.	The process of new product development includes idea generation, idea screening, concept development and testing, tangible product development, business analysis, market strategy development, market testing and commercialisation. Refer to sub section **2.5.3 New product development process**

2.11 Case Study:Tensator-the Innovator

Tensator is a small organisation, which until a few years ago, was not known for its innovation. The organisation's sales and marketing director **Terry Green** stated, *"I am a very firm believer that innovation doesn't need to be revolutionary. There's nothing my organisation has done that couldn't be done by anyone else."*

The Constant Force Spring, an item utilised in the production of vehicle seat belts across Europe, was manufactured by the light engineering firm Tensator. Even while the company is still making this product for this market, it has found much greater success with its newly released product lines.

It wasn't until Green joined the company in 1989 that he saw its full potential. Plans to manufacture waiting barriers for banks, supermarkets, and other establishments using the constant force spring were proposed in 1978. According to Green, "even though there was a feeling it could be expanded further," the team hadn't done much with it. The new product idea was his main point of persuasion.

Researchers polled present and future buyers to gauge their thoughts on the product's potential and identify ways it may outperform the competition. I couldn't have done it without the market research. The customer's demands and needs are the most important thing, as pointed out by Green, even though the task was not particularly complex.

The company's R&D efforts led to the release of Tensa Barrier. With a turnover of GBP 3 million in 1996, the product was exported to 36 countries. Compared to the original product, which had been developed in 1978 and was now contributing only a small portion of the company's revenue, this was a significant improvement in sales.

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Tensa barriers come in a wide range of designs and sizes presently. A bolt-down barrier and an electronic movement sensor are available for use in the checkout version specifically designed to deter theft. A lot of initiative went into the development of these and other advancements. "As soon as you understand that communicating with clients about their issues and how you might address them is the most important step," the author says.

In 1995 and 1996, Tensator introduced thirteen new goods to the market. Although the number of employees increased from 120 to 200 between 1988 and 2018, the total turnover more than tripled to GBP 10 million. "Innovation is about the successful implementation of new ideas, and it is as simple as that," Green says, making his case. It's not always about making ground-breaking innovations. Rather than discarding one major notion in favour of another, it's about making small adjustments to the way you do things.

Discussion Questions

1. Why do you think the new application of the constant force spring is more successful than its predecessor? (Hint: Developed after an extensive research and development program)
2. To what extent is the above case study, a good example of product portfolio planning? (**Hint:** Tensator followed the right approach by realising its potential and making plans to increase its product portfolio)

2.12 References and Suggested Readings

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CHAPTER

3 Inventory Planning

Structure

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Learning Objectives

After studying this chapter, you will be able to:

- discuss the concept of process planning and designing
- explain the various process types in manufacturing
- explain the various process types in services

3.1 Introduction

In the previous chapter you have studied the concept and significance of product analysis that is a systematic assessment of products. In addition, you also studied about the various steps involve in service design process. For analysing product and services effectively, an organisation needs to plan its production process with due care. In this chapter, let us discuss how organisations plan and design their processes for manufacturing products and providing services.

A process outlines the procedures and methods to be followed to produce and deliver a product or service. Designing of processes is one of the most crucial of the initial steps in operations management. Process designing can be defined as scheming of the activities that are pursued in an operating system. It indicates the manner in which the manufacturing resources are organised in the operations system. The designing of processes in manufacturing is very important as it helps in taking numerous decisions regarding how the flow of various processes in a manufacturing system should be arranged. For example, you may need to decide on the types of machines to use, the number of machines, and the way of their placement on a shop floor. Therefore, designing of processes ensure that flow patterns of this particular decision are optimised and appropriate operations management tools are used to control the overall operations effectively.

Designing an effective manufacturing process depends a lot on the detailed analysis of how each component will be manufactured. It consists of determining the number of steps involved in manufacturing, the machines used, and the time consumed in completing each step. This is generally called process planning. Effective process planning and design helps in improving performance and controlling operations at the production level.

Organisations, not only in the manufacturing sector, but in the service sector as well, gain competitive advantage over other players with improved processes. A well-designed and well-executed process increases operational efficiency, offers convenience to customers, reduces the cost of offering services, and improves the efficiency of service delivery. Effectively, it helps in achieving the goal of customer satisfaction. It also decides how much input and engagement from the client is needed during the service development and delivery processes. So, process design lays out a set of steps, the order in which they should be taken, and the responsibilities of the business, its intermediates, and its end users. It is a major factor in deciding how well service, production, and delivery are done.

If the manufacturing system produces a wide range of products, it requires certain types of process design for each type of products. However, if the manufacturing system is indulged into a mass production, where there are just one or two variations of products, a single process design is enough. By selecting an appropriate process design, a manufacturing organisation can not only easily streamline the product flow but also deploy the suitable operations management practices.

This chapter begins by explaining the basic concept of process planning and designing. Apart from this, the chapter also details about various process types in manufacturing and service sectors.

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3.2 Process Planning and Design

Process planning is the selection and sequencing of processes and operations for production. In other words, process planning is the act of preparing a comprehensive work guidelines that gives instructions to all the stakeholders about how to design the processes and operations to produce a product or service. It includes the selection of maufacturing processes and operations, production equipment, tooling, and fixtures. It also consists of determining manufacturing parameters and criteria to ensure product quality.

An efficient process planning mainly comprises:

- An interpretaion of the specifications regarding a part with dimensions and tolerances, surface roughness, material type, blank size, number of parts in a batch, etc.
- A detailed discription about the selection of processes and tools that are to be used for processing a part and its features
- A sequencing of opeartaions as a function of priorities at each level
- A grouping of basic operations on the same machine to reduce the operation time.
- A selection of machines to perform the different types of operations
- A selection of inspection methods and techniques to ensure the conformity of components with functional requirements
- A decision on how each and every operaition should be designed to control maximum time and cost involved in performing each operation
- Assembling the various process sheets in a comprehensive process planning file to be transferred to the manufacturing department for execution.

During the designing phase the process planning ideas and specifications are followed to provide detailed specifications of all components and sub-assemblies till the final product or delivery of service. It includes detailed drawings, assembly sketches and bills of materials that help in scheming the manufacturing process. With the help of process design, it becomes easy for the manufacturer to identify the required manufacturing facilities and equipment. A comprehensive and effective process planning and designing is essential to manufacture good quality products and services.

There are three major functions involved in the design and manufacturing interface of process planning for a product or service. These are:

1. Marketing and sales
2. Design
3. Manufacturing

Usually, marketing and sales function helps in analysing the existing market needs and trends regarding new product development. It also helps in generating specifications for the future development of current products. The design function takes the idea generated by marketing function and provides a detailed guideline regarding the desired output. The process requirement that is generated at the design phase is then passed to manufacturing function. The manufacturing department prepares detailed work instructions for producing products and services.

Therefore, although the design and manufacturing functions are separated, the process planning links them together. Fig. 3.1 shows that how process planning works as a design and manufacturing interface:

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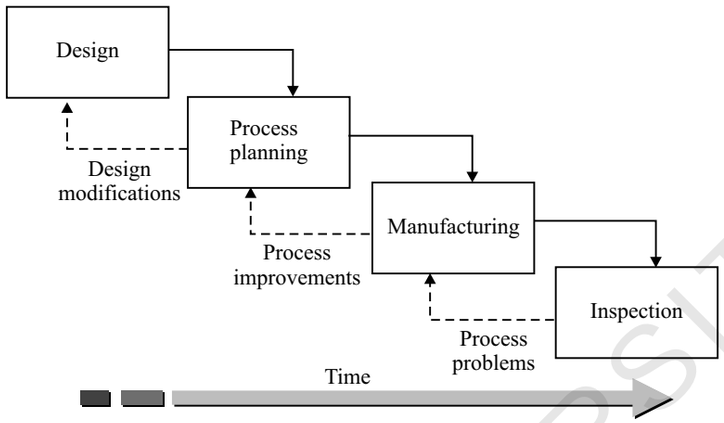

Fig. 3.1: Process Planning: Design And Manufacturing Interface
(**Source:** *Process Planning: The design/manufacture interface By Peter Scallan)*

Self-Assessment Questions

1. Process _____is the selection and sequencing of processes and operations for production.
2. Name the three major functions involved in the design and manufacturing interface of process planning for a product or service.
3. The design function takes the idea generated by marketing function and provides a detailed guideline regarding the desired output. (True/False)

3.3 Process Types in Manufacturing

Manufacturing processes can be defined as steps through which raw materials or input is transformed into a final product or output. In other words, the manufacturing process starts with creating materials that are modified to become the desired output. The manufacturing processes include treating (such as heat treating or coating), fabrication, or reshaping the material. It also includes planning the production process and testing and controlling for quality assurance during or after the manufacturing.

The manufacturing processes can be broadly classified into the categories shown in Fig. 3.2:

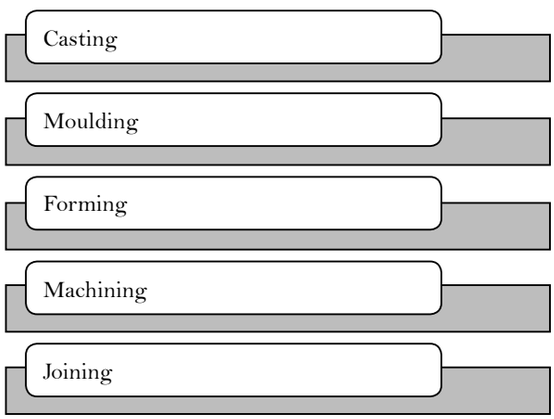

Fig. 3.2: Types of Manufacturing Process

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- **Casting:** It refers to a manufacturing process in which a liquid material is poured into a mould that comprises a deep cavity of the desired shape, and then the liquid is allowed to harden. After hardening, the liquid metal takes the shape of mould cavity. This solidified part is called casting, which is ejected out of the mould to complete the process. Casting materials are usually metals, such as epoxy, concrete, plaster, and clay that are made after mixing two or more components together. The metal casting process involves three steps:
  - Melting the metallic material by heating it in an appropriate furnace
  - Pouring of hot liquefied metal into a colder mould cavity
  - Removing the solidified cast from the mould cavity
- **Moulding:** The inverse of a cast is a moulding. Molds or matrices are hard frames that are used to mould raw materials, whether they are liquid or malleable. Molds are often hollow blocks that are filled with a liquid or flexible substance, such as molten metal, ceramic, glass, or plastic. Substantiating its form, the liquid solidifies within the mould. Furniture, home goods, cases, and structural materials are just a few examples of the many uses for moulded plastics.
- **Forming:** Metal forming is another name for it. The term 'forming' refers to the mechanical deformation process used to make metal components and finished products. The forming process involves reshaping the metal without changing its bulk in any way. That is to say, the geometry is only altered by manually shaping the metal that already exists. Mechanical deformation of metals requires forces greater than their yield strengths. It causes a tiny amount of material to be compressed, stretched, or bent, and the geometric changes persist even after the stress is withdrawn.
- **Machining:** The term refers to the manufacturing process wherein a block of raw material is controlled-removal-process-cut into the specified size and shape. To rephrase, it is a technique that involves cutting away excess material from a raw material in order to get a specific shape. Since the majority of the raw material is removed during machining to produce the finished product, it is not the most cost-effective procedure for primary manufacturing. Consequently, the initial stage of production could be quite expensive. Consequently, machining is typically reserved for cases where a small amount of material needs to be removed, such as when creating prototypes or engaging in secondary production procedures. It is common practise to enlarge or improve an existing component of a product via machining.
- **Joining:** It is the manufacturing process that is primarily concerned with the assembly of the components into subassemblies or final products. Joining can be further divided into three major categories:
  - **Fasteners:** These are mechanical devices that assemble materials via applying force, pressure, or friction, for example, threaded fastener, pins, and riveting.
  - **Welding:** It involves joining of two or more pieces of material by applying heat, pressure, or both. Welding produces a temporary amalgamation through fusion or recrystilisation and results in creating a chemical bond. Welding can be in the form of electrical, mechanical, chemical, and optical, such as beam or rays. Arc welding, resistance spot welding, and friction welding are few examples of welding process.
  - **Adhesives:** It refers to a welding process that joins two or more material through glues. In other words, it is a gluing process that depends on adhesive bonding.

Notes

3.3.1 Job shop

A job shop is a kind of manufacturing that produces a wide variety of goods in small quantities. The majority of manufactured goods in a job shop necessitate a one-of-a-kind arrangement and sequence of production stages. Typically, job shops are companies that make specialised components for other companies. Some examples of job shops that produce bespoke goods in small batches include machine tool shops, machining centres, paint shops, and commercial printing shops. Custom items made in small batches are what these companies specialise in.

Job shops are one of the first structures for a manufacturer in the process life cycle as it produces variety of customised products in small quantity. Job shops give the manufacturers greater flexibility in making a variety of products to meet customer's expectations regarding quality standards. However, as the manufacturer starts manufacturing in large volume and standardising the product offerings, the basic job shop structure also augments into more complex manufacturing structures. For example, with increased volume of manufacturing, a job shop may turn into a batch flow production, assembly lines, or continuous flow production that denote to a less flexible, standardised, and complex form of manufacturing structures. With high volume and standardisation, both flexibility and unit costs tend to decrease.

When planning the process layout in the work shop, it is common practise to group together pieces of machinery or tasks that perform comparable duties. Say, for instance, a separate room for grinding machines and another for drill presses. The goal of the process design was to reduce the amount of time, effort, and money spent on material handling and process inventory management. Workers in a job shop typically possess extensive skill sets and are able to operate a wide variety of machinery. A job shop is seen in Fig.3.3:

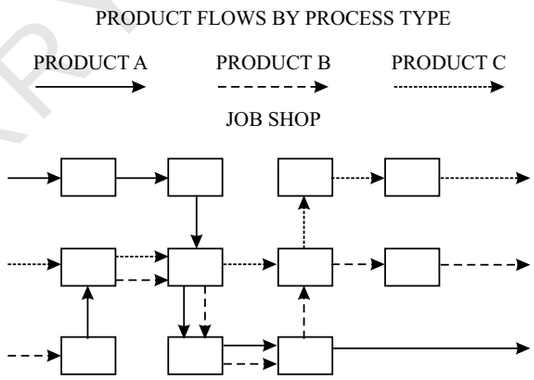

Fig.3.3: Job Shop

*(**Source:** https://www.google.co.in/url?sa=t&rct=j&q=&esrc=s&source=web&cd=9&cad=rja&uact=8&ved=0CEIQFjAI&url=http%3A%2F%2Fwww.ohio.edu%2Fpeople%2Fcutright%2FPROCESSMANAGEMENT.doc&ei=_BcAVOm0Ksm5uATJp4CYCA&usg=AFQjCNHhx2wS3lvJSy70uPTj0-g8iN_ovA&bvm=bv.74115972,d.c2E)*

3.3.2 Flow shop

In flow shop manufacturing process, there are multiple jobs that require processing on different machines. In other words, it is a special type of job shop where *n* numbers of machines are used and a job may require maximum of *n* operations. It means one machine is needed to work on one operation. These machines are numbered as 1, 2, 3, 4…. *n*. Further for every job, if operation *h* precedes operation *j*, then machine required for operation *h* would have lower number than the machine required for operation *j*. Unlike, job shop, a flow shop process is less flexible and uses specialised resources and fixed path to accomplish the work. Fig. 3.4 shows an example of a pure flow shop:

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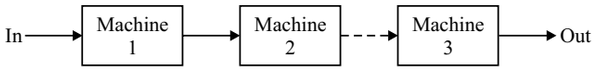

Fig. 3.4: A Pure Flow Shop
(**Source:** *Modern Production / Operations Management, 8th ed. by Buffa, Sarin)*

Fig.3.4, shows an example of a pure flow shop where all the jobs require one operation on each machine. However, in many cases, a job may require more than one operation and all the operations need not to be performed on adjacent processors. Such examples of flow shops are known as general flow shop.

Fig. 3.5 shows an example of a general flow shop:

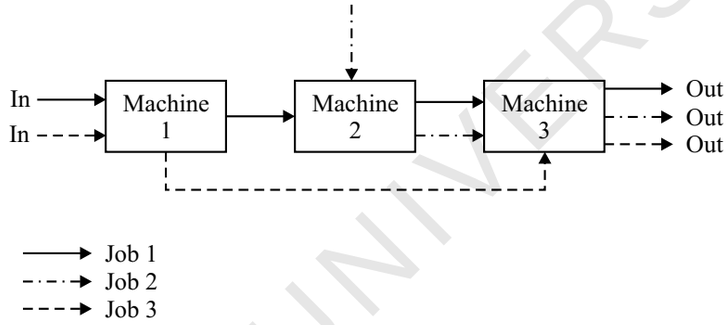

Fig. 3.5: A General Flow Shop
(**Source:** *Modern Production / Operations Management, 8th ed. by Buffa, Sarin)*

In the example shown in Fig. 3.5, job 1 is processed on all three machines, 1, 2, and 3. Job 2 is processed on machines 2 and 3, and job 3 is processed on machines 1 and 3.

Assembly line is one example of flow shop where work progresses from one stage to another in the same direction. In addition, many manufacturing units, such as the manufacturer of printed curcit boards use the same sequence of operations for large number of orders.

3.3.3 Batch manufacturing

In batch production process, goods are produced in batches instead of being produced in line. This type of production is majorly used by pharmaceuticals, shoes manufacturers, purifying manufacturers, etc. The products have different variety and size of batches. However, the batch size is not usually very large as in the case of mass production. In batch production, scheduling is performed for a particular batch and its sequence,and not for the complete product. General machines can be easily used for a different variety and batches of products. It is a repetitive production process, in terms of the stocks of the product. Unlike mass production, batch production is no longer a continuous production,because the batches keep changing.

In the batch production, scheduling can be chalked out according to specific orders or on the basis of demand forecasts. Prof. Druncker has given a single name "unique product production" to job and batch type of systems.

In batch system, once the orders are received, production-scheduling operations begin. Here, the schedules are not prepared in advance. Similarly, no advance planning and scheduling are done for procurement of raw materials for these systems. Systems working starts only on the receipt of orders from the customers.

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Fig 3.6 depicts the different stages of a batch on the assembly line:

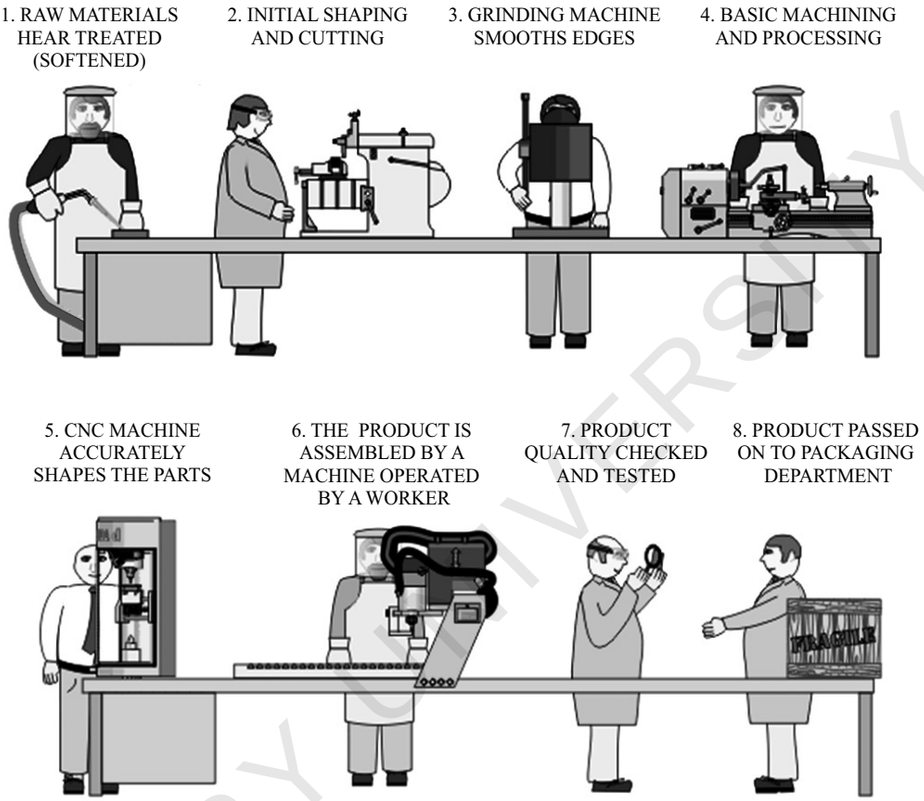

Fig 3.6: Various Stages in Batch Production
(**Source:** *http://www.technologystudent.com/images4/bat2a.gif)*

Let us now discuss the characteristics of batch production:

- A flexible workforce is required, because workers are expected to switch between the different parts of the production line
- The production line is frequently changed to produce different batches of a variety of products
- It is easy to design and produces a variety of products
- The production cost is even lower than mass production
- The products produced have better quality, because a particular batch is concentrated at once.

3.3.4 Line manufacturing/Assembly line

Line manufacturing or assembly line manufacturing can be defined as a manufacturing process with various operations in line. In an assembly line, a conveyor belt is used to move products from one workman to anotherand every workman adds his bit to the product. The product arrives on the belt in the form of separate parts and at the end of the line, transforms into a complete product. These small parts are often referred as sub-assemblies in mass production terminology.

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In assembly line, each worker is responsible for fixing and adjusting one specific part of the product. For example, a carpenter builds a complete product from start to finish, whereas, using the assembly line technique, tasks like cutting, affixing and decorating can be distributed among different carpenters, so that one carpenter is responsible for only cutting every piece, another for adjusting and fixing, and a third one for decorating the product as required. This helps the carpenters produce more finished goods than the total of their individual efforts. Fig 3.7 depicts the line manufacturing functions:

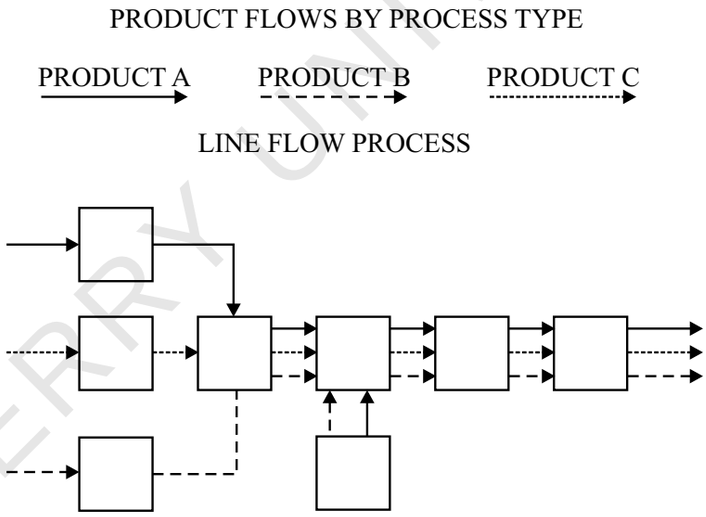

Fig 3.7: Line Manufacturing

(**Source:** *https://www.google.co.in/url?sa=t&rct=j&q=&esrc=s&source=web&cd=9&cad=rja&uact=8&ved=0CEIQFjAI&url=http%3A%2F%2Fwww.ohio.edu%2Fpeople%2Fcutright%2FPROCESSMANAGEMENT.doc&ei=_BcAVOm0Ksm5uATJp4CYCA&usg=AFQjCNHhx2wS3lvJSy70uPTj0-g8iN_ovA&bvm=bv.74115972,d.c2E)*

The line maufacturing method can be dated back to 1913 when a'Model T' by Ford Company gained so much popularity that it was demanded by almost half of the US. Henry Ford then decided to start bulk production to meet the huge demand and this is how the modern mass production came into existence.Henry Ford wanted each worker to remain at an assigned place to perform the assigned task. Thus, the automobile was produced faster and in larger quantities, saving a lot of time. Since then, line manufacturing has been successfully absorbed and adopted for mass production by manufacturers.

3.3.5 Mass manufacturing

Mass manufacturing is the process of producing similar types of goods in large numbers. It often uses assembly line technology for production. Mass manufacturing is a low-cost, time-saving process and produces standardised products. In addition, mass manufacturing allows

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a manufacturer to produce a larger quantity using lesser workforce, so that the goods can be bought at lower costs. Mass manufacturing takes advantage of both highly-skilled and un-skilled labour. Highly-skilled labour usually designs a product along with setting up a system for its production, while unskilled labour produces standardised parts of the products with the help of specialised machinery. Specialised machineries used in mass manufacturing also help in easy employment of un-skilled labour, because no special skills and training are required and expected from them.

Mass manufacturing was adapted by manufacturers during the industrial revolution, but it was the invention of the assembly-line technology that made mass manufacturing a real success. Let us now discuss the characteristics of mass manufacturing:

- The mass manufacturing process is highly mechanised and is interlinked. Thus, in mass manufacturing different process work in synchronisation with each other and have very little manual intervention.
- A large number of machines and standard methods are employed for mass manufacturing, with most of the equipment being automatic and semi-automatic in nature.
- Products are standard i.e. whatever is produced is of a similar type, irrespective of the quantity of the product.
- In mass manufacturing, high standard of accuracy is maintained in products. This helps in minimising the number of errors.
- Semi-skilled and un-skilled workers can be easily employed, because most of the work is automated and requires no special skills and training.
- The process is designed to achieve high volume of production and hence is low on cost.
- There is an elaborate mechanism for ensuring the continuous supply of raw materials. This ensures that there is no compromise on the quality and the quantity of the production process.

3.3.6 Continuous manufacturing

The term "continuous manufacturing" describes a process that involves making a product with no breaks in between. Since the production of goods necessitates the sequential execution of several processes on a number of machines that receive raw materials through a closed channel, this method is also known as a continuous process or continuous flow process. Every step of the processes is dynamic, as they undergo heat treatment, chemical interactions, or both. Industries such as paper and chemicals often use continuous manufacturing. Equipment or work processes are organised in accordance with the precise procedures in making the product in this style of production, which is known as flow operations.

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The continuous production function is illustrated in Figure 3.8.

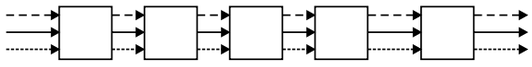

Fig.3.8: Continuous Manufacturing

(Source: https://www.google.co.in/url?sa=t&rct=j&q=&esrc=s&source=web&cd=9&cad=rja&uact=8&ved=0CEIQFjAI&url=http%3A%2F%2Fwww.ohio.edu%2Fpeople%2Fcutright%2FPROCESSMANAGEMENT.doc&ei=_BcAVOm0Ksm5uATJp4CYCA&usg=AFQjCNHhx2wS3lvJSy70uPTj0-g8iN_ovA&bvm=bv.74115972,d.c2E)

Some common continuous processes are:

- Oil refining
- Chemicals
- Synthetic fibres
- Fertilisers
- Pulp and paper
- Blast furnace (iron)
- Metal smelting
- Power stations
- Natural gas processing
- Sanitary waste water treatment
- Continuous casting of steel
- Float glass

Employees working in such manufacturing processes, commonly work in rotating shifts as the processing of materials never tends to pause or stop. In continuous manufacturing, processes are operated continuously as shutting down and starting up many continuous processes is usually costly and may also result in poor quality product. For example, in many instances, tanks, vessels and pipes in the manufacturing units cannot be left full of materials/chemicals as it could result in chemical reactions, settling of suspended materials or hardening of materials. Also, cycling temperatures and pressures from starting up and shutting down certain processes (line kilns, boilers, blast furnaces, pressure vessels, etc.) may cause metallic weariness and they may break due to pressure.

3.3.7 Project manufacturing

Project manufacturing is a manufacturing process designed to produce big, exclusive, and specific, products such as customised buildings, large bridges, defence weapons like aircraft carriers and submarines, and aerospace products like passenger planes, and the space shuttle. It uses multiple operations designed to produce exclusive but similar products.

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Project manufacturing is usually very flexible as each project is often unique in nature and therefore demands high customisation. In addition, as such projects are very large, highly customised, and expensive; they may require a long time to get completed.

Self-Assessment Questions

4. What do you understand by manufacturing processes?

5. _____refers to a manufacturing process in which a liquid material is poured into a mould that comprises a deep cavity of the desired shape, and then the liquid is allowed to harden.

a. Forming

b. Machining

c. Casting

d. Joining

6. Forming is the process in which a piece of raw material is cut into a desired shape and size by a controlled material-removal process. (True/False)

7. Why does machining is considered as very costly at primary manufacturing stage.

8. _____involves joining of two or more pieces of material by applying heat, pressure, or both.

9. Job shops are one of the first structures for a manufacturer in the process life cycle. (True/False)

10. Define flow shop.

11. In batch production, production line is frequently changed to produce different batches of a variety of products. (True/False)

12. What among these is not a characteristics of batch production:

a. Workers are expected to switch between the different parts of the production line

b. It is easy to design and produces a variety of products

c. The production cost is higher than mass production

d. The products produced have better quality, because a particular batch is concentrated at once.

13. In mass production, each worker is responsible for fixing and adjusting one specific part of the product. (True/False)

14. _____allows a manufacturer to produce a larger quantity using lesser workforce, so that the goods can be bought at lower costs.

15. "In continuous manufacturing, processes are operated continuously." Why? Give reason to support your answer.

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Activity

Using Internet, search for examples of products for which the process of mass production is used. Also, attempt to differentiate products being produced in batches. Present your findings in a short note.

3.4 Process Types in Services

In today's competitive scenario, service has become crucial to an organisation's success. This is not only applicable to the service industry but many manufacturing organisations as well. When products of a similar quality are compared, the quality of service offered becomes the basis for differentiation.

Services create a unique position in the market for manufacturing organisations. Products are increasingly associated with service components. This is known as the servitisation of products. For example, IBM manufactures physical goods such as computers and servers, but treats its business as a business solution service. Similarly, organisations like General Motors, the Tata Group, Samsung and Hewlett-Packard have also recognised the importance of delivering quality service.

Designing service processes is an activity of planning and organising people, structure, communication and other components of a service to improve its quality and develop the interaction between service provider and customers. Similar to product processes, the processes of services are also designed by the organisations with greater emphasis. The purpose of designing service processes is to meet the needs of customers, so that the service is considered by them as user-friendly, competitive and relevant.

Production and delivery are interwoven in the service industry, making differentiation between the two impossible. So, anything having to do with making or delivering the service is part of the process. In addition, the whole attention and effort of the service staff is required for processes to be finished properly. Keep in mind that services cannot be passed on or claimed as debt because they:

- cannot be stocked or shipped
- perish immediately after delivery
- come into existence at the time they are bought and consumed

Let us look at an example of a service. Suppose you have booked an air-ticket to fly to Singapore on a certain date. You can use the service, i.e. travel on the date mentioned on your ticket. However, in case you do not avail the service on the specific date, the ticket will "perish" or become unusable immediately. Besides this, you cannot stock or re-use the same ticket as you have already consumed the service at the time you travelled.

The service sector is characterised by its diversity. On the one hand, there are large service organisations that offer a vast range of services in sectors such as insurance, railways, banking, freight transportation, hospitality, telecommunications and computer software. On the other hand, there are numerous locally owned and operated small businesses, such as laundry services, barbers, plumbers and carpenters that also play an important role in our daily lives.

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Processes in services are classified on the basis of service process matrix that is a classification matrix for service industry organisations and classifies service processes based on their characteristics. Service process matrix was derived by Roger Schmenner in 1986. Fig.3.9 shows the service process matrix:

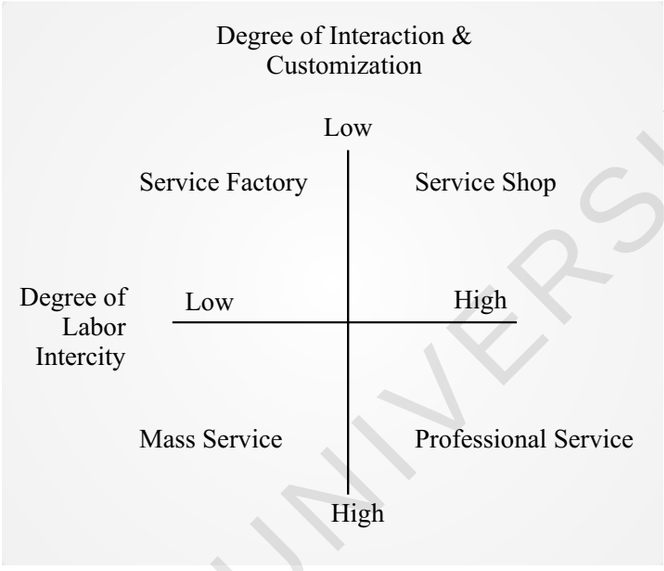

Fig.3.9: Service Process Matrix

(**Source:** *Adapted from Schmenner, Roger W. Service Operations Management, Englewood Cliffs, NJ: Prentice Hall, 1995, page 11)*

As shown in Fig.3.9, the classification of service processes is based on two dimensions:

- **The degree of labour intensity:** Labour intensity is the ratio of labour cost to plant and equipment. Organisations whose product or services, require a huge time and effort with relatively lesser plant and equipment cost are called labour intense.
- **The degree of customer interaction and customisation:** The term "customer contact" describes the level of participation from the client in the service delivery procedure. Because there is a lot of back-and-forth, clients can easily request more or less of certain features. Contrarily, customisation is the act of altering services to meet the needs of clients. There are four distinct types of service procedures that can be defined by these two criteria:
- **Mass services:** Organisations with a high labour intensity but low interaction and customization level are located in the lower left quadrant of Figure 3.9. The term "mass service" describes this section. Wholesalers, full-service stores, spectator sports, and big classrooms are all examples of this type of service. Processes and standards are heavily standardised in mass services. High volume output and process repeatability are more likely to occur as a result of standardised services. Due to the high degree of standardisation in the processes and the low frequency of client interaction, the demand for professional workers may fluctuate.
- **Professional services:** Companies with a high level of interaction and customisation, as depicted in the lower right quadrant of Figure 3.9, are associated with a high level of labour intensity. This section is devoted to service providers with extensive expertise and specialist knowledge in their respective fields; they are known as professional

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service providers. Service industries like healthcare, legal, accounting, architecture, and investment banking are known for their high levels of client involvement, personalisation, and labour intensity. Providers that engage in this service process typically have extensive one-on-one interactions with clients in order to understand their unique requirements and design individualised solutions.

- **Services shops:** Fig. 3.9 shows that businesses with a low labour intensity but high interaction and customisation rate are located in the top right quadrant. The service shop is marked on this quadrant. Customer requirements and preferences are given a great deal of attention in processes that fall under service shops, which also entail regular interaction between staff and consumers. Service shops demand highly skilled workers due to the high degree of personalisation of services offered, in contrast to service factories or mass service operations that offer more uniform offerings. The reason behind this is that personnel frequently have to deal with unusual or novel services that customers request. Some examples of such establishments include hospitals, repair businesses, and fine dining restaurants.
- **Service factory:** Organisations with a low level of interaction and customisation, as depicted in the upper left quadrant of Figure 3.9, are those with a low degree of labour intensity. Service factory describes this section. These companies take advantage of economies of scale by hiring low-cost, unskilled labourers because there is little client engagement and customisation and the labour intensity is minimal. Services such as these are provided by many businesses and organisations, such as movie theatres, dry cleaners, airport baggage handling, public transit, banks, insurance, and postal service facilities. The purpose of the interaction between staff and clients in these types of procedures is to provide uniform service. Furthermore, it is in self-service mode if the consumer is engaged.

Self-Assessment Questions

16. It is not possible to differentiate production from delivery in services as they are inseparable in nature. (True/False)

17. The classification of service processes is based on two dimensions. Name them.

18. Processes under _____involve frequent interaction between the employees and customers and considerable attention is given to a customer's needs and preferences.

19. Due to low labour intensity and very less customer interaction or customisation _____ organisations take advantage of economies of scale and may hire low-cost unskilled manpower.

a. Mass services

b. Service factory

c. Professional services

d. Services shops

20. In mass services, specifications are under tight control and processes are highly standardised. (True/False)

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3.5 Summary

- Process planning is the selection and sequencing of processes and operations to transform a particular raw material into desired final component.
- The design function follows the process planning ideas and specifications to provide detailed specifications of all components and sub-assemblies for the final product or service.
- The manufacturing process starts with creating materials that are modified to become the desired output.
- Types of manufacturing process can be classified into:
  - Casting
  - Moulding
  - Forming
  - Machining
  - Joining
- A job shop denotes to a manufacturing process where small batches of a range of products are made.
- In flow shop manufacturing process, there are multiple jobs that require processing on different machines.
- In batch production process, goods are produced in batches instead of being produced in line.
- Line manufacturing or assembly line manufacturing can be defined as a manufacturing process with various operations in line.
- Mass manufacturing is the process of producing similar types of goods in large numbers.
- Continuous manufacturing is a production method used to produce materials without any disruption.
- Project manufacturing is a manufacturing process designed to produce big, exclusive, and specific, products such as customised buildings, large bridges, defence weapons, etc.
- Processes in services are classified on the basis of service process matrix that is a classification matrix for service industry organisations and classifies service processes based on their characteristics.
- The classification of service processes is based on two dimensions:
  - The degree of labour intensity
  - The degree of customer interaction and customisation
- Service processes can be classified into four categories
  - Mass services
  - Professional services
  - Services shops
  - Service factory

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3.6 Glossary

- **Assembly line:** A method that is employed in production, where a product is assembled from various sub-assemblies with the help of specialised machines and using fewer workforces.
- **Batch production:** A production method where the required product is produced in a stage-by-stage process over a series of workstations.
- **Mass production:**The production of standardised articles in mass quantity all at once.
- **Lot size:** The size of the product quantity that needs to be produced during one production cycle.
- **Fabrication:** It is an operation, where products are generated from raw material by using a line function.

3.7 Terminal Questions

1. Discuss the significance of process planning and design.
2. Discuss the various types of manufacturing process.
3. What do you understand by mass production? Discuss.
4. Write a short note on assembly line.
5. Define batch production. How is it different from mass production?
6. Discuss the various process types in services.

3.8 Answers

Q.	Self Assessment Questions
1.	Planning
2.	The three major functions involved in the design and manufacturing interface of process planning for a product or service are: a. Marketing and sales b. Design c. Manufacturing
3.	True
4.	Manufacturing processes can be defined as steps through which raw materials or input is transformed into a final product or output.
5.	c. Casting
6.	False
7.	Machining is not the most economical choice for a primary manufacturing process as the major part of the raw material is cut away to achieve the final part.
8.	Welding

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9.	True
10.	In flow shop manufacturing process, there are multiple jobs that require processing on different machines.
11.	True
12.	c. The production cost is higher than mass production
13.	False
14.	Mass manufacturing
15.	In continuous manufacturing, processes are operated continuously as shutting down and starting up many continuous processes is usually costly and may also result in poor quality product.
16.	True
17.	The two dimensions for classifying service processes are: a. The degree of labour intensity b. The degree of customer interaction and customization
18.	Service shops
19.	b. Service factory
20.	True
Q.	**Terminal Questions**
1.	Process planning and design is the selection and sequencing of processes and operations to transform a particular raw material into desired final component. Refer to section ***3.2* Process Planning and Design.**
2.	The various types of manufacturing process can be classified into, casting, moulding, forming, machining, and joining. Refer to section ***3.3* Process Types in Manufacturing.**
3.	Mass production is the process of producing similar goods in large numbers and often uses assembly line technology for the production. Refer to section ***3.3* Process Types in Manufacturing.**
4.	Assembly line can be defined as the line with various operations in line, where a conveyor belt is used to move a product from one workman to another, so that each workman can add his bit to the product. Refer to section ***3.3* Process Types in Manufacturing.**
5.	In the batch production process, goods are produced in batches instead of being produced in line. This type of production is majorly used by pharmaceuticals, shoes manufacturers, purifying manufacturers, etc. Refer to section ***3.3* Process Types in Manufacturing.**
6.	Service processes can be classified into four categories, namely mass services, professional services, services shops, and service factory. Refer to section ***3.4* Process Types in Services.**

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3.9 Case Study: Mass production vs. Batch Production

ABC Pvt. Ltd. is a manufacturing organisation that produces biscuits. After doing well for years and making a place in the hearts of consumers, the company decided to increase the variety of biscuits such as peanut biscuits, cashew-nut biscuits, butter cookies, and chocolate biscuits. Initially, it only produced salted biscuits by using the mass production process. Since the company was well established and already had the machineries for mass production, it started creating new varieties with help and guidance from a team of food experts. Experts not only suggested them the new flavours but the best quality of material and processing, so that the new varieties produced by the company may be as good as their previous products. However, even six months after the latest set-up, the company was unable to meet the market demand for the new variety of biscuits. The management then decided to look into the matter on a priority to resolve the issue at the earliest.

The production manager who was given responsibility to investigate the matter found that the company was either producing too much or too less as per the demand of the market. This was happening, because the company was into mass production and did not consider introducing batch production to produce the right amount of quantity for each variety i.e. larger batches for products with more demand and lesser for products with less demand. Management immediately incorporated the batch production process and the company soon started doing well again.

Discussion Questions

1. Why do you think the company did not succeed through mass production?

   (**Hint:** The mass production process was producing some flavours of biscuits in more quantity than their demand. This leads to the excess storage of the finished product, which leads to the wastage and loss.)

2. How did the process of batch production help the company?

   (**Hint:** The batch production process helped the company in making batches as per the demand so there were no stocks of finished goods and hence no wastage.)

3.10 References and Suggested Readings

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CHAPTER

4

Plant Location and Layout Planning

Structure

Notes

Learning Objectives

After completing this chapter, you will be able to:

- explain the concept of facility location
- discuss the factors that affect a facility location
- elaborate on the current trends in industry location
- explain the concept of plant layout
- discuss the principles of selecting a plant layout

4.1 Introduction

The previous unit discussed about process design used in the manufacturing organisations. This unit focuses on the selection of the plant location and layout for manufacturing the goods and services. Selection of an appropriate plant location and layout are the two most important strategic decisions made by an organisation. This is because the overall profitability of an organisation depends on the location and layout of its plant as it affects the cost in terms of accessibility of various resources. In fact, it is a big strategic decision that may affect the revenue, growth and can be decisive for future prospects of the organisation as well. An organisation invests a large sum of money for selecting a plant location and developing a layout. Therefore, an improper location and layout of plant may incur heavy losses.

Plant location refers to a region or site selected by an organisation for setting up a business or factory. Selecting a plant cannot be changed very often. Therefore, an organisation selects a plant location after analysing the cost and benefit aspects of different alternative sites. An ideal plant location is one where the cost of the product is kept at minimum with a large market share and lower risks. To achieve this objective, an organisation needs to take into account various factors, such as proximity to market and raw materials, environmental policy and availability of labour and capital.

After selecting a plant location, the next challenge for an organisation is to design an effective plant layout. Plant layout is all about the arrangement of physical facilities, such as machinery, equipment, and tools in a way to maintain a quick flow of materials at a minimum handling cost. A well-designed plant layout helps an organisation to make efficient utilisation of available floor space and labour, reduce accidents and improve its productivity.

This chapter begins by explaining the concept of facility location and factors affecting it. Next, it explains Alfred Weber's theory of industrial location and Sargent Florence's theory of industrial location. The chapter further discusses current trends in choosing the industry location. Towards the end, it explains the concept of plant layout and its importance.

4.2 Concept of Plant Location

Plant location of a business plays a significant role in the growth as a proper plant location helps to gain a competitive advantage by reducing various production and distribution costs. An organisation should be careful while selecting its plant location as any mistake at this stage may have adverse effects on its operations, thereby incurring huge losses for the organisation. For example, the cost of procuring raw materials would be lesser for an organisation located near the sources of raw material as compared to that of an organisation located at a distant place. Similarly, an organisation that is located near the market would be able to launch its products in the market quicker as compared to an organisation located in a remote area. Thus,

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A good plant location helps an organisation in establishing a plant layout ensuring an adequate supply of raw materials. Some of the important factors that should be considered by an organisation while selecting its plant location are proximity to raw materials, proximity to customers, availability of labour, and environmental policy. An organisation may look for a new plant location for the following reasons:

- Commencement of a new business
- Obsolescence of the existing technology
- Expansion of the existing business
- Expiry of the lease agreement
- Reduction in overall costs
- Irregular supply of labour
- Market fluctuations

Regardless of the reason for selecting a new plant location, an organisation should consider all the factors that affect its plant location. Although it is difficult to find out a location having all the desired plants, an organisation should select a location that would generate maximum growth, competitive advantage and low costs.

4.2.1 Factors affecting a plant location

While selecting a plant location, an organisation should consider various factors that can have significant impact on its production and service. These factors are shown in Fig.4.1:

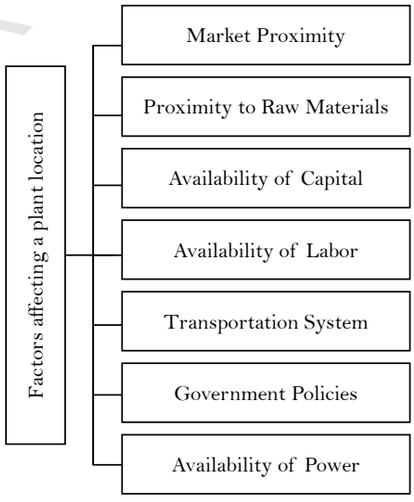

Fig.4.1: Factors affecting a plant location

The factors are explained as follows:

- **Market Proximity:** It implies the accessibility of an organisation to the market. Market proximity allows an organisation to deliver its product on time, which, in turn, results in one aspect of customer satisfaction. Apart from this, market proximity leads to reduction in transportation costs. This ultimately helps an organisation to reap the benefits of favourable prices and high market demand.

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- **Proximity to Raw Materials:** Accessibility to the sources of raw materials reduces the transportation cost of an organisation and maintains regular supply of raw materials. This enables an organisation to carry out its production process smoothly. Therefore, while selecting a plant location, an organisation should also perform in-depth analysis of the time and cost involved in the procurement of raw materials. In case the time and cost for the procurement of raw materials are high, the organisation should search for other available alternatives.
- **Availability of Labour:** It is another important factor that an organisation should take into account while selecting its plant location. Labour is a vital resource in the production process of an organisation. The machines and equipment of an organisation cannot produce anything without the availability of skilled labour. Therefore, an organisation should look for a location where there is easy availability of labour at minimum cost.
- **Transportation System:** Availability of proper transportation can ensure timely and regular supply of raw materials and finished goods at a relatively low cost. Therefore, it is necessary for an organisation to give due consideration to the availability of transportation facilities while selecting a plant location. Transport systems include airplanes, trains, buses, trucks, and ships.
- **Government Policies:** To ensure a balanced regional development, the government undertakes various schemes and policies. For example, the government provides various incentives and subsidies to organisations that establish their units in backward areas. On the other hand, the government restricts the location of industrial units in certain areas, such as residential areas. Therefore, it is important for an organisation to thoroughly study all government policies before selecting a location.
- **Natural Factors:** These include factors such as land, water, and agricultural climate. These factors are important for some industries, including cotton, textiles, sugar, and jute as these industries depend on favourable climatic conditions and proximity to the source of raw materials.
- **Availability of Power**: The production process of an organisation would come to a halt in the absence of power. Therefore, proper availability of power is vital for an organisation to function properly.

4.2.2 Alfred Weber's theory of industrial location

Alfred Weber, a German economist, made an attempt to analyse the factors that influence industrial location. According to him, the factors that affect facility location can be broadly classified into two categories, which are shown in Fig.4.2:

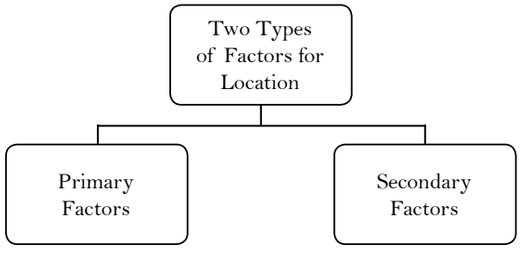

Fig. 4.2: Factors Affecting a Facility Location

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The two types of factors that affect the location of a facility are explained as follows:

- **Primary Factors:** These include the following:
  - **Transportation Cost:** It implies the cost that is incurred by an organisation while moving raw materials from a market to warehouse; and finished goods to the market for the purpose of selling. The transportation cost depends on two factors, namely distance to be covered and weight of products to be transported.

    While moving raw materials from the market to warehouse, the transportation cost depends on the type of raw materials. An organisation can procure two types of raw materials, namely ubiquities and localised raw materials. Ubiquities refer to materials that are available everywhere, for example, water and bricks. On the other hand, localised raw materials are the materials that are available at specific places, for example, coal and minerals.

    Weber has further classified localised raw materials into two categories, namely pure materials and weight losing materials. Pure materials are the ones that retain their weight in the production process, for example, iron and wood. On the other hand, weight losing materials do not retain their weight in the production process, for example, sugar cane.

    According to Weber, the extent to which localised raw materials go with their weight till the final product is the governing factor for the location of an industry. The ratio of the weight of localised raw materials to the weight of finished products is called material index, which is mathematically expressed as follows:

    $$\text{Material Index (MI)} = \frac{\text{Weight of locatlised raw materials}}{\text{Weight of finished product}}$$

    If MI is greater than one, it is advisable to establish a plant near the sources of raw materials. On the other hand, if MI is less than one, the industry should be located near the consumption centre.
  - **Cost of Labour:** It signifies the cost incurred by an organisation to acquire services from labour. Weber has advocated that if the concerned industry is labour intensive, it would tend to locate near the labour centre. Otherwise, the industry would prefer its location in conformity with transportation costs.
  - **Secondary Factors:** These include both agglomerative and deglomerative factors. An agglomerative factor refers to an advantage of reducing the cost of production due to centralisation of industries. On the other hand, a deglomerative factor is an advantage of reducing the cost of production due to decentralisation of industries. Agglomerative and deglomerative factors further depend on two regional factors, namely transportation cost and labour cost.

4.2.3 Sargent Florence's theory of industrial location

One of the main critics of Weber's deductive theory of industrial location was Sargant Florence. He criticised the geographical aspect of location in Weber's theory. In his theory of industrial location, Sargant Florence has shown a relationship between industry distribution and population distribution. He advocated that the relationship between an industry and the distribution of population is more important than the relationship between an industry and its area. In his theory, he developed two new concepts, namely location factor and coefficient

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of localisation to explain the pattern of the location of an industry. These two concepts are discussed as follows:

- **Location Factor:** It indicates the extent of concentration of industries in a particular region. According to Florence, location factor can be determined by considering two ratios. First is the ratio of number of workers employed in an industry to the number of workers in the region where the industry is located. Second is the ratio of number of workers in the region to the number of workers employed nationwide in that industry. The location factor is calculated by dividing the former ratio by the later one.

  Location factor= Number of workers employed in an industry to the number of workers in the region / Ratio of number of workers in the region to the number of workers employed nationwide in that industry

  If the quotient is equal to one, it represents even distribution of industry all over the country. On the other hand, if the quotient is greater than one, it signifies higher share of industry in the region. A quotient lower than one indicates that the concerned region does not have sufficient share of the industry.

- **Coefficient of Localisation:** It refers to the relationship between percentage of workers employed in a particular industry in a specified region and the percentage of workers employed nationwide in that industry. The coefficient of localisation indicates the propensity of an industry for concentration. It is concerned with a particular industry and not with a particular region.

  However, this theory has been criticised on the following grounds:

  - The theory is unable to explain the reasons behind the selection of a location.
  - Instead of using political regions for finding out the coefficient of localisation, the theory has used economic regions.
  - The theory has advocated that all countries have identical localisation. However, in reality, the local conditions of different countries vary from each other.

4.2.4 Influence of government on industry location

In the private sector, the main objective of every organisation is the profit maximisation. Therefore, an organisation generally prefers to establish in urban or developed regions that yield maximum profits. Such type of practice of organisations may result in the concentration of organisations in some selected regions. This would act as a major constraint in the balanced regional development of a country. To restrict such practices of organisations, the government has launched various schemes and policies. Some of these policies are explained as follows:

- Various incentives and rewards are announced periodically by the government to motivate organisations for locating their units in underdeveloped and backward areas.
- The government always selects less developed areas for establishing public sector units.

Activity

Visit any manufacturing plant (factory) in an industrial area and meet its industrial/ factory manager. Note down the factors that are considered for its selection.

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Self-Assessment Questions

1. Which of the following cannot be reason for an organization to look for a new facility location?
   a. Commencement of a new business
   b. Obsolescence of the existing technology
   c. Regular supply of labor
   d. Expansion of the existing business
2. _____implies the accessibility of an organisation to the market.
3. Alfred Weber, a German economist, made an attempt to analyse the factors that influence industrial location. (True/ False)
4. On what factors, does a transportation cost depend?

4.3 Current Trends in Industry Location

The advancement in technology and transport facilities has added a new dimension in the concept of industry location. Today, industries are no longer dependent on traditional factors, such as proximity to the market, sources of raw material, and supply of labour. With the availability of substitute raw materials and the development of several new transportation facilities, industries have become quite flexible in selecting their plant location. The following are the current trends in industrial location:

- **Development of industrial estates**: It refers to a large area of land that is planned and zoned for the establishment of industrial units. In India, state governments are responsible for developing industrial estates in their respective states. The formation of industrial estates has significant impact on the pattern of industry location in India.
- **Restriction on centralisation of industries**: It refers to intervention made by the government to ensure the decentralisation of industrial units. For instance, the industrial policy of the government of India ensures that the industrial units should not be concentrated in a particular area. The main aim of the government for formulating such policy is to ensure balanced regional development. For example, establishment of new industrial units are not allowed in populated areas. To motivate and influence industries to locate their units in underdeveloped and backward areas, the government also announces various incentives and rewards.

Self-Assessment Questions

5. The main aim of the government for formulating industrial policy is to ensure balanced regional development. (True/ False)

4.4 Concept of Plant Layout

To carry out its operations smoothly, it is imperative for an organisation to have a proper plant layout. As discussed earlier, a plant layout refers to the process of arranging various physical facilities, such as machinery and equipment, within a factory or plant in such a way to maintain a quick flow of materials at minimum cost. The following are some of the popular definitions of plant layout:

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

According to **Knowles and Thomson, plant layout** involves:

i. *"Planning and arranging manufacturing machinery, equipment and services for the first time in completely new plants;*

ii. *The improvements in layouts already in use in order to introduce new methods and improvements in manufacturing procedures*"

The concept of plant layout is not only confined to the initial movement of machines and equipment, but also involves re-arrangement of the existing layout to improve its performance. It should be noted that there is no definite pattern of a plant layout. The design of a plant layout varies across organisations depending upon their nature and location of industry. For instance, a layout that is effective for the manufacturing industry may not be suitable for the packaging industry.

4.4.1 Objectives of an effective plant layout

As mentioned before, for a company's manufacturing process to run properly, it requires an appropriate plant structure. These goals should be the focus of any well-designed plant layout:

- **Minimum material handling:** When machinery and equipment are organised in a way that minimises the need for manual handling, we say that the plant layout is effective. In the end, this helps a company save money on material handling.
- **Elimination of bottlenecks:** Plant constraints caused by inadequate storage and machine capacity can be mitigated with an appropriate arrangement. Problems like traffic, manufacturing delays, wasteful use of space, and accidents result from these bottlenecks. A well-planned industrial layout might help a company avoid these problems. To illustrate the point, a well-planned facility with a large number of machines can eliminate production delays caused by a lack of machines.
- **Shorter production cycles:** Because each production activity takes less time when the facility is well-designed, production cycles are shortened. In order to facilitate the finishing process, it is possible, for example, to place all of the machines that require cooperation in one area.
- **Reduction in production delays:** The timely execution of various operations is greatly influenced by the plant layout. Lessening the sources of production delays is possible with an efficient plant structure. Some examples of such reasons are material transportation across great distances and a lack of available space.
- **Improved quality control:** In order to effectively oversee an organisation's materials, a plant layout is necessary. Inspection at different stages of production is made easier with a well-designed layout. Therefore, it guarantees that the produced result meets the specified quality standards.
- **Efficient utilisation of labour:** An efficient plant layout will structure each process such that each worker's time is used to its fullest potential..

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- **Improved employee morale:** Assuming everything is going swimmingly in the office, workers will be upbeat and eager. Employee morale is boosted by a well-planned industrial layout because it guarantees:
  - Enhanced workplace quality
  - Accidents have decreased.
  - Profit growth
  - Improvements to working conditions

4.4.2 Types of layouts

A plant layout differs from one organisation to another depending on their requirements. Based on the requirements of different organisations, there can be different types of plant layouts, which are as follows:

- **Process Layout:** It involves grouping of similar types of machines at one place. Plant layout is also known as functional layout. For instance, in the process layout, all the machines involved in the packaging of goods are grouped in the packaging department. In this type of layout, process is given more importance as compared to the product. During the production process, a product is moved from one department to another where similar types of machines are grouped together. In a product layout, the following points should be kept in mind while grouping machines:
  - The principle of sequence of operations should be followed while grouping machines in their respective departments.
  - There should be shorter distance among departments.
  - There should be proper inspection of machines and operations.

  The following are the advantages of the process layout:
  - Requires minimum investments in machines
  - Enhances the flexibility of an organisation by producing different products without changing the arrangement of machines
  - Facilitates specialised supervision
  - Does not interrupt the production flow due to machine breakdowns
  - Ensures optimum utilisation of equipment

  The major disadvantages of the process layout are as follows:
  - Requires back-tracking and long-routing of processes, which increases material handling cost
  - Requires a large floor area, which can be expensive for an organisation
  - Requires prolonged processing time
- **Product Layout:** This signifies a layout where machines are arranged in a sequence required in the production process. A product layout is also known as straight-line layout. In this layout, materials pass through each machine as sequenced in the process. In this layout, each stage of operation is carried out by a specialist machine. Therefore, the product layout requires a larger number of machines as compared to the process layout. The product layout is generally implemented by paper and sugar industries. In

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this type of layout, special purpose machines are used for production. An organisation using the product layout should consider the following points while grouping different machines:

- All the machines and equipment should be arranged in a sequence as required in operations.
- Two machines should not be coinciding with each other.

The following are the advantages of the product layout:

- Requires minimum material handling cost
- Reduces bottlenecks in the production process
- Provides better control of the production process
- Reduces manufacturing time
- Requires minimum inspection

However, the following are the disadvantages of the product layout:

- Provides lesser flexibility
- Requires huge investments for arranging and grouping different machines
- Requires the execution of individual incentive schemes, which can be difficult for an organisation
- Lacks specialised supervision

- **Fixed Position Layout:** This involves movement of men, machines, and materials to the place of production. Normally, in case of process layout and plant layout, materials are moved to different locations for processing, while machines remain static in their respective location. However, if materials are heavy and large in size, it becomes very difficult and expensive to move them to different locations. In such a case, materials to be processed for producing the output remain static at a particular location and all the machines and equipment required in the production process are bought near the production site. Therefore, such type of layout is called fixed position layout. This type of layout is used by organisations involved in the manufacturing of buildings, ships, and aircrafts.

  The following are the advantages of the fixed position layout:

  - Ensures optimum utilisation of machines and men
  - Requires minimum investment
  - Eliminates problems associated with the transportation of bulky materials

- **Cellular Manufacturing Layout:** It implies placing of machines in groups or cells. This layout is implemented in conditions when establishing a pure line layout is not possible. In this layout, each group of machines constitutes family parts demanding same treatment. This layout lies amid product layout and process layout.

  The following are the advantages of the cellular manufacturing layout:

  - Provides greater flexibility as compared to a line layout
  - Enhances visual control

- Reduces material handling costs
- Ensures lower production costs

  However, the main disadvantage of the cellular manufacturing layout is that it increases machine down time in certain cases.

- **Combined Layout:** It requires a combination of both the product layout and the process layout. Pure process layout or pure product layout are very rarely found in organisations. Therefore, efforts are being made to prepare a layout having a balanced combination of both the layouts. This type of layout is usually implemented in organisations involved in assembling and fabrication activities.

4.4.3 Factors affecting a plant layout

Before selecting a plant layout, an organisation should consider the following factors that affect a plant layout:

- **Infrastructure:** It is one of the most important factors that should be considered by an organisation while selecting its plant layout. The nature and size of a factory building helps an organisation to determine the space available for layout. Apart from this, an organisation should also consider special requirements, such as air ventilation, dust control, and humidity control, while selecting its plant layout.
- **Nature of Product:** An organisation produces two kinds of products, namely uniform products and custom-made products. In such a case, product layout is suitable for uniform products, while process layout is appropriate for custom-made products.
- **Machinery:** The usage of machinery varies across organisations. Some organisations use machinery for general purpose, while others use machinery only for some specific purposes. However, general purpose machinery is arranged as per process layout, while specific purpose machinery is arranged according to product layout.
- **Production Process:** The production process adopted by different organisations varies depending on their requirements. Product layout is suitable for assembly line industries, while process layout is appropriate for industries using job order or intermittent manufacturing techniques.
- **Management Policies:** Management policies have significant impact on the selection of a layout. Some of these management policies are as follows:
  - Degree of automation
  - Production volume
  - Future expansion plan
  - Buying decisions
  - Personnel policy
  - Purchasing policy
- **Employee Needs:** An organisation should consider the needs of its employees while selecting a layout. Therefore, there should be proper facilities for employees, such as cloakrooms washrooms, lockers, and drinking water. Moreover, proper provisions should be made for the disposable of wastes.

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4.4.4 Principles for selecting a plant layout

A plant layout of different organisation varies based on the type of plant and industry and geographical location. However, basic principles governing the selection of a plant layout are the same. These principles are as follows:

- **Principle of Minimum Travel:** The distance travelled by men and materials should be shorter to avoid the wastage of time, make efficient utilisation of labour, and prevent delays in production.
- **Principle of Sequence:** A sequential order should be followed while arranging machinery and operations. This principle yields the best results in case of the product layout. However, an attempt should be made to implement this principle in case of the process layout.
- **Principle of Compactness:** All the men, machines, and materials involved in the production process should be integrated to achieve the desired output.
- **Principle of Flexibility:** An organisation should select a layout in which modifications can be made as and when required with minimum cost and efforts.
- **Principle of Usage:** There should be effective utilisation of floor space for performing different operations.

4.4.5 Prerequisites for developing a plant layout

An organisation's total efficacy and efficiency are significantly affected by the structure of its plant. A plant's structure has a significant impact on several organisational functions, including production, administration, and storage. Consequently, prior to creating a plant layout, a company should do thorough planning and study of its different operations. Developing an appropriate plant layout requires, among other things, the following:

- **Developing Process Charts:** These provide a visual depiction of the production processes carried out by a company. A process chart is a useful tool for showing and analysing the whole manufacturing process in a methodical way. Two other types of process charts exist: operation process charts and flow process charts.
- **Making Process Flow Diagrams:** On a floor plan, it shows how materials go from one place to another. With these schematics, a company can keep industrial operations running smoothly and cut down on unnecessary material shipments.
- **Developing Machine Data Cards:** This helps with the configuration of equipment by giving details about power and material handling capability and requirements.
- **Visualising the Layout:** As far as layout planning techniques go, this is by far the most used one. Making copies of machinery and setting them up in two or three dimensions to test out different layouts is what it entails.

4.4.6 Process of designing a layout

Designing a plant layout requires a systematic approach. It involves a number of steps, which are as follows:

1. Determining the goals and objectives of an organisation
2. Collecting information related to the volume of production and sales forecasts

3. Formulating different charts, such as flow diagrams, process flow charts, and string charts
4. Planning the production process
5. Planning material handling and a pattern for material flow
6. Determining the requirements for a work centre
7. Designing a work centre for individuals
8. Assorting equipment for material handling
9. Evaluating storage conditions
10. Developing ancillary and service facilities
11. Formulating a routing plan for performing various operations
12. Determining the specifications of a factory building by taking into consideration the layout requirements
13. Indicating the position of doors, staircase, and windows with the help of a floor plan
14. Devising exploratory layout plans
15. Formulating a comprehensive drawing of the layout to get top management approval
16. Preparing a work schedule for the implementation of the layout

4.4.7 Designing of a plant layout through computers

In the business environment, computers have become indispensible by accomplishing tasks quickly with more accuracy. Similarly, they have also contributed in the domain of layout engineering to a large extent. Nowadays, organisations are using various computerised techniques for designing and evaluating their plant layout. Some of these techniques are as follows:

- **Computerised Relative Allocation of Facilities Technique (CRAFT):** When it comes to layout engineering, it's one of the simplest and oldest methodologies out there. Armour and Buffa created this method. The following data types are required by CRAFT for usage in layout engineering:
  - Total area of usable floor space
  - Specifics regarding the area needed by every department
  - Analysis of the cost-flow relationship for each work station
  - Design of the first phase
- **Automated Layout Design Programs (ALDEP):** It is an algorithm that uses facility-related data to generate a layout design. The algorithm rearranges the various divisions of a company's structure. An evaluation is conducted following the arrangement of these divisions in the blueprint. The total of each department's proximity rating values is this score. To get the highest possible score, this procedure is repeated. The plan with

the highest score is put into action. Here is the data needed for this algorithm:

- Divisions' relative sizes in relation to one another
- The REL charts show relationships
- Departments' permanent locations

- **Computerised Relationship Layout Planning (CORELAP):** It alludes to R. C. Lee's layout engineering algorithm. The algorithm prioritises a company's most important division and positions it at the centre of the layout. The next step is to position the department that is geographically nearest to the ones that have already been put. Starting in the middle, this algorithm designs the arrangement. Taking the proximity values of several departments into account determines the layout's final score. Here is the data needed for this algorithm:
  - Departmental count and geographic scope
  - The REL chart shows the close relationship between different departments.
  - Level of production

4.4.8 Revision of an existing layout

The efficiency of an existing layout depends on how frequently it is revised by an organisation. The revision of an existing layout ranges from minute modification to complete demolition of the structure. An organisation revises its existing layout for various reasons, which are as follows:

- **Expansion:** It refers to one of the most common reasons for layout revision. An organisation cannot use the same layout in case it desires to expand its business. For example, if an organisation wants to expand its product line, it requires installation of new machines and more floor space. To do so, the organisation needs to revise its existing layout and make decisions accordingly.
- **Technological Development:** It refers to the fact that technological developments have direct impact on the performance of plant and equipment. In today's dynamic business environment, the existing technology of an organisation can become obsolete any time. To adopt new technologies, an organisation needs to revise its existing layout.
- **Layout Improvement:** It refers to a process that an organisation needs to make regular improvements in its plant layout to enhance its overall operational efficiency. This can be possible by inspecting the existing layout, identifying the problems, and rectifying them.

Activity

Learn about the role of computers in the plant layout decisions of organisations. Name some software that are used for designing the plant layout.

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Self-Assessment Questions

6. Which of the following technique is developed by R. C. Lee?
   a. CORELAP
   b. ALDEP
   c. CRAFT
   d. OLAP
7. _____ involves arrangement of machines and equipment in the order as they are required in the production process.
8. _____ is a computer program used to assist an organization in selecting a proper layout.
9. Which of the following is not a step for designing a process layout?
   a. Determining the organizational goal
   b. Collecting information related to the volume of production and sales forecasts
   c. Collecting information related to the competitors' strategies
   d. Formulating different charts, such as flow diagrams, process flow charts, and string charts
10. Process layout is suitable for assembly line industries. (True/ False)

4.5 Summary

- An appropriate plant location helps in increasing the profitability, decreasing the costs and gaining the competitive advantage by the organisation.
- The factors that affect a plant location are market proximity, proximity to raw materials, availability of labor, transportation system, availability of power and government policies.
- The advent of new technologies has led to birth of new trends in industrial arena such as industrial estates have been developed and decentralization of industries has occurred.
- A plant layout is more essential for the organisation than a plant location as it helps in carrying the operations smoothly.
- The objectives of plant layout are minimum material handling, elimination of bottlenecks; shorten production cycles, and reduction in production delays.
- The different types of plant layouts are process layout, product layout, fixed position layout, cellular manufacturing layout and combined layout.

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4.6 Glossary

- **Agglomeration:** It refers to the concentration of industries at one location
- **Deglomeration:** It indicates the decentralisation of industries
- **Plant Layout:** A manner in which machines and equipment are arranged for production purposes
- **Plant Location:** It refers to a place where an organisation is located

4.7 Terminal Questions

1. State the factors affecting the location of a plant
2. Explain the different types a of plant layouts.
3. Mention the principles of selecting a layout.
4. Write a note on current trends in industry location.
5. What are the prerequisites for developing a layout?

4.8 Answers

Q.	Self Assessment Questions
1.	c Regular supply of labor
2.	Market Proximity
3.	True
4.	The transportation cost depends on two factors, namely distance to be covered and weight of products to be transported.
5.	True
6.	CORELAP
7.	Product Layout
8.	CRAFT
9.	c Collecting information related to the competitors' strategies
10.	False
Q.	**Terminal Questions**
1.	The factors that affect a plant location are market proximity, proximity to raw materials, availability of labor, transportation system, availability of power and government policies. Refer to sub section **4.2.1 Factors affecting a plant location**
2.	The factors that affect a plant location are market proximity, proximity to raw materials, availability of labor, transportation system, availability of power and government policies. Refer to sub section **4.4.2 Types of layouts**

3.	The principles of selecting a layout are principle of minimum travel, principle of sequence, principle of compactness, principle of flexibility, principle of usage. Refer to sub section **4.4.4 Principles for selecting a plant layout.**
4.	New trends in industrial arena include development of industrial estates and decentralisation of industries. Refer to section **4.3 Current Trends in Industry Location.**
5.	The prerequisites for developing a layout are developing process charts, making process flow diagrams, developing machine data cards and visualising the layout. Refer to sub section **4.4.5 Prerequisites for developing a plant layout.**

4.9 Case Study: Plant Location of ABC Ltd.

ABC Ltd. is a leading recycling organisation. The organisation's area of operation is mainly confined to Northern India. It deals with recycling of various products such as plastics, newspapers, cardboard boxes, and cans. In the last one year, ABC Ltd. has seen a tremendous growth in its business. The annual profit of the organisation has reached up to Rs. 50, 00, 00, 000.

The main objectives of ABC are as follows:

- Reusing and recycling waste for sustainable environment
- Encouraging the citizen participation in the recycling program
- Facilitating the sharing of information and resources with organisations
- Improving the quality of post-consumer plastics

ABC plans to expand its business in the Southern region of the country to maximise its profits. The plant location was selected in one of the city. The only factor that was considered for location of the plant was its proximity to raw materials. Other factors such as transportation system, government policies were ignored. ABC's research and development team failed to identify that there were major problems in the area selected. For example, the power availability was not functioning properly. Also, the transportation system was weak. Cost of labour was high.

Due to transportation issues, it was not able to connect to other organisations easily for coordinating with them. The layout of the machines in the plant was improper. Different types of machines were placed in one group which created the chaos in recycling the products. Materials require lot of time to move. This delayed the production process. This impacted the profitability of the ABC. Thus, it planned to hire an advisor, Mr. Arora for quick solution to the problem.

Discussion Questions

1. What factors could have been considered by ABC while selecting its facility location? (**Hint:** Availability of Capital and labour; Government Policies etc)
2. Suppose you are Mr. Arora. What you will suggest for solving the ABC's problem. (**Hint:** change in layout; analysing the factors that affect the layout; following a proper process for designing a layout.

Notes

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CHAPTER

5 Capacity Management

Structure

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Learning Objectives

After studying this chapter, you will be able to:

- define capacity
- explain the concept of capacity management
- elaborate on how to estimate equipment requirements
- explain the concept of capacity planning
- apply the methods of measuring capacity in manufacturing process

5.1 Introduction

In the previous unit, you have studied about facility location and layout. After deciding the location and layout of a facility, an organisation needs to determine the capacity of the plant to produce a product. Do you know what capacity is? Capacity is the capability of an individual to perform a particular work in a given time period. For example, the amount of load you can lift for a specific period of time is your capacity. Similarly, the capacity of a sugar factory can be expressed in terms of the tons of sugar cane (input) crushed per day or in terms of the tons of sugar (output) produced per day. Thus, capacity of a production plant refers to its ability to produce an output over a period of time under normal conditions. However, in the case of organisations producing multiple products, capacity is measured in terms of critical resources and inputs, such as labour hours, number of machines available, storage capacity, working capital and logistics infrastructure.

To carry out its production process effectively, an organisation needs to measure the capacity of its production plant. While measuring the capacity, an organisation needs to take into account various factors, such as the demand for products, cost of production, scale of production, and future expansion plans of the organisation.

Capacity management is a process which ensures that the available capacity of a production plant is capable of fulfilling business requirements. Effective management of capacity helps an organisation to reduce the cost of production and increase its revenue. An organisation can manage its capacity effectively only if it plans the capacity properly. Capacity planning is all about determining the level of capacity required to manufacture a specific product with the defined amount of quantity in a stipulated time period.

The chapter begins by explaining the concept of capacity. Further, it discusses the factors that influence the capacity of a production plant of an organisation. In addition, it elaborates on the concept of capacity management. Next, it focuses on how to estimate equipment requirements. The chapter also explains the concept of capacity planning. Towards the end, it details upon different methods for measuring capacity.

5.2 Concept of Capacity

Capacity refers to the ability of a production unit to produce products using the available resources within the given time period. The capacity of a production unit depends on the demand for products or services. The demand for a product or service is largely influenced by the location in which the product is sold. For example, the demand for financial services is higher in urban areas as compared to rural areas. Similarly, the demand for woollens is more in Kashmir as compared to Mumbai.

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The capacity of a production unit can be expressed in terms of input or output. For example, the capacity of a car-manufacturing organisation can be expressed as the number of cars produced per year. In this case, the capacity is expressed in terms of the output. In the situations where the output is too complex, the capacity is expressed in terms of the input. For example, the capacity of a hospital is expressed in terms of the total number of beds.

The capacity of a production plant depends on various factors, such as the demand, cost and scale of production.

Capacity is easy to measure in some cases, for example, the number of cars (output) produced per day, as mentioned above. The concept of aggregation can be used in these cases. Aggregation implies a calculation by using a standard average production rate expressing capacity in terms of the standard product. In the case of an airline, the capacity may be expressed by the total number of seats, which are measured in terms of the input. Future capacity needs can be viewed from a long-term or short-term perspective. The short-term view is based on a time horizon, varying from 12 to 18 months. The forecast of demand for different products is based on the past data and the actual orders received by the firm. The existing capacity is adjusted to meet the demand. When we go for the long-term perspective, the requirements are fetched either by expanding or shredding the extra capacity and some currently available resources.

Capacity can be of different types. These types are shown in Fig 5.1:

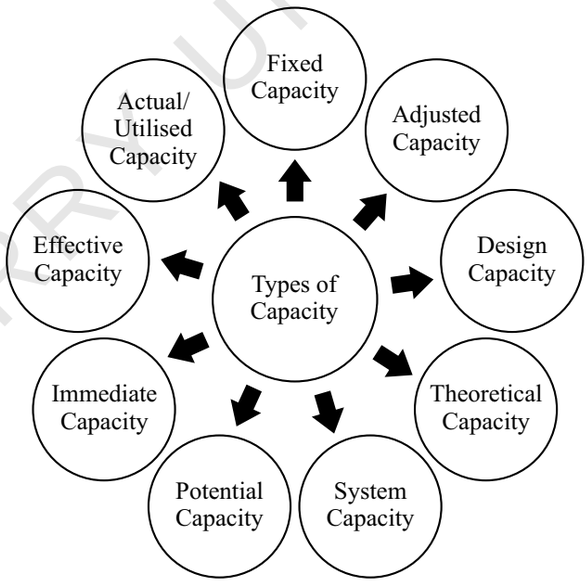

Fig 5.1: Different Types of Capacities

Let us discuss these types in detail.

- **Fixed capacity:** Capital assets of an organisation at a given period of time are known as fixed capacity. These assets are not liable to change within the short or intermediate range of production planning.
- **Adjusted capacity:** It entails the size of the workforce, employee working hours on a weekly basis and the number of shifts and the extent of sub-contracting of resources.
- **Design capacity:** It is the planned rate of the output of goods or services under normal or full-scale operating conditions. It is also known as installed capacity.

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- **Theoretical capacity:** It is a kind of an idealised goal that can rarely be achieved practically. It may also be defined as the rate of work to be achieved during the functioning of machine at its full-rated speed for 100 per cent of the time.
- **System capacity:** It refers to the optimal output of certain products or services, or a mix of product and services, which a production system is able to produce at a given point of time.
- **Potential capacity:** It is the capacity that can be made available within the decision horizon of the top management. In other words, it is the maximum possible level of output that a given system can potentially produce over a given period of time. For example, it helps senior management in making decisions about the growth of business, investment etc.
- **Immediate capacity:** It is the capacity that can be made available within the current budget period.
- **Effective capacity:** It is the maximum rate of output that can be practically achieved. Effective capacity is always lesser than the design capacity. It is used within the current budget period. It is also known as practical capacity or operating capacity.
- **Actual or utilised capacity:** It is the actual output achieved during a particular time period. The actual output may be equal, more, or less than the rated output. Few reasons for this may be actual demand, employee absenteeism and inconsistent productivity levels.

5.2.1 Short run average costs

At least one input quantity is conceptually fixed in the short run, but the amounts of the other inputs are freely variable. In the near term, things like land and machinery don't change. Contrarily, variables like labour and capital change with time. The expansion is accomplished in the short term by expanding capital and employing more workers. There is no way to expand the current plant or building size in the near future. This short-term analysis takes into account the following cost concepts:

- **Average Fixed Costs (AFC)**: It refers to the per unit fixed costs of production. In other words, AFC implies fixed cost of production divided by the quantity of output produced. It is calculated as:

  AFC= TFC/Output

  As discussed earlier, Total Fixed Cost (TFC) is constant as production increases, thus AFC falls. Fig. 5.2 shows the AFC curve:

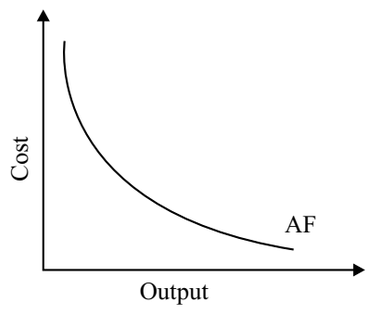

Fig. 5.2: AFC curve

In Fig. 5.2, AFC curve is shown as a declining curve, which never touches the horizontal axis. This is because fixed cost can never be zero. The curve is also called rectangular hyperbola, which representrbcs that the total fixed costs remain same at all the levels.

- **Average Variable Costs (AVC)**: This refers to the per unit variable cost of production. It implies the organisation's variable costs are divided by the quantity of output produced. It is calculated as:

  AVC= TVC/ Output

  Initially, AVC decreases as output increases. After a certain point of time, AVC increases with respect to increase in output. Thus, it is a U- shaped curve, as shown in Fig. 5.3:

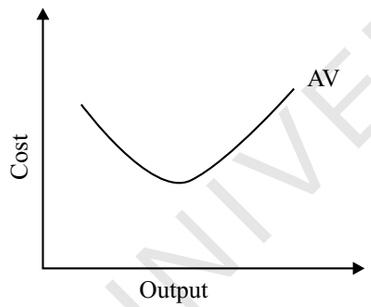

Fig. 5.3: AVC curve

5.2.2 Long run average cost

The LAC is calculated by dividing the total costs over the long term by the level of output. From the curves representing the average costs in the short run, the long term average costs may be derived. Each short-run curve represents a different plant, and in the short-run, plant is fixed. Because it aids in the development of organisational strategies for increasing production while maintaining minimal cost, the long term average costs curve is also known as the planning curve or the envelope curve. The origin of the LAC curve is seen in Figure 5.4:

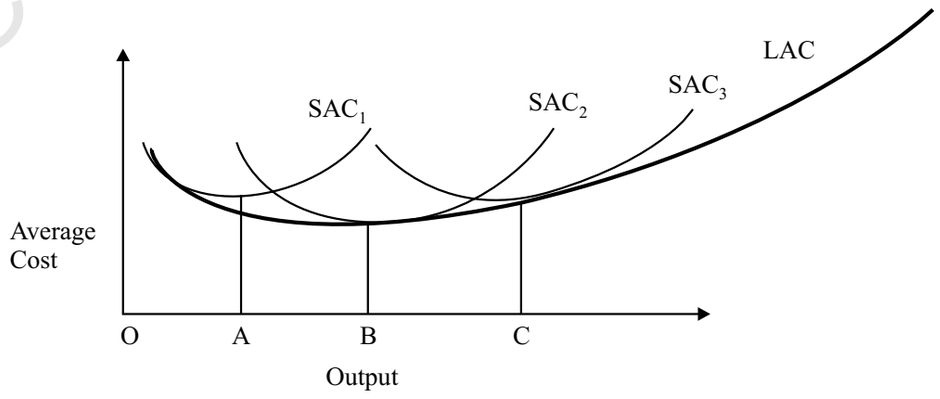

Fig. 5.4: Derivation of LAC Curve

Assume that the plant can only be manufactured in three sizes. The plant sizes remain constant in the short run. So, the company can change the variable elements by adding or removing

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them. But in the end, the company can choose the plants that would help them achieve the lowest feasible cost while maintaining a specific level of production. Operating on plant SAC2 is advantageous for the organisation till OB amount of production since it involves lower expenses than SAC1, as shown in Figure 5.4. The production of OA using the plant SAC2 would result in higher costs. Therefore, it's evident that the producer would produce till OB on plant SAC2 in the long term. The producer would continue producing up to the OC amount of output on SAC2. Organizations that aim to outperform OC should prioritise SAC3 production over SAC2.

So, in the end, a company can choose to use the plant that costs the least to achieve their output goals. Loss-Average Cost (LAC) shows the cheapest feasible way to produce various amounts of output. The merging of the short run average cost curves' lowest minimum costs yields the LAC curve. Its U-shaped curve is the result of its initial descent and subsequent ascent. Returns to scale have an impact on LTC and LAC as well. The idea of returns to scale was introduced in the prior chapter, and it states that an organization's output may be changed by changing its inputs. Changes to any and all production inputs have an effect on output in the long run.

5.2.3 Long run marginal cost

Assuming that all inputs are variable, the cost of manufacturing an extra unit of a commodity is known as long run marginal cost (LMC). The short-run marginal cost is the source of this expense. The LMC is obtained on the graph from the tangent points (P, Q, and R) that connect LAC and SAC. Figure 5.5 can be used to learn the LMC curve:

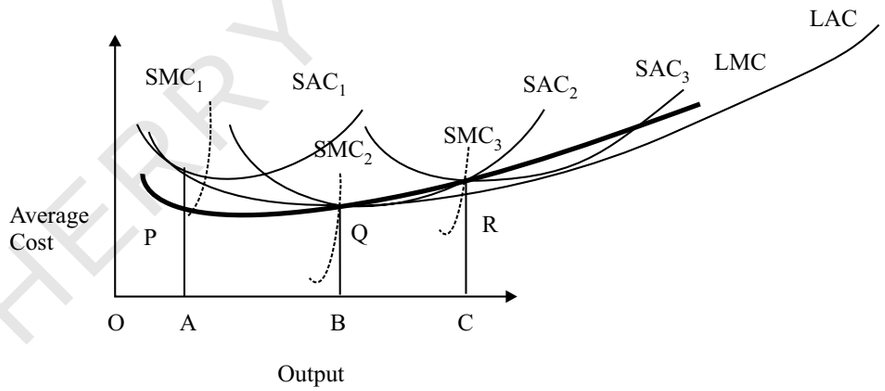

Fig. 5.5: LMC Curve

The SMC curves would cross at points P, Q, and R, respectively, if perpendiculars were drawn from points A, B, and C, respectively. Gathering points P, Q, and R together would form the LMC curve. It should be mentioned that when LMC is perpendicular to the LAC, SMC equals LMC. The output that is seen in Figure 5.5 is OB. OB is the output at which:

$SAC_2 = SMC_2 = LAC = LMC$

We can also draw the relation between LMC and LAC as follows:

When LMC < LAC, LAC falls

When LMC =LAC, LAC is constant

aWhen LMC >LAC, LAC rises

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5.2.4 Economies of scale

Economies of scale are defined as the cost advantages that an organisation can achieve by expanding its production in the long run. In other words, these are the advantages of large scale production of the organisation. Less overall spending per unit is how the savings are realised. A long-term view is required. As a company's sales volume grows, it is able to take advantage of economies of scale. Consequently, the organisation is able to acquire raw materials in bulk because to its increased savings. As a result, the company is better able to negotiate lower prices with its raw material suppliers. The term for these advantages is economies of scale.

Below, we'll break down economies of scale into its component parts: internal and external.

- **Internal Economies:** It alludes to the tangible cost savings that come from growing the company's physical plant. These economies are a natural byproduct of the expansion of the organisation. Internal economies of scale can be seen in the following examples:
  - **Technical economies of scale:** It happens when businesses spend a lot of money on fancy new gear. This aids businesses in reducing and managing their production costs. The organisations benefit from these economies as a result of the technical efficiency they have achieved. A company can crank out a tonne of products in no time at all thanks to its cutting-edge technology. A car factory, for instance, can take advantage of technical efficiencies through the use of mass production processes, specialisation, and the division of labour. Because of this, economies of scale cause production costs per unit to reduce.
  - **Marketing economies of scale:** It happens when major companies distribute their marketing expenditure among a big quantity of output. Buying in bulk, establishing a brand, and promoting all lead to marketing economies of scale. For instance, since they reach a wider audience, big businesses can save money on advertising. Conversely, tiny businesses spend the same amount on ads as big businesses, but they don't get the same returns because their target audience is smaller.
  - **Financial economies of scale:** When big companies borrow money at cheaper interest rates, this happens. These companies are well-respected in their industry. Financial institutions are more likely to extend credit to well-established businesses that have proven themselves to be reliable borrowers.
  - **Managerial economies of scale:** This happens when big companies hire designers, engineers, quality assurance managers, project managers, etc., to handle certain jobs. These employees are at the top of their game, and they use their expertise to help the company make as much money as possible.
  - **Commercial economies:** In these types of economies, businesses are able to purchase raw materials and sell completed goods at reduced prices. Companies with a large purchasing power often get preferential treatment when it comes to transportation costs, bank loans, and product turnaround times since they purchase raw materials in bulk.
- **External economies:** These economies take place in sectors that are useful to businesses. Organisations may reap the benefits of an improved transportation network, infrastructure, and other amenities as an industry grows. This contributes to a reduction in an organization's expenditure.

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The following are a few instances of external economies of scale in action:

- **Economies of Concentration:** It describes economies that benefit from things like easy access to financing, skilled workers, and transportation.
- **Economies of Information:** It suggests benefits gained from publishing trade and business-related content. Companies get their data from the major research institutes.
- **Economies of Disintegration:** It alludes to the cost savings that occur when businesses separate their operations.

5.2.5 Diseconomies of scale

When an organisation's long-term average costs go up, it's experiencing diseconomies of scale. Such a situation occurs, when a company expands too much. Put simply, larger organisations are compelled to produce goods and services at higher costs due to diseconomies of scale.

Here, we'll go over the two main categories of diseconomies of scale: internal and external.

- **Internal diseconomies of scale:** It describes inefficiencies that drive up a company's production costs. Lack of decision-making, supervision, and technological challenges are the primary elements that impact an organisation's production cost.
- **External diseconomies of scale:** It describes the obstacles to growth that an organisation or business faces, such as diseconomies. The rising cost of production, limited availability of raw resources, and lack of competent labourers are the issues that limit expansion.

Several factors can lead to diseconomies of scale. Here are a few things that can go wrong and produce diseconomies of scale:

- **Poor Communication:** One of the main causes of diseconomies of scale is this. Organisational overproduction or production can occur if workers are not informed of the organisation's production goals and objectives. The result can be a loss of economies of scale. In addition to this, when the organisation's communication process is weak, employees will not receive sufficient feedback. Consequently, the manufacturing process would be impacted because there would be less face-to-face interaction among personnel.
- **Lack of Motivation:** Levels of production decline as a result. A lack of intrinsic motivation might set in when employees of a big company feel unappreciated and alone in their work. When there is a breakdown in communication, it becomes more difficult for managers to connect with their staff and foster a feeling of community. This causes a decline in output production as a result of demotivation. Consequently, the organisation's expenses go up even more.
- **Loss of Control:** For big companies, this is the biggest issue. It becomes extremely expensive and impossible to monitor and manage the work of every person in a huge organisation. It becomes more difficult to discern that every employee of a company is striving for the same objective. Managers find it challenging to keep tabs on their subordinates in big companies.
- **Cannibalisation:** It suggests a scenario where a company's own product poses a threat to the market share of the competitor. While big companies may discover that their own products are competing with one another, small businesses confront competition from the products of other companies.

NOTES

Self-Assessment Questions

1. The capacity of a facility is defined as the _____ load that can be handled by it during a given time period.
2. The capacity that can be made available within the current budget period is _____ capacity.
   a. Effective capacity
   b. Immediate capacity
   c. Actual or utilised capacity
   d. Design capacity
3. If the output is too complex, capacity can be expressed in terms of the input. (True/False)
4. System capacity is also known as installed capacity. (True/False)
5. Effective capacity is always _____ the design capacity.
   a. Lesser than
   b. Greater than
   c. Equal to
   d. Reverse of
6. Effective capacity is also known as:
   a. Practical capacity
   b. Operating capacity
   c. Both a and b
   d. Theoretical capacity
7. _____refers to the per unit fixed costs of production.
8. Initially, AVC increases as output increases. After a certain point of time, AVC increases with respect to decrease in output. (True/False)
9. Long run Average Cost (LAC) is equal to long run total costs divided by the_____.
10. Define long run marginal cost (LMC).
11. _____are defined as the cost advantages that an organisation can achieve by expanding its production in the long run.
12. _____ take place when large organisations borrow money at lower rate of interest.
    a. Technical economies of scale
    b. Marketing economies of scale
    c. Financial economies of scale
    d. Managerial economies of scale
13. Diseconomies of scale occur when the long run average costs of the organisation increases.(True/False)
14. What are the various causes for diseconomies of scale?

Activity

Give some examples of measuring capacity in terms of input.

Notes

5.3 Concept of Capacity Management

Capacity management is all about ensuring whether the available capacity of a production plant is sufficient to meet the business requirements effectively. If the capacity of an organisation is not managed properly, it may have an adverse impact on its financial performance. Let us understand the management of capacity in a production plant with the help of an example. Suppose an organisation wants to prepare its production schedule. For this, the production department of the organisation needs to determine the available and required capacity of its production plant. The department finds out that the available and required capacity of the organisation does not match. Considering the present situation, the production manager needs to take the decision in such a manner that the organisation can run its production process effectively. In this case, the production manager can take any of the following decisions:

- **Ignore the issue:** The production manager can choose to ignore the imbalance between the required and available capacity. This decision may have two consequences, which are as follows:
  - If the available capacity of the production plant is not sufficient to meet the business requirements, there would be a pile of pending orders. This would result in undue delay in the delivery of products.
  - If the available capacity is greater than the required capacity, there would be surplus of finished goods. This would lead to a significant increase in different types of costs, such as the holding cost of inventory and wastage cost.
- **Introduce changes in the required or available capacity:** The production manager needs to make alterations in the existing production plans, master schedules, etc. Apart from this, the production manager can also use the following alternatives to make alterations in the existing capacity of the production plant:
  - Preparing an efficient production schedule
  - Using alternate routings, that is, ensuring production from a different workstation instead of the one mentioned in the route sheet
  - Shifting employees from the area having abundant capacity to the area of the required capacity
  - Outsourcing manufacturing services
  - Employing contract labour according to the situation
  - Introducing or reducing additional work shifts
  - Purchasing new equipment or maintaining the existing one

Capacity management refers to the short-term adjustments made in capacity so that it tallies with the forecast demand. Working time is chosen for this. Overtime is used to increase the capacity and short time to reduce it. There are a number of ways for ensuring capacity management. These are as follows:

- **Working hours and shift management:** As per the requirement, the management can change the working hours and shifts.
- **Part-time staff:** Part-time staff members can be deployed to meet the peak demand.
- **Process adjustment:** The process can be adjusted in such a manner that the set up time is reduced.

- **Adjusting equipment and process:** Work can be speeded up and slowed down by adjusting production processes.
- **Self-service:** The customers can be encouraged to do some work, for instance, use ATMs or pack their own bags in a hypermarket.

The above-mentioned measures are short-term adjustments that incur their own cost. Some of these also affect the manpower adversely. These are temporary measures, and should be exercised sparingly.

The capacity management process of an organisation begins with determining capacity requirements. Let us discuss how to determine capacity requirements in detail in the next section.

5.3.1 Determining capacity requirements

An organisation can determine the capacity requirements of a production plant by converting its production schedule into standard hours. Capacity requirement is determined based on various production schedules as shown in Table 5.1:

Table 5.1: Production Schedule and its Unit of Measurement

Production Schedules	Production Schedule's Unit of Measurement	Production Units for which the Capacity Requirement is Determined
Production plan	Aggregate number of end items	Organisation, plant
Master schedule	Number of end items	Organisation, plant
Planned order schedules for parts and assemblies	Number of parts and assemblies	Department
Open order schedules for parts and assemblies	Number of parts and assemblies	Work centre/machine

Another important factor for determining capacity requirement is the level at which the capacity should be defined. For example, the estimation of capacity requirement at machine level requires detailed information of machine as compared to the estimation of capacity requirement at plant level. Therefore, capacity requirements for different levels are determined by using different methods based on available information.

5.3.2 Relationship among design capacity, system capacity, and actual output

As discussed in the previous sections, the capacity of a production unit can be expressed in terms of the input or the output. Therefore, we can say that there is a relationship between capacity and output or input.

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Table 5.2 represents this relationship:

Table 5.2: Relationship among Design Capacity, System Capacity, and Actual Output

Design Capacity	System Capacity	Actual Output
• Design capacity of a facility refers to the fixed rate of output under normal conditions. For example, the design capacity of a cement plant is 200 tons per day. • Design capacity reflects an organisation's strategy for meeting demands.	• System capacity refers to the maximum output that can be produced within the existing production facility. • System capacity is less than the design capacity because of the limitation of product mix, quality specification and breakdowns.	• Actual output refers to the exact output obtained from a production facility. • Actual output is lesser than the system capacity because of the short-term effects, such as the breakdown of equipment and inefficiency of labour.

The capacities mentioned in Table 5.2 help in determining the two important measures of system effectiveness, namely, efficiency and utilisation. The efficiency of a production plant can be expressed as follows:

$$\text{Efficiency} = \frac{\text{Actual output}}{\text{Effective capacity}}$$

On the other hand, utilisation can be expressed follows:

$$\text{Efficiency} = \frac{\text{Actual output}}{\text{Effective capacity}}$$

Self-Assessment Questions

15. An organisation can determine the capacity requirements of a production plant by converting its production schedule into _____.

16. Capacity management refers to the short-term adjustments in capacity so that it tallies with the _____.

17. If the capacity of an organisation is not managed properly, it may have an adverse impact on its _____.

18. The efficiency of a production plant can be calculated by dividing _____ by effective capacity.

Activity

Give an example of how an IT organisation manages its capacity.

5.4 Estimation of Equipment Requirements

After determining the required capacity, it is important for an organisation to estimate equipment requirements. This is because capacity limitations are always expressed in terms of

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equipment efficiencies or scrap loss. The formula used for measuring equipment requirements is as follows:

$$N = \frac{T * P}{60\ D * E}$$

Or

$$\text{Number of machines needed} = \text{Processing time per unit (h)} \times \frac{\text{(Required output rate)}}{\text{(Available time/period)}}$$

Where P = Units of output per period

T = Processing time per unit

D = Time of an operation period in hours (for one shift D = 8, for two shifts D= 16, and for three shifts D = 24)

E = Efficiency of equipment expressed as percentage of running time per period

N = Number of machines required

Let us understand how to estimate equipment requirements with the help of some examples.

Example-1: Suppose the fabrication department of an organisation needs to supply 6,000 parts to another department for assembly on a daily basis. The processing time is 2.50 min/unit and the daily equipment efficiency for two shifts is estimated as 80%. Determine the equipment requirement of the fabrication department in this case.

Solution: The equipment requirement for the fabrication department of the organisation can be determined as follows:

$$N = \frac{T.P.}{60\ D.E.} = \frac{(2.50)(6,000)}{60(16)(.80)} = 19.54 = 20 \text{ machines(say)}$$

In practical situations, the proposed method for determining equipment requirements must be used with caution. In particular, it is important to examine P and D more extensively. It should be noted that the total number of units processed includes the units that meet specifications and can be forwarded to the next production stage along with some defective units. Thus,

$$P = P_g + P_d$$

Where P_g denotes to good units and P_d are defective units

For the given operation, the number of defective units can be expressed as a percentage of defective units P over the total number of units processed. By substituting the values, we get:

$$P_g = (P - P_d) = \left[- \frac{P_d}{P} P \right] = P - P_p = P(1 - P)$$

Example-2: The A.M. Company makes product K. Each unit of product K is made up of three components identified as X, Y and Z. These components are manufactured in separate departments. The efficiency of departments producing parts X, Y and Z is estimated at 80, 90, and 70 per cent respectively. The assembly department has estimated efficiency of 90 percent. The scrap or reject levels for X, Y and Z are estimated at 10, 5, and 20 per cent respectively. No scrap losses are assumed for the assembly operation. According to the relevant work and processing standard, each of the parts X, Y and Z require 1 hour of machine time per unit and the assembly operation requires 0.5 hours per unit. The management wants to determine

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machine time and the total labour time requirements for 100 units of product K. The problem is summarised in the product structure tree as follows:

Part X Scrap	=	10% PEF= 80%
Part Y Scrap	=	5% PEF= 90%
Part Z Scrap	=	20% PEF= 70%
Assembly Operation Scrap	=	0% PEF= 90%
Product K	=	100 Units

Solution: The different steps for solving the above problem are:

1. **Scrap Factor Adjustment:** It involves in determining the number of input units utilised for producing a specific number of output units for different parts of product K. The number of input units used for producing X, Y and Z and the number of sets of parts X, Y and Z going into assembly are:

Part X: 100 (required output) x 1/0.90 (yield)	=	111 units input
Part Y: 100 (required output) x 1/0.95 (yield)	=	105 units input
Part Z: 100 (required output) x 1/0.80 (yield)	=	125 units input
Assembly: 100 (required output) x 1/1 (yield)	=	100 sets input

2. **Plant Efficiency Factor Adjustment:** It refers to the second step in which the total machine and labour time for producing 100 units of product K is determined. Here, it is assumed that the time taken by machine for producing all the parts is same (1 hour per unit). In addition, the plant (departmental) efficiency factors for the three departments producing parts X, Y, and Z are 80, 90 and 70 per cent respectively. In such a case, the total expected machine time required by departments for producing X,Y, and Z parts of product K can be determined as follows:

Part X: 111 units x 1 hours/unit x 1/0.80 (PEF)	=	139 hours
Part Y: 105 units x 1 hours/unit x 1/0.90 (PEF)	=	117 hours
Part Z: 125 units x 1 hours/unit x 1/0.70 (PEF)	=	179 hours
		435 hours

2. **Assembly time required:** It involves the following calculation:

   Assembly time = 100 sets x 0.5 hr/set x 1 hour/0.90 = 56 hours

   However, the theoretical limit required would be:

   100 sets x 1 hour/unit x 1 x 1(PEF) = 100 hours for each of the three parts = 300 hours

   In such a case, the theoretical assembly time required is 100 sets x 0.5 hours/set x 0.5 hours/ set x 50.0 hours

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Table 5.3 summarises these computations and allows a comparison to be made between the theoretical and the expected results:

Table 5.3: Summarised Calculations

	Theoretical Units(sets)	Theoretical Time (hours)	Expected Units (sets)	Expected Time (hours)	Unit Difference (3-1)	Time Difference (4-2)
	(1)	(2)	(3)	(4)	(5)	(6)
Part X	100 Units	100	111 Units	139	11 Units (11%)	39 hrs. (39%)
Part Y	100 Units	100	105 Units	117	5 Units (5%)	10 hrs. (17%)
Part Z	100 Units	100	125 Units	179	25 Units (25%)	79 hrs. (79%)
Sub-total	300 Units	300	341 Units	434	41 Units (12%)	134 hrs. (45%)
Assembly	100 Sets	0.5hr/set or 50hr.	100 Sets	56	0 sets (0%)	6 hrs. (12%)
Total		350				141 hrs. (22%)

Note

The figures shown in Table 5.3 have been rounded off at each computational stage because the precision in computing both raw material requirements and actual output generally cannot be justified.

Self-Assessment Questions

19. Capacity limitations are always expressed in terms of equipment efficiencies or scrap loss.(True/False)

20. Give the formula for measuring equipment requirements.

5.5 Concept of Capacity Planning

Capacity planning refers to the process of determining the level of capacity required to manufacture a specific product with a defined quantity. There are several factors that can affect capacity planning. These factors include the number of workers and their skills, number of machines, productivity of employees, number of suppliers, government regulations and preventive maintenance.

The process of capacity planning involves a number of activities to be performed in a sequential order. These activities are as follows:

1. Identifying demand
2. Measuring the current capacity of the production plant
3. Determining alternative methods for making alterations in the capacity of the production plant

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4. Performing the financial, economic and technical analysis of the alternative methods
5. Selecting and implementing the best alternative

Following are the advantages of capacity planning:

- **Helps in meeting the demands of customers on time:** If the demand exceeds in a particular time period, it can be fulfilled by planning the production capacity in advance. More resources can be arranged prior to the commencement of the production process.
- **Increases the efficiency of business operations:** Advanced capacity planning helps in a smooth functioning of business operations, as the production process gets organised due to capacity planning.
- **Makes the scheduling system more effective:** It helps in creating delivery schedules for supplies and shipping schedules for finished goods.
- **Helps in monitoring costs:** Carefully planned capacity helps the organisation to monitor its cost during the growth or recession period.
- **Helps in setting up a new facility:** The needs of facilities and personnel can be more accurately identified by using the data of the capacity planning of the existing facility.

5.5.1 Classification of capacity planning

Capacity planning decisions of an organisation can be classified into four different categories. Fig5.6 shows different types of capacity planning:

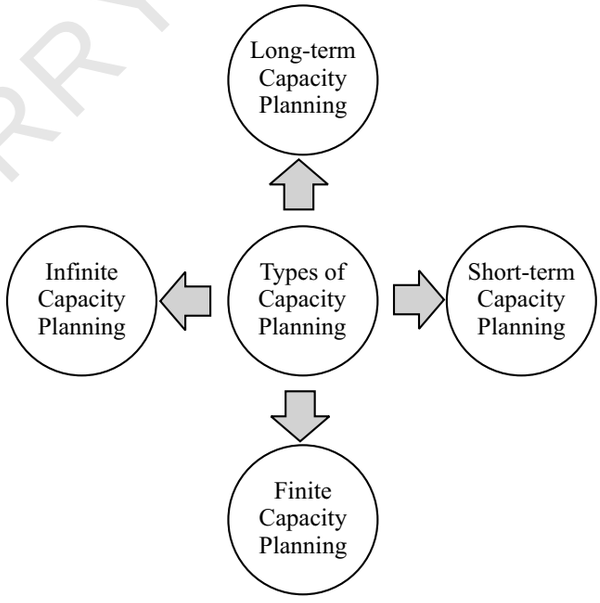

Fig 5.6: Different Types of Capacity Planning

Now, let us have a look at different types of capacity planning in detail:

- **Long-term capacity planning:** It is concerned with accommodating major changes that affect the overall level of output in the long run. It involves decisions with respect to the overall capacity, such as facility size, acquisition or disposal of equipment,

buildings and facilities. Long-term capacity decisions are taken when an organisation plans to produce a new product or expand the existing product. These decisions may lead to major changes in the overall capacity of the production plant. Therefore, while taking long-term capacity decisions, it is important for an organisation to estimate the demand accurately and implement various strategies for meeting the demand.

- **Short-term capacity planning:** It involves decisions with respect to production schedules, workforce levels and overtime. Generally, the fundamental capacity of a production plant is fixed for short-term durations. The major facilities of the production plant do not change while small alterations in the capacity are quite possible. Different ways of adjusting capacity based on the varying demands in the short-term time horizon are as follows:
  1. Use of overtime or idle time
  2. Increasing the number of shifts per day to meet a temporary strong demand
  3. Sub-contracting to other firms
- **Finite capacity planning:** While fixing the time period according to customers' required delivery date or processing cycle, one can plan backwards to accommodate these times. This type of planning is known as finite capacity planning. Time and capacity are two conflicting constraints in finite capacity planning.
- **Infinite capacity planning:** If the time of processing is not a constraint, as in the case of the Make to Stock (MTO) production system, a forward plan based on the finite capacity is created. This type of capacity planning is known as infinite capacity planning.

Self-Assessment Questions

21. _____ refers to the process of determining the level of capacity required to manufacture a specific product with a defined quantity.

22. Capacity planning helps in meeting the _____ of customers on time.

23. While making long-term capacity decisions, it is important for an organisation to estimate the demand accurately and implement various strategies for meeting the demand. (True/False)

24. _____ and_____ are two conflicting constraints in finite capacity planning.

25. Processing time is not a constraint in case of finite capacity planning. (True/False)

Activity

Give an example in which the production manager has to plan the capacity of the production plant to meet the customers' demand.

5.6 Methods for Measuring Capacity

There are certain ways to measure the capacity of organisations. The capacity can be measured in the form of input, output or a combination of these two. For example, a textile company calculates its capacity based on the clothes produced in a given period of time. This capacity

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is measured theoretically as well as on the rating basis. Theoretical capacity is the maximum output at a given time, wherein there is no downtime allowed, and the rated capacity is used for calculation purpose, as it is based on a long-term analysis of the actual capacity.

In a broader view, three strategies are used for capacity measurement, which are shown in Fig 5.7:

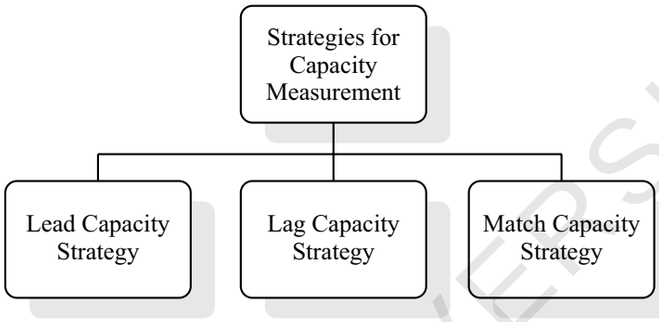

Fig 5.7: Strategies for Capacity Measurement

Now, let us discuss these strategies in detail.

- **Lead capacity strategy:** In this strategy, capacity is added even before the occurrence of the actual demand. This strategy is exercised by the organisation in order to level up the production at a manufacturing plant, especially when the orders are not piling up. Organisations give preference to this approach as it minimises risks. For every organisation, customer satisfaction stands over and above everything. No organisation would want to lose the confidence of the customer by failing to meet the delivery dates because of the lack of capacity. On the other hand, this strategy also provides organisations with a competitive advantage. For instance, in the rainy season, umbrella manufacturers increase the production of umbrellas. They increase the capacity according to the anticipated demand. Apart from the benefits listed above, this strategy has some limitations as well. For example, in case if the demand does not turn up as anticipated, it may cause huge losses to the organisation in terms of capital invested in the production process. In the absence of demand, the products will also be piled up, and the organisation may have to sell them at lower prices.
- **Lag capacity strategy:** Lag capacity strategy is considered as the reverse of the lead capacity strategy. In this case, the organisation will not level up the capacity until there is a demand from the market. Though the use of this strategy may not guarantee success, it offers some advantages, for instance, it reduces risks up to a certain level by saving the undue investment in the capital assets at the low demand level. In addition, the organisation will gain minimum profitability as compared to others' who invested in capacity enhancement.
- **Match capacity strategy:** Using this strategy, organisations try to increase their capacity in instalments. This increase is in accordance with the increase in the volume of demand. This strategy does minimise the risk of overcapacity and under capacity.

For a smooth functioning of its business operations, it is important for an organisation to determine the capacity of its production plant. An organisation needs to be careful while measuring its production capacity. This is because if the capacity is overestimated, there may be excess production of goods. On the other hand, if the capacity is underestimated, there may

be a number of pending customer orders, which cannot be fulfilled because of lack of capacity. An organisation uses different methods for measuring its capacity, which are shown in Fig 5.8:

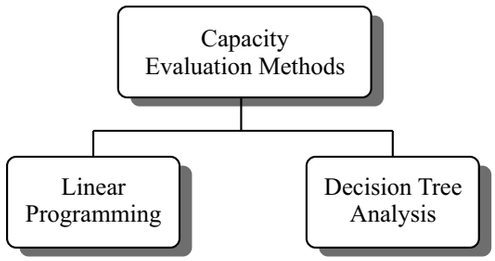

Fig 5.8: Methods for Production Capacity Estimation

Now, let us discuss these methods in detail in the subsequent sections.

5.6.1 Linear programming

Organisations often turn to linear programming, a mathematical technique, when they have optimisation difficulties, such maximisation or minimisation of production costs. Variables with linear connections are included in these optimisation problems. To rephrase, under some circumstances, linear programming gives the optimal answer for optimisation problems and resource allocation. Since linear programming doesn't tell us anything about how economies function, it doesn't see much use in economics.

When using linear programming to solve optimization issues, certain assumptions are made. The following are the assumptions:

- **Linearity:** It presupposes that the inputs and outputs of production are linearly related. It is a prerequisite for linear programming and an assumption in and of itself. In the near term, the factor of production generates equal returns, as per the linearity assumption. A linear equation depicts the input-output relationship in a linear fashion. As an example, in order to produce one unit of output, a manufacturing company needs 25 workers, 10 machines, and 0.6 tonnes of raw materials (O). Hence, the following is a representation of the input-output relationship:

  10M + 0.6R + 25W = 1O

  However, this assumption has restricted the application of linear programming to linear input and output relationship only.

- **Continuity:** According to this theory, any variable may only be considered measurable if it can be quantified numerically. This theory states that the only way to ensure consistency in measuring variables is to use numerical values.

- **Independence and additivity:** The underlying premise is that there is no interdependence between variables and the numerical values they hold. Within these bounds, variables are picked at random. Assumption number two concerns the additive nature of the variables to be combined. No variables can be used in linear programming if they cannot be joined together.

- **Proportionality:** It presupposes that all variables are proportionate to one another. In determining the answer, the proportionality of the variables does not change. This means that regardless of the level of output, the proportional relationship among the variables

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remains constant. In the case when 5 units of input are needed to create 1 unit of output, for instance, 50 units of input would be required to create 10 units of output.

- **Constant price:** It presupposes that, irrespective of the amount bought or sold, the input with no change to the prices of produce.

We can learn how to solve these business difficulties using linear programming. Maximising profits is a typical problem that is solved using linear programming. In this case, P and Q are the inputs that allow an organisation to manufacture two products, A and B. The organisation needs 800 units of P and 1000 units of Q in terms of total inputs per unit of time. A yields 5 rupees in profit while B yields 4 rupees per unit. The following are the requirements for making Products A and B, as indicated in Table 5.4:

Table 5.4: Conditions for Production

Input	Total Input Available to Organisation	Requirement of input for producing per unit of product	
		A	B
P	800	4	2
Q	1000	2	5

In order to maximise profit (π), the organisation must determine the optimal combination of inputs. In order to use the linear programming method to solve this problem, we must follow these procedures to generate the equations:

1. **Objective function:** It alludes to the initial stage, where the objective function for the problem's solution is formulated. Here is the objective function representation for Table 5.4:

   Maximise

   The above-mentioned equation represents the overall profit, where A and B are the quantities of production that would be multiplied by the profit per unit. The values of A and B in the previous equation are determined using the linear programming technique.

2. **Constraint equation:** This tool is useful for calculating the total profit an organisation may make as well as the inputs needed to make a certain quantity of output. Here we can express the constraint equation for P in the given example:

   According to the preceding equation, there is an 800-unit supply of input P. Two units of input P are utilised to create output B, while four units are utilised to create output A. The constraint equation for Q can also be found and represented in the following way:

   Assuming Q, the overall inventory is 1000. One unit of input Q makes two units of output A, while five units make up one unit of output B.

3. **Non-negativity condition:** It is the necessary condition for obtaining a more practical answer to the maximisation issue. The real world cannot conceivably accommodate a solution to linear programming that contains a negative value. Consequently, the non-negative strategy is chosen to prevent this kind of circumstance. Here is an expression for the non-negativity requirement in our example:

   $A \geq 0$ and $B \geq 0$

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The complete linear programming equation can be expressed as follows:

Maximise $\delta = 5A + 4B$

Subjects to constraints,

Where, $A, B \geq 0$

5.6.2 Decision tree analysis

Organisational decision-making models are often referred to as decision tree analyses. To determine the optimal answer to an issue, decision tree analysis draws a structure similar to a tree. The proper order for a decision tree's branches is left to right. The decision tree format is illustrated in Figure 5.9:

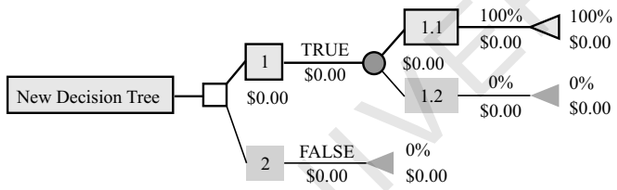

Fig 5.9: Format of a Decision Tree Analysis

(**Source:** *http://www.epmptools.com/*)

Let us understand the working of a decision tree with the help of an example. Suppose a restaurant owner wants to expand the facility. There are two options to do this. The first option is to expand on a large scale and risk the smaller demand. The second option is to expand on a smaller scale in spite of the fact that there may be a need to expand it again in three years. Which option do you think is the best for the owner? This problem can be solved by using the decision tree shown in Fig5.10:

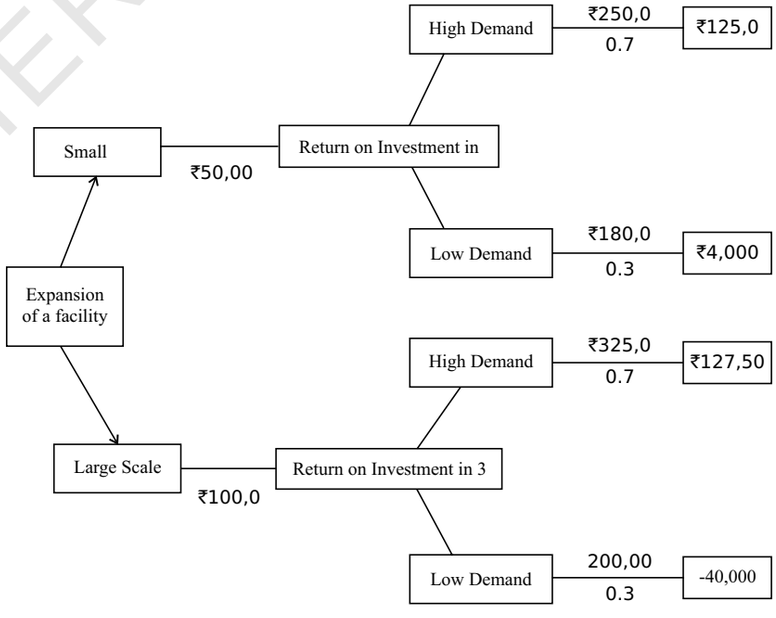

Fig 5.10: Decision Tree for Restaurant Facility Expansion

In Fig5.10, the decision tree shows investments at both small and large scale. Now, let us analyse the outcomes of these two investments. At small scale, the restaurant owner invests

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₹ 50,000 and at large scale, his/her investment is ₹ 100,000. The outcomes for these two investments can be high demand and low demand. The estimated returns projected for three years at small scale are as follows:

At small scale,

On high demand = ₹ 250,000

On low demand = ₹180,000

The probabilities assigned to the outcomes are 0.7 for high demand and 0.3 for low demand. Now, let us calculate the profits generated by expanding the facility at small scale.

Profit on high demand = 0.7 * 250,000 - 50,000 =₹125,000

Profit on low demand = 0.3 * 180,000 - 50,000= ₹4,000

The estimated returns projected for three years at large scale are as follows:

On high demand = ₹325,000

On low demand = ₹200,000

The probabilities assigned to the outcomes are 0.7 for high demand and 0.3 for low demand. Now, let us calculate the profits generated by expanding the facility at large scale.

Profit on high demand = 0.7 * 325,000 - 100,000 = ₹127,500

Profit on low demand = 0.3 * 200,000 - 100,000 = -₹40,000

From the above-mentioned calculations, it is evident that the profit generated at large scale (₹127,500) is more than that generated at small scale (₹125,000) at the time of high demand. However, in case of low demand, if the owner of the restaurant invests at large scale, he/she would incur a loss of ₹40,000. On the other hand, if he/she invests at small scale, the loss will be ₹4,000. So the best option is to expand the facility at a small scale.

Self-Assessment Questions

26. _____ strategy is used to add capacity even before the occurrence of the actual demand.

27. _____ strategy helps in reducing risks up to a certain level by saving the undue investment in the capital assets at the low demand level.

28. Linear programming refers to the mathematical technique used for solving optimisation problems. (True/False)

29. _____ analysis is used to draw a tree-type structure for deciding the best solution for a problem.

5.7 Summary

- Capacity may be defined as the ability of a production unit to produce within the given time period by using available resources.
- The capacity of a production unit depends on the demand for products or services.
- Capacity management in an organisation is very essential for a smooth working of its production processes.

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- Capacity management may be defined as the short-term adjustments made in capacity so that it tallies with the forecast demand.
- Determination of capacity requirements is an important part of capacity management process.
- Capacity requirements of a production plant can be determined by converting its production schedule into standard hours.
- Equipment is associated with a fixed cost and a running cost.
- The fixed cost is the cost of procuring and installing the equipment, whereas the running cost is the cost of operating the equipment in order to generate the required product or service.
- Some equipment becomes obsolete when a new technology of the same category is introduced.
- After determining the required capacity, organisations estimate equipment requirements as capacity limitations are always expressed in terms of equipment efficiencies or scrap loss.
- Capacity planning refers to the process of determining the level of capacity required to manufacture a specific product with a defined quantity.
- The capacity of an organisation can be measured in the form of input, output or a combination of these two.
- Linear programming refers to the mathematical technique used for solving optimisation problems, such as maximisation and minimisation problems of businesses.
- In the decision tree analysis, a tree-type structure is drawn to decide the best solution for a problem.

5.8 Glossary

- **Capacity Utilisation:** The ratio of the actual output to design capacity.
- **Capacity:** A facility's maximum productive capability, usually expressed as the volume of output for a defined time period.
- **Design Capacity:** The maximum rate of output that can be achieved under ideal conditions.
- **Effective Capacity:** The maximum rate of output that can be practically achieved under time constraints consumed in set-ups, oiling and cleaning, defective items, etc.
- **Efficiency:** The ratio of the actual output to the effective capacity.

5.9 Terminal Questions

1. What is meant by the capacity of a facility? Explain the different types of capacity.
2. Explain the concept of capacity management.
3. Write short note on capacity planning.
4. Differentiate between:
   a. Short-term and long-term capacity planning
   b. Finite capacity planning and infinite capacity planning

Notes

5. What are the different strategies used for capacity measurement?

6. Explain the different methods used for measuring capacity.

5.10 Answers

Q.	Self Assessment Questions
1.	Maximum
2.	a. Effective capacity
3.	True
4.	False
5.	a. Lesser than
6.	c Both a and b.
7.	Average fixed costs (AFC)
8.	False
9.	Level of output
10.	Long run Marginal Cost (LMC) is defined as added cost of producing an additional unit of a commodity when all inputs are variable.
11.	Economies of scale
12.	c. Financial economies of scale
13.	True
14.	Poor Communication, lack of motivation, loss of control, and cannibalisation are the major causes for diseconomies of scale.
15.	Standard hours
16.	Forecast demand
17.	Financial performance
18.	Actual output
19.	True
20.	$\text{Number of machines needed} = \text{Processing time per unit (h)} \times \frac{(\text{Available time/period})}{(\text{Required output rate})}$
21.	Capacity planning
22.	Demands
23.	True
24.	Time; capacity

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25.	False
26.	Lead capacity
27.	Lag capacity
28.	True
29	Decision tree
Q.	**Terminal Questions**
1.	Capacity refers to the ability of a production unit to produce something using the available resources within the given time period. The different types of capacities are fixed capacity, adjusted capacity, design capacity, theoretical capacity, system capacity, potential capacity, immediate capacity, effective capacity, and actual or utilised capacity. Refer to section ***5.2* Concept of Capacity.**
2.	Capacity management refers to the management of available capacity of a production plant in such a manner that it is sufficient to meet the business requirements of an organisation effectively. Refer to section ***5.3* Concept of Capacity Management.**
3.	Capacity planning refers to the process of determining the level of capacity required to manufacture a specific product with a defined quantity. Refer to section ***5.5* Concept of Capacity Planning.**
4.	Capacity planning decisions of an organisation can be classified into four different categories, that is, short-term capacity planning, long-term capacity planning, finite capacity planning and infinite capacity planning. Refer to section ***5.5* Concept of Capacity Planning.**
5.	Different strategies for capacity measurement are lead, lag and match capacity strategies. Refer to section ***5.6* Methods of Measuring Capacity.**
6.	Different methods used for capacity measurement are linear programming method and decision tree analysis. Refer to section ***5.6* Methods of Measuring Capacity.**

5.11 Case Study: Nestle

A number of coffees are roasted, ground, and packaged at the Nestle drinks facility in Suffolk, Virginia (USA). Two distinct structures make up the plant. Their main brand is manufactured at one location with a huge capacity and continuous production lines. The roasting procedure on this line is done in a single batch stage, however the batches are consistently 1,000 lb, which allows the line to operate in a continuous mode. A smaller batch size of about 400 lb can be handled by the alternative facility. This line is specifically engineered to process data in batches. Instead of feeding into a continuous process operation, the roasted beans are held in specially built hoppers, and the roasters may handle 400 kg at a time. To facilitate their storage as WIP, these hoppers are mobile (WIP). Then, in accordance with the designated delivery dates, these work-in-progress batches are scheduled for grinding and packaging. Nestle did not include two distinct buildings in the plant's design only to accommodate

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capacity needs. For smaller customers, the main objective was to enable them to run small amounts of specialty coffee. The base demand could be met by the huge continuous process facility, and the demand fluctuations induced by seasonal cyclical impacts could be adjusted using the batch facility. Even if the batch line makes 1 lb of coffee more expensive than the continuous process line. Due to the small batch line's flexibility, the combined facilities can produce 1 lb of coffee at a lower cost than the continuous process facility, according to the real schedule of demand (when double-shift operation is taken into account).

Discussion Questions

1. In the above-mentioned scenario, how should the company balance the production capacity between the two lines?

   (Hint: The company need not use both the facilities at the same time, during period of less demand. However, in case of high demand the company may utilise both the facilities simultaneously. This would save cost of production for the company)

2. What will be the impact on the total production capacity if one of the lines is being closed for capacity adjustment?

   (Hint: It will reduce the total production capacity of the organisation.)

5.12 References and Suggested Readings

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CHAPTER

6

Concept of Production Planning & Control

Structure

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Learning Objectives

After studying this chapter, you will be able to:

- explain the concept of production planning
- discuss production planning as a part of corporate planning
- explain the concept of production control
- elaborate on the integration of production planning and control
- explain the techniques of production planning and control
- outline the importance of production planning and control

6.1 Introduction

The previous unit discussed about capacity management in detail. This unit focuses on concept of production planning and control. The Production Planning and Control (PPC), a tool that helps an organisation to achieve its pre-determined objectives is the key ingredient for the success of a manufacturing organisation. Production planning is a part of corporate planning, which is all about determining what to produce, when to produce and how much to produce in a given point of market situation. The main objective of production planning is to ensure the availability of the right quantity and quality of inputs for the production process based on the requirement. On the other hand, production control involves identifying deviation between the actual production and planned production and taking the corrective actions to reach the objectives.

Production planning and control together ensures the optimum utilisation of production capacity. Moreover, it helps an organisation in maintaining an adequate level of inventory as well as a balanced and uninterrupted production flow. Production planning and control aims at conforming to delivery commitments and making adjustments in production as per the changes in demand.

The chapter begins by explaining the concept of production planning in detail. Next, it discusses production planning as a part of corporate planning. The chapter further details upon the concept of production control. In addition, it elaborates on integration of production planning and control. The chapter also sheds light on the concept of PPC and its importance. Towards the end, it outlines the importance Line of Balance (LOB).

6.2 Concept of Production Planning

Production planning refers to an activity that involves determining the inputs such as men, materials, and machines required for achieving the pre-determined production goals. These goals can be related to producing the desired finished products at an appropriate time at minimum possible cost. Alford and Beatty have defined production planning as, *"the techniques of foreseeing or picturing ahead, every step in a long series of separate operations, each step to be taken in the right place, of the right degree, at the right time, and each operation to be done at maximum efficiency"*. In other words, it can be said that production planning involves preparing a blueprint of the production process to achieve the desired performance. The following are the main objectives of production planning:

- **Determining resources:** This objective is about estimating the quality and quantity of resources required for producing finished products. This estimation is performed on the basis of sales forecasts and using several analytical methods.

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- **Minimising cost:** This objective is about the production planning aims at making effective utilisation of resources and reducing wastage, thereby minimising overall production cost and increasing the efficiency of production process.
- **Setting production goals:** This objective is about determining the production objectives and scheduling resources to achieve those objectives. To do so, an organisation uses various mathematical and analytical techniques.

The entire production planning process of an organisation involves the following steps:

1. Determining production objectives
2. Specifying production priorities
3. Evaluating production environment
4. Setting an achievable production target
5. Managing the available resources to achieve the production target

6.2.1 Production planning- a part of corporate planning

Production planning is closely related to corporate planning. For example, if the production goal of an organisation is to produce 10 tons of output in the coming year, the corporate objectives would be to earn maximum profit by selling 10 tons of output. Fig. 6.1 shows interlink between corporate planning and production planning:

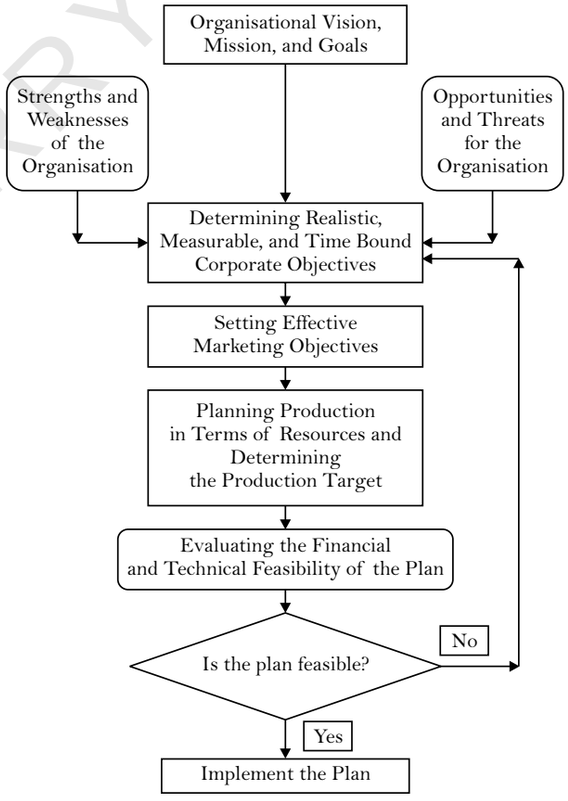

Fig. 6.1: Flowchart of Corporate Planning

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Self-Assessment Questions

1. Which of following refers to an activity that involves determining inputs, such as men, materials, and machines, required for achieving pre-determined production goals?
   a. Production Planning
   b. Production Scheduling
   c. Production Controlling
   d. Production Planning and Control
2. Production planning is closely related to corporate planning. (True/False)

6.3 Production Planning Techniques for Various Process Choices

Production planning is a process of routing, scheduling, dispatching and coordinating the resources (men, machine, and material) for achieving the objectives of manufacturing. In simple words, production planning involves what products to be produced and in what quantities and when are they required. It also plans for the required materials for production. This planning can be short term and long term in nature. The different processes used in manufacturing are job shop, flow shop, line manufacturing, mass manufacturing and continuous manufacturing. The common techniques of production planning used in these processes are as follows:

- Forecasting
- Material Requirement Planning

Note

Aggregate planning is one of the important methods of production planning, which is discussed in detail in unit-7.

6.3.1 Forecasting

In order to prevent issues like under- or overproduction, a company needs data pertaining to the anticipated demand for its goods and services. Predictions are used for this purpose. Foretelling can be done in two ways. Predictions based on data collected from surveys constitute the first strategy. Second, you can use statistical methods to look at previous data and make predictions about what's to come. So, we can classify forecasting strategies as either survey methods or statistical methods. While statistical approaches are more suited for long-term event predicting, survey methods are more useful for short-term forecasting. Figure 6.2 illustrates these two methods:

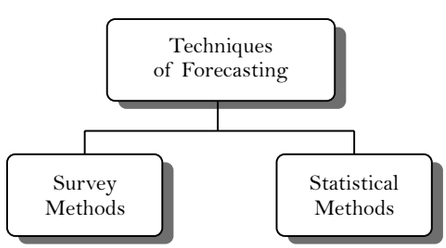

Fig. 6.2: Forecasting Techniques

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Let us discuss these techniques (as shown in Fig. 6.2) in detail, in the next sections.

- **Survey method:** Among the many popular and straightforward approaches to short-term event forecasting, the survey method stands out. This approach takes into account customers' intents and plans for future purchases. With this strategy, a company asks people to fill out questionnaires about an event. As illustrated in Figure 6.3, the survey approach carries out three exercises:

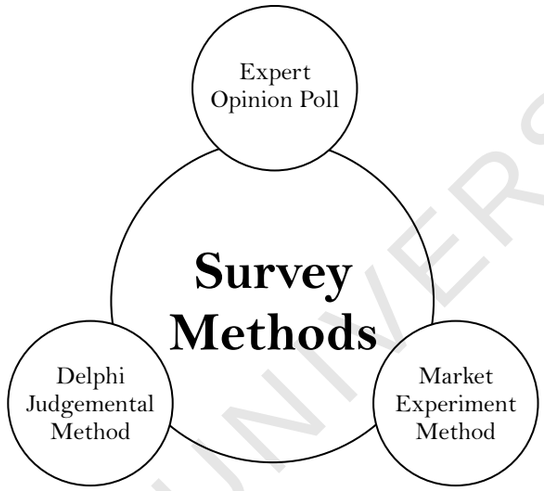

Fig. 6.3: Survey Methods

The exercises undertaken in the survey method (as shown in Fig. 6.3) are discussed as follows:

- **Expert opinion poll:** One way to get experts' thoughts on a product is to conduct an expert opinion poll. In a business setting, for instance, salespeople play the role of experts by gauging product demand in various locations. Since they are constantly interacting with customers, salespeople know what those customers want, how they will respond to changes in the market, and how they feel about competing items. They give a ballpark figure for how much interest there is in the company's wares. This approach is less costly and requires little effort. Nevertheless, the following are some of its limitations:
  - Supply projections based on the knowledge and expertise of market specialists. These abilities are unique to each person. This makes it hard to make precise predictions.
  - Includes the assessor's subjective judgement, which could result in an over- or under-estimation. Data supplied by sales people, who might not have sufficient market knowledge, is relied upon.
  - Does not take into account variables that can be useful for predicting, such as changes in the GDP, the availability of financing, and the industry's future prospects.
- **Delphi judgemental method:** What it means is that it's a method for making predictions as a group. This technique involves polling a panel of experts with one-on-one questions about their thoughts on a potential business-related event. Until an agreement is reached, these questions are posed again and again. Furthermore, this approach gives each expert access to the group's previous estimates, allowing them to adjust their own estimates in light of the group's collective wisdom. Experts verify each other's predictions in this way, leading to more reliable information for equitable

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decision-making. Each expert has the opportunity to respond to and offer ideas regarding the estimations made by their peers. For the sake of impartial evaluation and to lessen the impact of a halo effect, experts typically exchange estimates while remaining anonymous. One major perk of this approach is how efficient it is in terms of both time and money. By quickly contacting multiple specialists, you won't have to spend as much on other resources. Nonetheless, this approach could result in decisions that are based on personal opinions.

- **Market experiment method:** Using this strategy, you can get all the facts you need about an event, both past and present. It is responsible for conducting research and experimentation on customer behaviour in real-world market settings. This strategy involves picking out certain markets that have characteristics like population, income, culture, and customer preferences. By manipulating prices and expenditures, market experiments can be conducted and the resulting changes to the event can be documented. Foretelling a future event is much easier with these findings.

There are various limitations of this method, which are as follows:

- Alludes to a pricey procedure; so, it may be out of reach for little organisations
- Various social and economic factors, including strikes, political instability, and natural disasters, impact the outcomes of trials.

6.3.2 Statistical methods

In order to make accurate predictions, statisticians use a wide variety of techniques. For long-term event forecasting, these strategies are employed. This technique uses both historical and cross-sectional data to make predictions about the future. For example, you may find market survey reports and balance sheets from prior years, as well as other sources of historical data. Conversely, surveys of consumers and interviews with specific persons provide cross-sectional data. Statistical approaches are less prone to subjectivity and so more cost-effective and dependable than survey methods. Figure 6.4 shows the three primary exercises that comprise these methods:

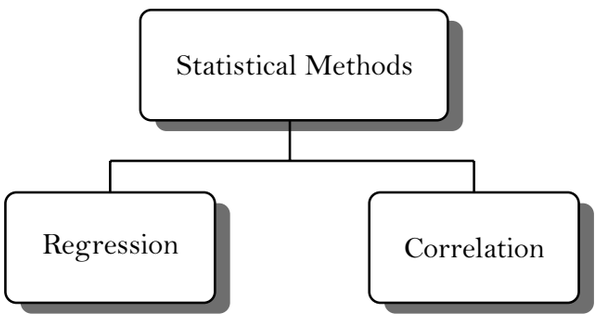

Fig. 6.4: Statistical Methods

The different statistical methods (as shown in Fig. 6.4) are explained in the next sections.

- **Regression Method:** The most common method to making predictions is known as regression. The purpose of the regression method is to estimate an event by making use of both independent and dependent variables. Where the event is the dependent variable and its determinants are the independent variables in this scenario. An event is

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considered to be a single-variable event if it is affected by just one variable. This leads to the utilisation of basic regression methods. A multi-variable event is one in which more than one variable influences the outcome. Hence, multiple regression is employed in this scenario. What follows is a discussion of both the simple and multiple regression methods:

- **Simple regression:** It refers to studying the relationship between two variables where there is an independent variable and a dependent variable. The equation to calculate simple regression is as follows:

  $Y = a + bX$

  Where, Y = Estimated value of Y for a given value of X

  b = Amount of change in Y produced by a unit change in X

  a and b = Constants

  The equations to calculate a and b are as follows:

  $a = Y - bx$

  $b = \sum x_i y_i / \sum x_i^2$

  $\sum x_i^2 = \sum X_i^2 - nX^2$

  $\sum x_i y_i = \sum X_i Y_i - nXY$

  Where, X_i = ith value of X variable

  X= Mean of X variable

  Y_i= ith value of Y variable

  Y= Mean of Y variable

  n= Number of pairs of observations

- **Multiple regression:** It refers to studying the relationship between more than one independent and dependent variable. In case of two independent variables and one dependent variable, the following equation is used to calculate multiple regression:

  $Y = a + b_1X_1 + b_2X_2$

  Where, Y (Dependent variable) = Estimated value of Y for a given value of X_1 and X_2

  X_1 and X_2 = Independent variables

  b_1 = Amount of change in Y produced by a unit change in X_1

  b_2 = Amount of change in Y produced by a unit change in X_2

  a, b_1 and b_2 = Constants

  The equations used to calculate a and b values are as follows:

  $\sum Y_i = na + b_1\sum X_{1i} + b_2\sum X_{2i}$

  $\sum X_{1i}Y_i = a\sum X_{1i} + b_1\sum X_{1i}^2 + b_2\sum X_{1i}X_{2i}$

  $\sum X_{2i}Y_i = a\sum X_{2i} + b_1\sum X_{1i}X_{2i} + b_2\sum X_{2i}^2$

  The number of equations depends on the number of independent variables. If there are two independent variables, then there would be three equations, and so on.

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- **Correlation analysis:** It is the kind of analysis where the researcher looks at how different variables are related to each other. It also determines how much of an impact one variable has on the others. What follows is a description of the various kinds of correlation:
  - **Simple correlation:** The term describes a method for determining the strength of a correlation between two variables. When describing a relationship, it is the metric most often used. Karl Pearson is credited with introducing the coefficient of correlation, which is thus called Karl Pearson's coefficient. Assuming a linear relationship between two variables—one dependent and one independent—is necessary to compute a simple correlation. There are three possible kinds of correlation, as shown in Figure 6.5:

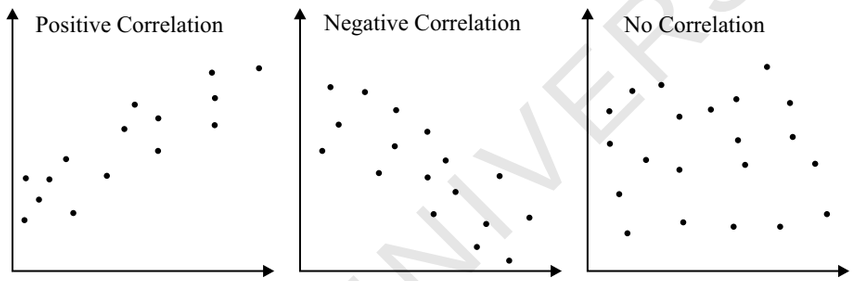

Fig. 6.5: Different Types of Correlation

The strength of association between two variables depends on the calculated value of the correlation. The value of the correlation coefficient lies between a range of -1 to +1. If the calculated value of the correlation is close to -1, then there is a strong negative correlation between the two variables. If the calculated value of the correlation is close to +1, then there is a strong positive correlation between the two variables. However, if the calculated value of the correlation is not close to -1 or +1, then there is a weak correlation between the two variables. For example, if the coefficient of correlation comes out to be 0.3/-0.3, then the association between the variables is weak; whereas, if the coefficient of correlation is 0.8/-0.8, then the association between the variables is strong. The formula used to calculate the correlation is as follows:

$$\text{Correlation}(r) = \sum(X_i-X)(Y_i-Y)/n\,\sigma_x\sigma_y$$

Or

$$\text{Correlation}(r) = (n\sum X_iY_i - \sum X_i\sum Y_i)/\sqrt{n\sum X_i^2-(\sum X_i)^2} * \sqrt{n\sum Y_i^2-(\sum Y_i)^2}$$

Where, X_i = ith value of X variable

X = Mean of X variable

Y_i = ith value of Y variable

Y = Mean of Y variable

n = Number of pairs of observations

σ_x = Standard deviation of X

- **Multiple correlations:** It represents the relationship between more than two independent variables and more than one dependent variable. It helps in finding out the effect of independent variables on the dependent variable. The formula for multiple correlation, when there are two independent variables and one dependent variable, is as follows:

$$\text{Multiple Correlation}(R) = \sqrt{b_1\sum X_{1i}Y_i - nYX_1 + b_2\sum X_{2i}Y_i - nYX_2 / \sum Y_i^2 - nY^2}$$

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Where, X_1 and X_2 = two independent variables

Y_i = ith item of dependent variable Y

Y = Mean of Y

X_{1i} = ith item of X_1 variable

X_{2i} = ith item of X_2 variable

X_1 = Mean of X_1

X_2 = Mean of X_2

b_1 = Constant for X_1

b_2 = Constant for X_2

- To calculate the multiple correlation, first calculate the mean and values of constants (b_1 and b_2) for the two independent variables. The general equation to calculate b is as follows:

$$\sum x_i^2 = \sum X_i^2 - nX^2$$

$$\sum x_i y_i = \sum X_i Y_i - nXY$$

$$b = \sum x_i y_i / \sum x_i^2$$

Calculation for b_1 is as follows:

$$\sum x_{1i}^2 = \sum X_{1i}^2 - nX_1^2$$

$$\sum x_{1i} y_i = \sum X_{1i} Y_i - nX_1 Y$$

$$b_1 = \sum x_{1i} y_i / \sum x_{1i}^2$$

Calculation for b_2 is as follows:

$$\sum x_{2i}^2 = \sum X_{2i}^2 - nX_2^2$$

$$\sum x_{2i} y_i = \sum X_{2i} Y_i - nX_2 Y$$

$$b_2 = \sum x_{2i} y_i / \sum x_{2i}^2$$

Similarly, we can also calculate b_3, b_4 and other b constants by changing the independent variables X_1 and X_2 to X_3, X_4 and so on in the preceding equations.

6.3.3 Material Requirement Planning

Material Requirement Planning (MRP) is a process of identifying the requirements of materials used for producing finished products. It also involves determining appropriate timing when these materials should be ordered so that delivery schedules mentioned in MPS can be met. MPS provides information related to the availability of raw materials, components, and demand for raw materials. Such information helps an organisation to complete production as per the plan, make timely delivery of products, and minimise investment in inventory. The following are the main objectives of MRP:

- Prevents excessive building up of inventory by determining the requirements of materials and procuring them as and when needed to meet MPS
- Reduces manufacturing and delivery lead time by determining the exact quantity of materials and timing when they need to be procured
- Helps in meeting delivery commitments by providing accurate and timely information related to delivery schedules

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- Increases the efficiency of production system by maintaining an uninterrupted flow of materials through the production line

To achieve the aforementioned objectives, MRP requires the following information:

- Product structure representing how a finished product is made up of assemblies, sub-assemblies, and components
- Lead times for procuring different items at different levels of production
- Demand and delivery schedules of finished products
- Information related to the current stock of materials

The efficiency of MRP depends on the quality of inputs. Fig. 6.6 shows the structure of MRP and inputs used in it:

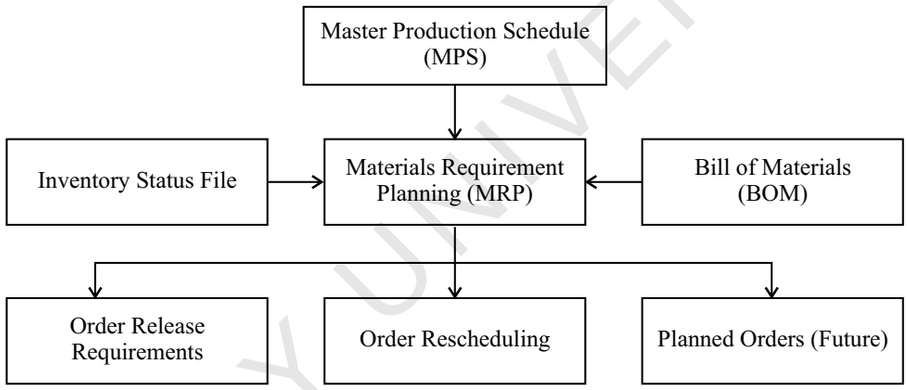

Fig. 6.6: MRP Structure

From Fig. 6.6, it can be seen that MRP requires three types of inputs, namely MPS, BOM and inventory record files. These are discussed in detail in the next unit.

Self-Assessment Questions

3. _____can be defined as a process of predicting the events or conditions that may take place in an organisation.
4. A method in which experts are requested to provide their opinion about the product is called Delphi method. (True/False)
5. What are the statistical methods of forecasting?
6. MRP stands for _____

6.4 Meaning of Production Control

Production control is a process of identifying variations between the planned production performance and the actual production performance achieved by an organisation. It also involves taking corrective measures in case there are variations between planned and actual production performance. Production control basically includes monitoring the flow of resources and ensures that each resource is used at the right place and at the right time. This ultimately helps in preventing the wastage of resources, thereby minimising costs. The

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following are the main objectives of production control:

- Monitoring the overall production process
- Ensuring effective functioning of the production process
- Making adjustments in the production process as per changes in demand

Fig. 6.7 shows a framework of the production control system:

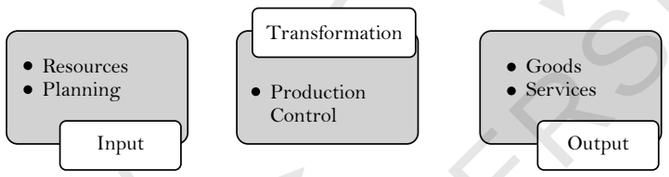

Fig. 6.7: Production Control System

It should be noted that production planning is performed before the initiation of the production process, while production control is performed during the production process. Thus, production control is an ongoing activity that continues throughout the production process. The following points discuss the importance of production control:

- Helps in organising production schedules
- Makes optimum utilisation of production resources
- Ensures an uninterrupted flow of production process
- Minimises production cost by reducing wastage
- Maintains a standard of quality throughout the production process

The production control activity varies across different organisations depending on various factors, such as nature of production, nature of operation, and size of operations.

Self-Assessment Questions

7. _____ is a process of identifying variations between the planned production performance and the actual production performance achieved by an organisation.
8. Production planning is performed before the initiation of the production process. (True/False)

6.5 Techniques of Production Control

Systematically planning, coordinating and directing the manufacturing activities come under the production control. It ensures that products should be produced on time with adequate quality and at reasonable cost.

The two important techniques of production control are as follows:

- Line of Balance
- Shop Floor Control

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6.5.1 Line of Balance

Line of Balance (LOB) is a technique that is used for scheduling and controlling upstream processing steps for producing products. This technique helps an organisation to monitor and control the actual production process so that it can meet the pre-determined production schedule, thereby avoiding delays in product delivery. Generally, manufacturing organisations do not fail to meet the desired production schedule until there is a lack of material supply. Therefore, the LOB technique not only keeps a check on the quantity of output produced as per the pre-determined schedule, but also keeps a tab on the quantity of materials supplied for the production process. To do so, a number of charts are prepared and calculations are performed. These charts represent the date-wise delivery schedule of the final output. To do so, individual process operations are arranged in a sequence on the basis of time taken by the previous operation to support the upcoming operation. Moreover, these charts mention the scheduled work-in-progress and the actual work-in-progress pertaining to a specified manufacturing plant. The LOB technique is mainly used in organisations where production jobs are repetitive in nature. Let us discuss the steps to be performed by an organisation for employing the LOB technique.

Steps Involved in LOB Technique

From the discussion so far, it can be said that the LOB technique is applied to ensure the timely completion of production activities as per the schedule. To apply this technique, an organisation needs to perform the following steps:

1. **Making an assembly chart or operation program:** This refers to the first and foremost step to be performed for applying the LOB technique. An assembly chart depicts the scheduled sequence of activities and the lead time of every individual operation in the manufacturing process.

2. **Preparing a cumulative process completion schedule:** This is about developing a schedule that displays the cumulative amount of output to be produced over a period of time. A cumulative schedule is usually prepared on a weekly basis. Let us understand the cumulative schedule with the help of an example. Consider a production schedule planned for 10 weeks to manufacture 100 units of output. Table 6.1 shows the cumulative schedule for producing 100 units of output in 10 weeks:

Table 6.1: Cumulative Schedule for Producing 100 Units in 10 Weeks

Date (Year-2011)	01/01	08/01	15/01	22/01	29/01	05/02	12/02	19/02	26/02	02/03
Quantity of output produced	2	4	4	10	8	22	20	10	10	10
Cumulative quantity of output produced	2	6	10	20	28	50	70	80	90	100

3. **Drawing the cumulative output chart:** This represents the cumulative amount of output to be produced in a graphical manner. A graphical format of the cumulative schedule is called LOB chart. To draw the LOB chart, the overall production activity is

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divided into distinct sections. For instance, the production activity of a manufacturing plant producing product P can be divided into three major sections, which are as follows:

- **Machining:** It involves producing different parts and components for the final output
- **Assembling:** It involves combining individual parts
- **Testing:** It involves checking the quality and performance of the assembled parts

Fig. 6.8 shows the graph that can be derived on the basis of the cumulative schedule shown in Table 1:

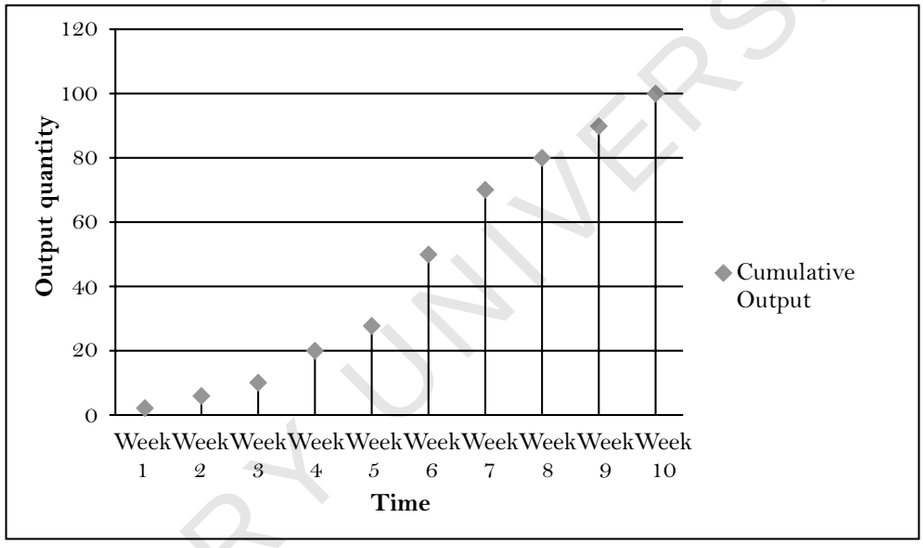

Fig. 6.8: Cumulative Output Chart

4. **Drawing a line of balance:** It involves drawing a line of balance with the help of the cumulative output chart. Fig. 6.9 shows how to draw a line of balance:

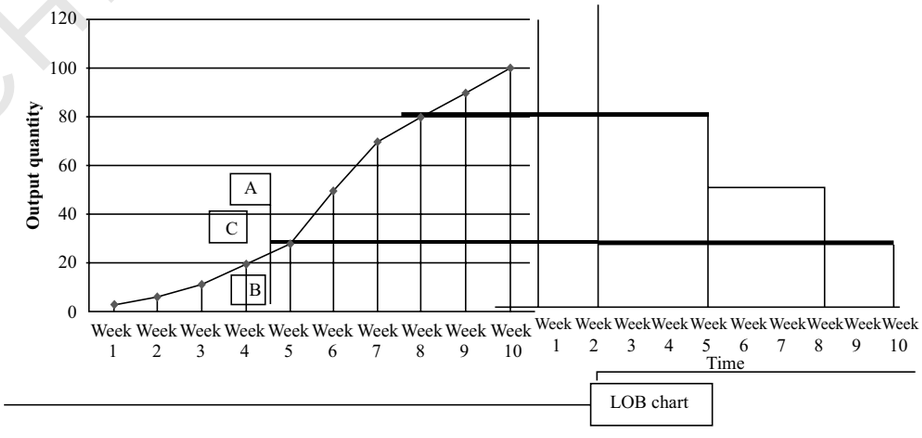

Fig. 6.9: Line of Balance Schedule

Fig. 6.9 shows how to draw LOB schedule with the help of the cumulative output chart. To draw this schedule, first of all, draw a vertical line AB on the cumulative output chart. Line AB is to be drawn at the week on which the monitoring of production is to be done.

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In this example, it is assumed to be drawn on the fifth week of production. Line AB intersects the cumulative output curve at point C. Now, draw the production sectional chart showing the major sections of production that are machining, assembling, and testing. For this purpose, the total time duration of 10 weeks is divided among three sections. In the total duration of 10 weeks, it is assumed that machining should be done by the end of fifth week, whereas assembling and testing would require three and two weeks respectively. Accordingly, three vertical lines are drawn. Now, draw a horizontal line from point C that intersects the cumulative output lines of week six till week ten at a gap of their respective lead times. The horizontal line creates a bar when it meets the vertical line of the testing section of the production process. The order at which this horizontal line divides the weekly interval of cumulative output chart refers to the time lag between the operations performed among different weeks.

It is already assumed that 80% of the machining work should be completed by the end of fifth week of production. Based on this assumption, draw another horizontal line representing 80 units of output in the cumulative output chart up to the level till it intersects the vertical line representing the machining work at week five. This horizontal line would represent the line of balance for the production process.

5. **Drawing a progress chart and taking corrective actions:** It refers to the last step of the LOB technique. As shown in the previous step, the line of balance schedule has been created on assumptions. Therefore, this schedule may vary at the time when the operations are actually performed every week. To identify the gap between actual production and desired production, a progress chart is drawn. A progress chart is drawn on the same sheet of the LOB chart by introducing the bars representing the completion of actual production as and when each individual operation is completed. Fig. 6.10 shows a progress chart:

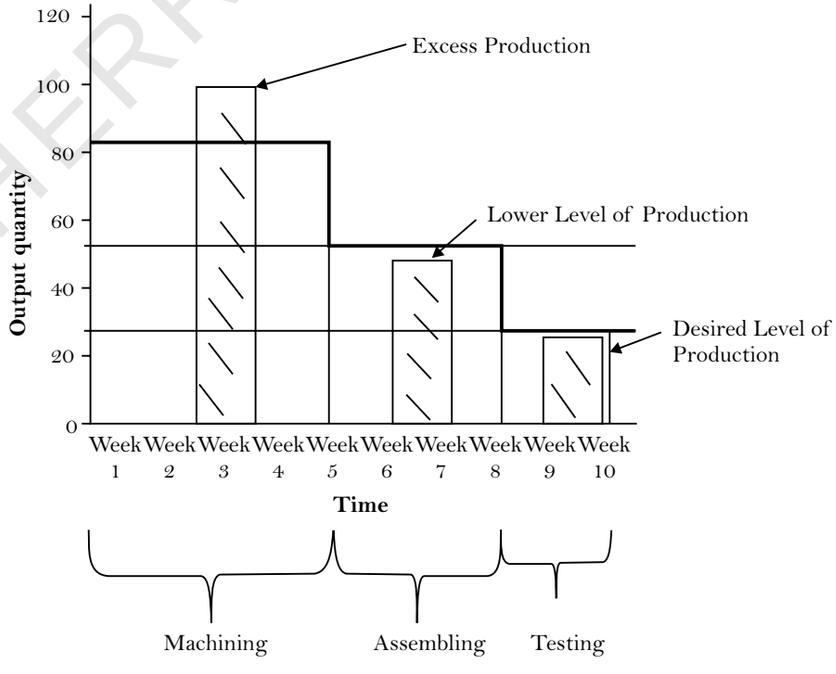

Fig. 6.10: Production Progress Chart

As shown in Figure 8, the production progress chart shows the comparison between the desired production and the actual production. The figure also shows the units produced at

the three major sections of production. At the first stage of production, that is machining, excess production has been identified. Such excess production needs to be controlled after reviewing the line of balance as it would lead to wastage of resources. At the second stage of production, that is assembling, the actual level of production is below the desired level. This again needs to be controlled after the review of line of balance as the lower level of production would lead to delays in delivery. Since the controlling techniques are applied at the first and second stages, the level of production at the third stage would match the desired level of production.

Advantages of LOB technique

The following points refer to the advantages of applying LOB technique in production:

- Helps in reviewing operations at every stage of production, which further helps in reinforcing the planned production schedule for attaining the desired level of output
- Reduces the number of errors in the production schedule, thereby increasing the efficiency of the production process
- Prevents delays in production by identifying shortfalls in the production process
- Avoids the wastage of valuable resources by identifying the excess of production

6.5.2 Shop Floor Control

Shop floor control is a method that controls the management activities and flow of materials in the plant. This method prioritises, monitor and controls the progress of the production orders and schedules. This method is mostly used in manufacturing processes such as job shop production and batch production as there are varieties of orders that are processed in these production processes.

The objectives of shop floor control include the following:

- Executes and releases the orders to the shop floor efficiently
- Delivers up to date information on material consumption
- Executes change management processes
- Automates the shop floor equipment control that reduce human errors and increase the productivity

There are three modules of shop floor control system namely, order release, order rescheduling and order progress.

- **Order release**: This involves generation of documents for processing a production order. The documents consist of route sheet, job cards that help in reporting the labour time and parts list that include the material details.
- **Order scheduling**: This involves assigning the production orders in the different work centres in the factory. This involves prioritising the work by giving schedules to each work centre.
- **Order progress:** This involves monitoring the status of the orders and work in process. The data is collected from various sources that help in knowing the production progress and performance.

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Self-Assessment Questions

9. _____ is a technique that is used for scheduling and controlling upstream processing steps for producing products.

10. A method that controls the management activities and flow of materials in the plant is called:

    a. Shop floor control

    b. Line of balance

    c. Correlation

    d. Delphi technique

6.6 Integration between Production Planning and Control

Production planning and production control are closely related to each other. As discussed earlier, production planning is concerned with the development of production strategies and a production target. On the other hand, production control is related to the implementation and execution of the pre-determined production plan. Fig. 6.11 shows the relationship between production planning and production control in the production process of an organisation:

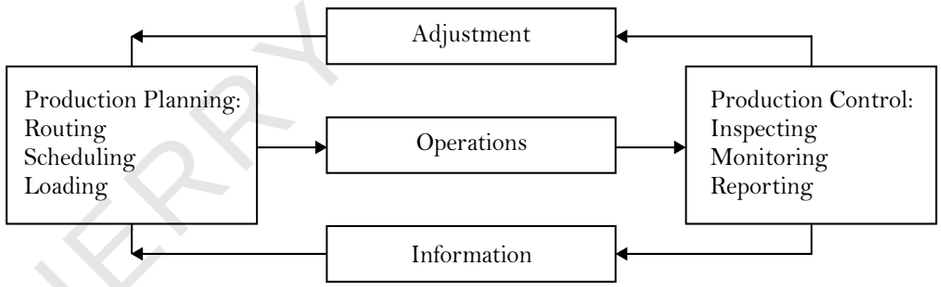

Fig. 6.11: Relationship between Planning and Control

From Fig. 6.11, it can be said that production planning and control functions of an organisation are interdependent. Production planning pre-assumes the actual production process and develops a framework of all operations to be carried out in the production process. At the same time, production control supervises and regulates these operations, monitors the actual and desired performance, and improves operations with necessary adjustments. The control function documents all these adjustments, which further helps in improving the efficiency of production planning in the future.

Planning is the most essential prerequisite for the production process. However, mere effective planning is not sufficient for the well-functioning of the production process. For the effective functioning of the production process, it is necessary for an organisation to execute the production plan effectively and take corrective actions whenever required. Production control ensures the proper execution of pre-determined production plan while the actual production process is going on. It also monitors the production process so as to facilitate prompt adjustments whenever required.

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Self-Assessment Questions

11. Production planning and production control are not related to each other. (True/False)

12. _____ is the most essential prerequisite for the production process.

6.7 Concept of Production Planning and Control

Production planning and control (PPC) involves establishing routes and schedules to achieve the desired production goals. It also aims at ensuring optimum utilisation of resources and minimising overall production cost. According to K. C. Arora, *"PPC is defined as the direction and coordination of the organisation's materials and facilities towards the attainment of specified goals in the most efficient way."* The following are the main objectives of PPC:

- Reducing machine idle time to ensure optimum utilisation of available resources
- Maintaining an adequate level of inventory, thereby reducing storage and material handling cost
- Introducing flexibility in the production process so as to cope with dynamic business environment
- Making effective utilisation of production capacity
- Monitoring overall production process
- Evaluating the performance of each shop floor and employee involved in production

Let us discuss the scope and importance of PPC in the next sections.

6.7.1 Scope of production planning and control

PPC deals with various areas related to production and operations management in an organisation. These different areas collectively form the scope of PPC, which is shown in Fig. 6.12:

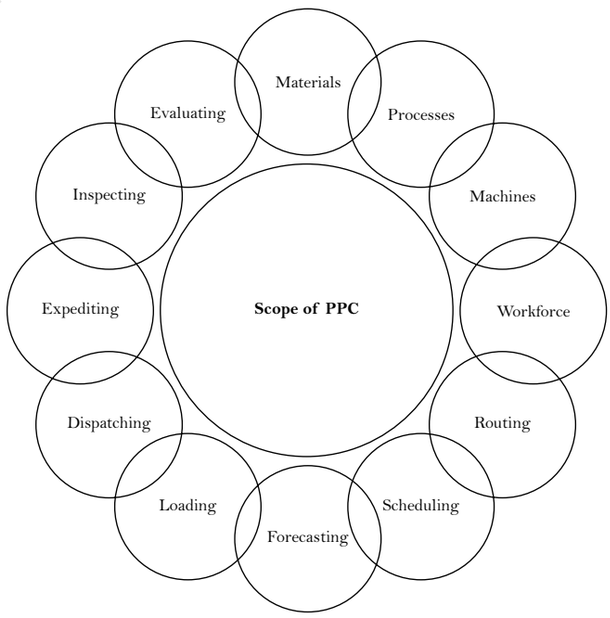

Fig. 6.12: Scope of PPC

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The areas constituting the scope of PPC (as shown in Fig. 6.12) are discussed as follows:

- **Materials:** It involves in estimating the quantity of materials, spare parts and components to carry out the production process. Apart from this, PPC also deals with getting the right quality of materials from the right source to maintain a smooth flow of production.
- **Processes:** This is about selecting the best process to carry out the production activity from all the available alternatives. PPC also deals with identifying the most profitable sequence of operations for the production process.
- **Machines:** It implies that PPC aims at deploying the best machines to execute various production activities as per the production capacity of an organisation.
- **Workforce:** It involves determining the requirements of manpower in a production plant. The workforce is deployed as per the required skills and competencies.
- **Routing:** It involves planning the most profitable workflow in the production process. Workflow is related to the movement of materials and processes throughout the production activity. While determining an optimum workflow in a production plant, an organisation takes into account various factors, such as plant layout, shop layout, storage facilities, and availability of materials.
- **Scheduling:** It involves allocating time for performing each individual operation of the production process. It helps in completing the production process on time and preventing unnecessary delays in the delivery of products.
- **Forecasting:** It refers to pre-visualising the production process. Forecasting involves defining the desired quality and quantity of output. This helps in achieving the production goals of an organisation in an efficient manner.
- **Loading:** It involves allotting different jobs to different machines. This allocation is performed in conjunction with pre-determined production capacity of an organisation.
- **Dispatching:** It involves actualising the pre-determined production plan as per the previously planned time schedule and routing.
- **Expediting:** It involves ensuring whether the activities are carried out as per the production schedule. It is done through monitoring work progress and identifying bottlenecks (such as redundant labor, defective machinery) and eliminating them.
- **Inspecting:** It involves examining the production process on a regular basis. This examination aims at maintaining the desired level of quality of output.
- **Evaluating:** It aims at improving the productivity of resources deployed for the production process. It involves analysing the existing and desired performance of resources and finding out the ways to improve the overall production process.

6.7.2 Significance of production planning and control

PPC is a key to effective manufacturing process. The significance of PPC is discussed under the following points:

- **Reduction of idle time for labour and machines:** It implies that PPC helps in scheduling men and machines into the production process. In a manufacturing plant,

most machines operate on the output produced by another machine. This makes machines wait for input till the process of the previous machine is completed. In such a case, PPC employs a technique of scheduling that plans a sequence of machines and men to be employed in the production process. This helps an organisation to make effective utilisation of resources.

- **Effective inventory management:** It involves in maintaining an adequate level of inventory required for the production process. If the inventory level is below the required level, there would be shortage of materials. In such a case, the production process may stop partially or completely. On the other hand, in case the inventory level is above the required level, it would lead to wastage of resources and incur high material handling and storage costs for an organisation. PPC applies various techniques to maintain an optimum level of inventory.
- **Desired level of quality:** It refers to one of the major advantages of PPC. The planning techniques in PPC aim at producing quality output through optimum utilisation of resources. Moreover, any breakdown in the system or fault in the machinery is quickly identified through PPC, which helps in ensuring quality of output. This ultimately builds goodwill of an organisation.
- **Maximisation of productivity:** This implies that PPC improves the productivity of an organisation by reducing the idle time of men and machines, ensuring the timely availability of resources throughout the production process, and maintaining an adequate level of inventory.
- **Minimisation of the overall production cost:** This implies that PPC reduces the total production cost by reducing the wastage of materials and inventory cost. This increases the overall profit of an organisation.
- **In-time production:** This implies that PPC allocates time for each operation to be performed in the production process. When products are produced at the right time, they are also delivered within the due time. This further helps an organisation to conform to delivery commitments.

6.7.3 Limitations of production planning and control

Although PPC provides a number of benefits to an organisation, it suffers from certain limitations. These limitations are as follows:

- Requires high cost, time, and efforts, which may delay the start-up of production
- Exercise control over inter-organisational factors, such as stock management and machine scheduling. However, external factors affecting production, such as legal regulations, political conditions, and market patterns, cannot be controlled through PPC.

6.7.4 Process of Production Planning and Control

PPC is a systematic approach to enhance the overall production process of an organisation. It involves a number of phases, which are shown in Fig. 6.13:

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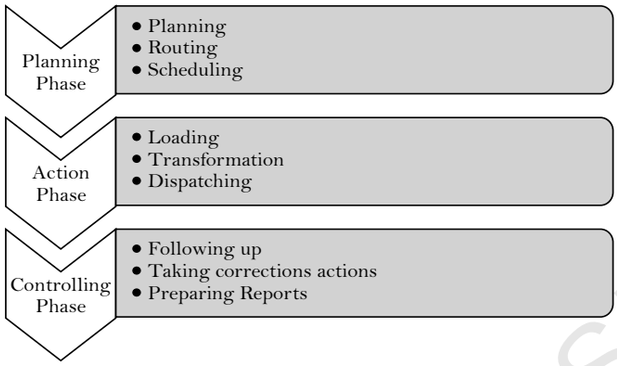

Fig. 6.13: Process of PPC

The different phases of the PPC process (as shown in Fig. 6.13) are explained as follows:

1. **Planning Phase:** This phase deals with the pre-production requirements. It involves three sub-phases, which are as follows:
   - **Production Planning:** It involves determining the resources required for producing finished products. It also includes determining the sequence of operations to be performed in the production process. The main aim of production planning is to fulfil customer demand and delivery commitments on time.
   - **Routing:** It plans the work to be performed to produce final products using available resources efficiently. Routing also involves deciding the flow of materials in the production process. The main objective of routing is to determine the most profitable path for the flow of resources.

Exhibit

Documents Required at the Time of Routing

Generally, an organisation needs three types of documents for performing routing procedures. These documents are as follows:

Route Sheet

Route sheet, also called route chart, lists all manufacturing operations in an organised manner. The flow of work from one department to another is also represented in the rout sheet. Therefore, it is also called travel sheet. In other words, a route sheet contains step-by-step listing of all the processes or transactions performed in the production process. A sample rout sheet is shown as follows:

Name of Part ……. Part No. …… Drawing No. ……

Product's Name ……... Product No. …… Quantity …….

Material …… Lot Size …….

Order No. …….. Due Date …….

Operation No.	Description of the Operations	Machine/ Equip-ment	Name of Department	Tooling Description

Format of a Route Sheet

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Operation Sheet

An operation sheet contains information related to all operations to be performed to manufacture a part or assembly. The sheet also specifies the types of machines required to carry out these operations. These operations differ for different parts and assemblies. A sample of operation sheet is given as follows:

Name of Part ……. **Material ……**				**Part No. ……** **Quantity required ……**			
Operation No.	**Operation**	**Machine/ Equipment**	**Cutting Tool**	**Cutting Speed**	**Feed**	**Depth of Cut**	**Analysis of Time**

Format of an Operation Sheet

Bill of Materials

As discussed in the previous units, Bill of Materials (BOM) provides information related to different components and raw materials required to produce finished products. Usually, an organisation assigns particular codes to each of these components and materials. A sample of BOM is given as follows:

Product's Name …….. **Prepared by ……** **Approved by ……..**			**Product No. ……** **Checked by …….** **Date ……**	
Serial No.	Part code	Part Description	Part Specifications	Weight/Quantity

Format of BOM

- **Scheduling:** It refers to a time-based framework of the production plan. A production schedule is also called the planned time-table of production. Scheduling specifies the start and end time of each operation to be performed in the production process. So, basically, it determines the time frame within which a particular operations needs to be performed.

Exhibit

Different Types of Schedules Considered for Production Scheduling

While performing production scheduling, an organisation needs the following types of schedules:

- **Master Schedule:** It contains information related to the type of product to be manufactured along with its quality, quantity, and date by which it should be made. The master schedule presents the weekly or monthly categorisation of production

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requirements in terms of resources. It is a base for all scheduling activities coming forth in the process. A detailed explanation of the master schedule has been given in the previous chapters.

- **Production Schedule:** It involves information related to machines, labour, and materials required to carry out the production process. The schedule contains detailed dispatch lists for labour and machines. The production schedule is prepared after completing the preparation of master schedule and is also called shop schedule. It also represents the starting and end time of each operation to be performed in the production process.
- **Manufacturing Schedule:** It identifies the type of manufacturing operation to be carried out in production. A manufacturing schedule demonstrates the required quality of each component to be manufactured along with the order in which their operation should be performed. This approach of scheduling is useful for the production plants in which certain repeated operations are required to be performed to produce single or few units of products at regular frequency.
- **Job Order Manufacturing Schedule:** It enables the prompt execution of each job in the overall manufacturing process. The manufacturing schedule helps an organisation in the following ways:
  - Specifies the sum of load on any particular operation
  - Determines the sequence of all the operations
  - Locates the stage of process by identifying the job being performed

2. **Action Phase:** This phase is all about putting the production plan into action. In this phase, the actual production is performed as per the planned schedule and the pre-determined rout. The action phase involves three sub-phases, which are as follows:
   - **Loading:** This refers to the allocation of different jobs to different work centres or departments. In this phase, different jobs are allotted based on the pre-determined schedule. In this way, loading identifies the right resource combination for effective production.
   - **Dispatching:** This stage involves setting production activities in a sequence through the release of orders. There are a number of production orders, which are as follows:
     - Order for the movement of materials from one department to another
     - Order for the movement of equipment and tools necessary for production
     - Order for initiating operation in different shop floors
     - Order for the movement of work based on the rout sheet
     - Order for the inspection of the entire production process
     - Oder for maintaining the record of time and cost for every individual operation
   - **Controlling Phase:** This stage begins as soon as the planning phase is completed. Thus, the action phase and controlling phase take place simultaneously. The controlling phase involves the following sub-phases:
     - **Following up:** It involves monitoring and inspecting the ongoing production process. At this phase, the output at each level of production is compared

with the pre-determined target to identify delays and deviations in the entire production process. The following up also involves identifying defects in the predetermined routing and scheduling of various jobs.

- **Implementing corrections:** It involves making adjustments in routing, loading, and scheduling as per the requirements of real-time production activities. Such adjustments are required as planning is based on assumptions related to various factors affecting the work performance. These assumptions might be different from the actual work conditions prevailing in a production unit.
- **Preparing review reports:** It involves maintaining records for future references. All the activities and decisions involved in the planning, action, and controlling phases so far are recorded in the form of reports. These reports, also called progress reports, help planners in identifying bottlenecks in advance, which further provides a scope for better planning in the future. Apart from this, these reports help controllers to take reference how different types of problems in the production process were handled in the past. These reports also enable production managers to have a clear vision of manufacturing operations. This ultimately helps in improving the productivity of an organisation.

Self-Assessment Questions

13. The main objective of _____ is to determine the most profitable path for the flow of resources.

14. Which phase of PPC involves the preparation of review reports?

a. Planning phase

b. Action phase

c. Control phase

d. Both panning phase and controlling phase

15. Review reports are also called progress reports. (True/False)

6.8 Summary

- Production planning is a continuous process of identifying the market requirements related to product. It is also regarded as a process of ensuring sufficient raw materials, staff and other necessary items to carry out the production process.
- The important techniques of production planning are forecasting and Material Requirement Planning (MRP).
- Production control can be defined as planning and supervising the activities of manufacturing. This ensures that the goods should be produced on time with adequate quality and reasonable cost.
- The techniques of production control are line of balance and shop floor control.
- Production planning and production control are closely related to each other as production control is related to the implementation and execution of the pre-determined production plan.
- PPC enhances the overall production process of an organisation. Process of PPC includes planning phase, action phase and controlling phase.

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6.9 Glossary

- **Cumulative Output:** It refers to the sum of total output produced at a particular point of time
- **Material Requirement Planning:** It is a production planning and inventory control system that helps in managing the production process.
- **Routing:** Determining the flow of work in the production process is called routing.
- **Scheduling:** This involves preparing a time-bound plan of the production process.

6.10 Terminal Questions

1. Explain the concept and objectives of production control?
2. What are the benefits of LOB technique in production?
3. Discuss the scope of PPC.
4. Describe the concept of production planning.
5. Explain one technique each of production planning and production control.

6.11 Answers

Q.	Self Assessment Questions
1.	a. Production Planning
2.	True
3.	Forecasting
4.	False
5.	Regression and Correlation
6.	Material Requirement Planning
7.	Production control
8.	False
9.	Line of Balance
10.	a. Shop floor control
11.	False
12.	Planning
13.	Routing
14.	c. Control phase
15.	True

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Q.	Terminal Questions
1.	A process of identifying variations between the planned production performance and the actual production performance is production control. Refer to section **6.4 Meaning of Production Control.**
2.	LOB monitors and controls the actual production process. Refer to sub section **6.5.1 Line of Balance**
3.	PPC deals with various areas related to production and operations management in an organisation. Refer to sub section **6.7.1 Scope of Production Planning and Control**
4.	An activity that determines the inputs of production is production planning. Refer to section **6.2 Concept of Production Planning.**
5.	The techniques of production planning include forecasting and material requirement planning. The techniques of production control include line of balance and shop floor control. Refer to section 6.3 Production Planning Techniques for Various Process Choices and **6.5 Techniques of Production Control.**

6.12 Case Study: Application of LOB Technique at XYZ Limited

XYZ Limited is a leading toy manufacturing organisation in Mumbai. As a result of its business efforts, the organisation has won an auction of a famous retailing chain organisation, M-mart. This is a lucrative business deal for the XYZ. However, the challenge before XYZ Ltd. is to meet the tight delivery schedule fixed by M-mart. The delivery schedule desired by M-mart is shown in the following table:

Table: Desired Delivery Schedule

Time	Output	Time	Output	Time	Output
By the end of (Month)	**Units to be Delivered**	**By the end of (Month)**	**Units to be Delivered**	**By the end of (Month)**	**Units to be Delivered**
Jan	1000	May	1000	Sep	2000
Feb	1000	June	2000	Oct	2000
Mar	1000	July	2000	Nov	2000
April	1000	August	2000	Dec	2000

To meet with the schedule, XYZ Ltd. has first analysed the process of producing one unit of output (toy) and divided it into eight significant stages. The organisation also established a relationship among these stages and the lead time of each stage. This relationship is shown in the following chart:

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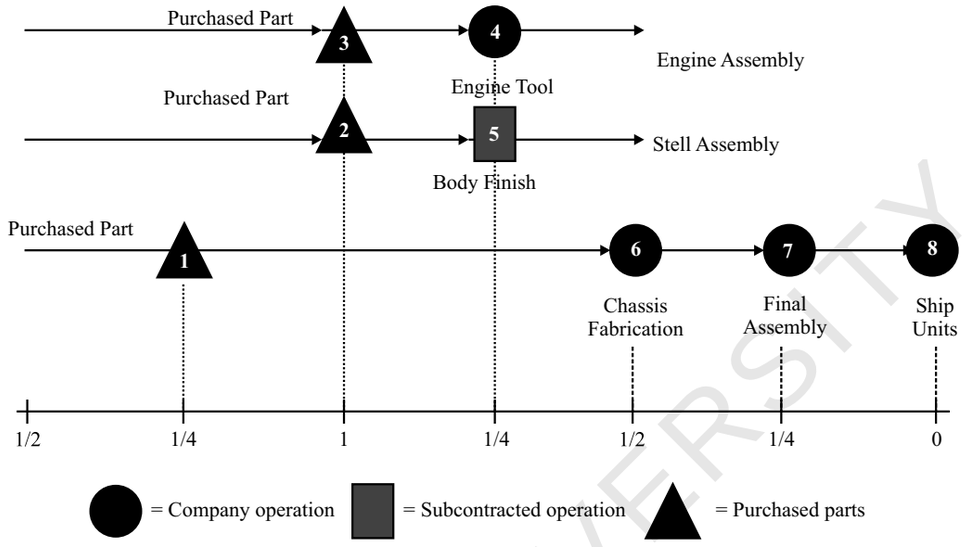

The organisation has started the production operations immediately after it has developed a tentative production plan. After carrying out the production process for eight months, the organisation prepared a cumulative production schedule. The preparation of cumulative production schedule was based on the delivery schedule (fixed by the client) and the total units of output that have passed at each of the eight stages involved in the production process.

The head of the production department has implemented the LOB techniques so as to avoid any delays in the delivery of the final output to M-mart. For this purpose, an LOB chart has been formed that has helped managers in identifying that the actual production level at the first and second stages has exceed the desired production level. It has also helped in identifying that final assembly and Chassis fabrication have produced 500 units less than the desired number of units.

Managers have identified that the major cause of decrease in output produced is certain problems with engine assemblies and shell assemblies. The units produced at the third and fourth processing stages are noted to be 500 and 1, 000 units, which is below the desired level. However, the fifth stage is performed on a contract basis. So, the deficiency in the units produced at the fifth stage is due to the fault of the supplier instead of purchases parts.

After evaluating all these conditions, the management has taken immediate corrective actions that would help the organisation in meeting the delivery schedule fixed by M-mart.

Discussion Questions:

1. Draw a cumulative output chart with the help of data given in the case.

   (**Hint:** The cumulative output chart drawn with the help of the production schedule given in the case)

2. What are the steps involved in LOB technique.

   (**Hint:** First two steps include making an assembly chart or operation program and preparing a cumulative process completion schedule.)

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6.13 References and Suggested Readings

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CHAPTER

7

Aggregate Planning

Structure

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Learning Objectives

After studying this chapter, you will be able to:

- explain the concept of aggregate planning
- describe the process of aggregate planning
- elaborate on the major aggregate planning techniques

7.1 Introduction

As discussed in the previous chapter, it is essential for an organisation to plan and control its production process. It helps in smooth functioning of the production process. For preparing a production plan, you need to forecast the demand of a product in the market. This helps in predicting the events or conditions that may occur in future. After forecasting the product demand, an organisation can prepare a more realistic production plan as the demand is forecasted on the basis of facts and figures.

Production planning is all about establishing the production goals and estimating resources required to achieve those goals. There can be three types of production planning, namely long-term planning, short-term planning, and intermediate planning. This intermediate production planning, with an intermediate time range of 3 to 12 months, is called aggregate planning, which lies between long-term and short-term planning.

Aggregate planning plays an important role in achieving long-term objectives of an organisation. It helps an organisation to achieve its financial goals by reducing the overall cost, by making efficient utilisation of resources it helps in attaining high customer satisfaction by matching the demands of the customer. Moreover, aggregate planning also enables an organisation to reduce investment in inventory stock.

Different organisations apply different techniques for aggregate planning. Linear programming and the transportation model are the two most commonly used techniques for aggregate planning.

In this chapter, you will study about the concept of aggregate planning. Under aggregate planning, you will study about the requisites, costs, and processes of aggregate planning. Towards the end, the chapter will acquaint you with the concepts of linear programming and transportation model as major aggregate planning techniques.

7.2 Concept of Aggregate Planning

Forecasting of product demand is more beneficial for aggregate planning. This is because aggregate planning is an intermediate term-planning decision. It is the process of planning the quantity and timing of output over an intermediate time horizon that usually ranges from 3-12 months. Within this range, the physical facilities are assumed to be fixed for the planning period. For example, an auto manufacturing organisation that is performing aggregate planning will consider all the departments within the organisation, instead of focussing on a single department within a time period of 12 to 18 months. You can take another example of a paint organisation that produces different colours of paints. In this case, the aggregate plan will include the total quantity of paint and not the different colours of paint separately. Thus,

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the forecasts of product demand in aggregate planning are more close to the actual demand of product in future.

Aggregate planning focuses on the products in an aggregate of the entire production or service system and not individually. This planning helps in cost optimisation. Aggregate planning possesses the following characteristics:

- It lasts for a year and includes regular plan updates.
- It thinks demand is unpredictable, cyclical, or subject to change.
- It makes it easier to alter the supply and demand factors simultaneously.
- Facilities that are not amenable to expansion fall into this category.

There are two types of aggregate planning which are as follows:

- **Manufacturing aggregate planning:** It is the preparation of a periodical statement that contains information related to production rates, workforce levels, inventory investments, capacity limits, and customer demand. This planning is also called production planning.
- **Service aggregate planning:** It is the preparation of a periodical statement that contains information related to the size and capacity of labour, given capacity limits, and customer's demand. This planning is also known as staff planning.

Fig 7.1 shows the relationship among short-term, long-term, and aggregate planning:

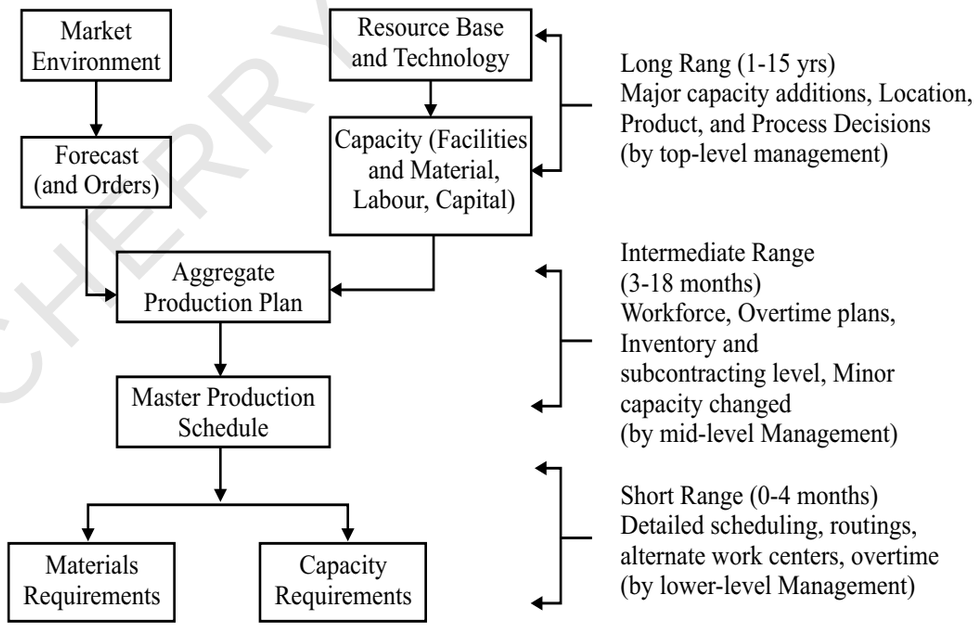

Fig 7.1: Aggregate Planning Flowchart

7.2.1 Master production schedule

Aggregate plan and Master production schedule (MPS) are closely related to each other. This is because MPS is derived from aggregate plan which is developed for individual products to be produced in a particular time period. On the other hand, the aggregate plan is a broad

schedule formulated for the whole family of products. When the aggregate plan is converted into MPS, the family of products is disintegrated into individual products. Table 7.1 shows how the aggregate plan is broken into MPS:

Table 7.1: Conversion of Aggregate Plan into MPS

Aggregate Plan		
Month	1	2
Total items	1000	1500

Week	1	2	3	4	5	6	7	8
Item A	200		100	100	500			100
Item B		100		100		100	200	100
Item C	200	100	100			100	200	200

Master Production Schedule

Aggregate planning acts as a guideline for MPS where MPS specifies the timing and volume of production for individual products. The sum of production quantities in MPS should be equal to the quantities in aggregate plan. If there is a gap in the values of MPS and aggregate plan, it may be due to capacity limitations.

7.2.2 Functions of master production schedule

MPS provides top management with the required information for planning and controlling the overall manufacturing process. It is developed by taking into consideration market forecasts, customer orders, inventory levels, and capacity requirements. MPS aims at making efficient utilisation of production capacity and achieving low production costs. The following are the main functions of MPS:

- **Translating aggregate plans**: This function implies that MPS helps in converting the aggregate plan into the number of items to be produced in a specific time period. MPS states what to be produced and when to be produced by an organisation.
- **Evaluating alternative master schedules**: This function implies that MPS is done on the basis of trial and error method. While developing MPS, a number of alternate schedules are evaluated and the best one is selected.
- **Identifying material requirements**: This function implies that MPS helps an organisation to determine materials required for carrying out the production process.
- **Determining capacity requirements**: This function states that MPS enables an organisation to determine labour and equipment capacity. This helps the organisation to ensure an adequate capacity level to meet business requirements effectively.
- **Processing information**: This function implies that MPS processes accurate information related to the manufacturing and delivery schedules of products.

7.2.3 Requisites for aggregate planning

Aggregate planning is all about preparing the production schedule of an organisation. This schedule includes planning related to sales forecasts, production levels, and inventory levels.

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To prepare this schedule, an organisation needs the following inputs:

- An aggregate demand forecast for the relevant period
- Operational status of the existing workforce, inventory level, and production efficiency
- Efficient organisation policy related to labour management and quality management
- Complete information related to available production facility and raw materials
- Estimated costs of various alternatives and resources

7.2.4 Costs of aggregate planning

An essential component of aggregate planning is the estimation of costs for different options and resources. In order to compare different aggregation plans using a total-cost metric, it is necessary to identify and quantify these costs. Here are a few examples of possible related costs:

- Spending on payroll
- Extra shifts, overtime, and subcontracting expenses
- Personnel expenses (both hiring and firing)
- Overstock and backlog expenses
- Variation in production costs

Self-Assessment Questions

1. _____ is the process of planning the quantity and timing of output over an intermediate time horizon that may vary from 3 months to 1 year.
2. Aggregate planning focuses on the products in a combined manner and not individually. (True/False)
3. Which among these is not a characteristics of aggregate planning possesses:
   a. It involves a period of 12 months and updates the plan on a periodic basis.
   b. It considers demand to be fluctuating, uncertain, or seasonal.
   c. It facilitates the possibility of changing only the demand variables.
   d. It includes the facilities that are considered fixed and cannot be expanded.
4. _____ is also known as staff planning.
5. _____ is a plan developed for individual products to be produced in a particular time period.
6. How aggregate plan and MPS are closely related to each other?
7. MPS enables an organisation to determine labour and equipment capacity. (True/False)

Activity

Identify various constraints that an organisation can face during aggregate planning.

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7.3 Aggregate Planning Process

An organisation's aggregate production plan can be developed methodically through aggregate planning. The following are some of the steps involved:

1. **Forecasting demand:** A methodical approach to predicting future demand for a company's goods or services is known as demand forecasting. It helps a company with a lot of decision-making, including production planning, raw material purchases, money management, and product pricing.
2. **Identifying planning variables:** It involves determining restrictions on planning variables. These variables include the total quantity of aggregate products to be produced in a particular time-period and the total number of direct labour required.
3. **Formulating the aggregate plan:** It involves developing a schedule that is concerned with the production schedule for later stages.
4. **Implementing the aggregate plan:** This step entails putting the plan into action by using various optimisation methods. It is not necessary that aggregate planning would always be successful. This is because demand may not be the same as predicted and employees may leave the organisation. Thus, the aggregate plan that is devised for 6 to 12 months cannot be used for the next months. Therefore, it is necessary for an organisation to update its aggregate plan regularly.

Self-Assessment Questions

8. _____ is a systematic process that involves anticipating the demand for an organisation's products or services in future.
9. _____ involves determining restrictions on planning variables.
   a. Forecasting demand
   b. Identifying planning variables
   c. Formulating the aggregate plan
   d. Implementing the aggregate plan
10. Implementing the aggregate plan involves developing a schedule that is concerned with the production schedule for later stages. (True/False)

7.4 Aggregate Planning Techniques

Different organisations use different techniques to aggregate planning. Linear programming and transportation model are the two techniques used for aggregate planning. Let us discuss these two approaches in detail in the next sections.

7.4.1 Concept of linear programming

Managers in the real world must maximise revenues while minimising expenses by making smart use of limited resources like people, money, and machinery. Linear programming is a technique that is used to select the best alternative from a set of feasible alternatives in situations when the objective function and the constraints are expressed in linear forms. For

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example, a manager has to take decisions related to the development of four new products. In this case, the quantity of raw materials, the availability of labour, and market demand are examples of constraints, and the goal function is to maximise profits obtained from new goods. When this occurs, the management can benefit from linear programming, which uses certain mathematical equations to determine the optimal course of action.

What follows is a discussion of the conditions that permit the application of linear programming.

- Maximising earnings and minimising expenses are two examples of objective functions that are both well-defined and quantifiable.
- For example, before production scheduling can begin, all activities that need to be considered must be precisely defined and quantitative in character.
- It is necessary to quantify the resources that are to be distributed.

When these aforementioned requirements are met in a situation, a problem can be expressed in algebraic form, which is called Linear Programming Problem (LPP), and solved for an optimal decision. You will learn about the formulation of LPP in later sections of the chapter.

Assumptions of linear programming

When using linear programming to solve optimization issues, certain assumptions are made. The following are the presumptions:

- **Linearity:** The premise here is that the inputs and outputs of production are linearly related. It is a prerequisite for linear programming and an assumption in and of itself. In the near term, the factor of production generates equal returns, as per the linearity assumption. A linear equation depicts the input-output relationship as a straight line. To illustrate the point, in order to produce one unit of output, a manufacturing organisation needs 25 workers, 10 machines, and 0.6 tonnes of raw materials (O). The following is a representation of the input-output relationship in this scenario:

  25W + 10M + 0.6R = 1O

  Nevertheless, because to this assumption, linear programming has only been used for input-output relationships that are linear.

- **Continuity:** According to this part, you can only call a variable measurable if it has a numerical value. This theory states that numerical values are the only ones that can provide consistency when measuring variables..
- **Independence and additivity:** In this respect, we presume that the variables and the numerical values of those variables are independent of one another. Within certain bounds, this indicates that variables are picked at random. Assumption number two concerns the additive nature of the variables to be combined. No variables can be used in linear programming if they cannot be joined together.
- **Proportionality:** It presupposes that all variables are proportionate to one another. As we work to solve the problem, the proportionality between the variables stays the same. This indicates that all levels of output have the same proportionate relationship among variables. If, for instance, 5 units of input are needed to make one unit of output, then 50 units of input would be required to make 10 units of output.
- **Constant Price:** It presupposes that, irrespective of the amount bought and sold, the input and product prices would be fixed.

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Advantages and limitations of linear programming

As discussed in the previous section, linear programming helps managers in many ways. The following are some of the important advantages of linear programming:

- **Providing scientific approach to problem solving:** It implies that linear programming provides a clear picture of ongoing problems by applying scientific methods. This leaves no scope for human error or personal bias while solving problems.
- **Evaluating all feasible alternatives:** It implies that some of the problems of an organisation are too complex that cannot be solved by using a traditional decision making approach. In such cases, linear programming helps managers to generate all possible alternatives and select the best alternative.
- **Helping in re-evaluation:** It implies that linear programming helps in re-evaluating the selected alternative against changing conditions. For example, an organisation has decided to develop a new product with maximum profits and minimum costs. However, this decision of an organisation may not provide the desired results in situations, such as changes happening in the tastes and preferences of customers and other market fluctuations. In such cases, linear programming helps managers to identify those factors that may change in the near future.
- **Making informed decisions:** It implies that linear programming helps managers to make realistic and sound decisions by clearly reflecting the strengths and weaknesses of the selected alternative. This enables managers to be aware of potential risks in advance.
- **Creating useful information base:** It refers to one of the most important advantages of linear programming. Linear programming provides an important database to managers by evaluating feasible alternatives with respect to prevailing constraints. This database helps managers to make the best allocation of resources.

Although linear programming has a wide application in business for solving optimisation problems, it has certain limitations. Some of the limitations of linear programming are as follows:

- **Linear relationship:** As discussed earlier, linear programming is only applicable when there is a linear relationship between the objective function and constraints. However, in real business problems, the objective function and constraints may not have linear relationship rather they can be expressed quite easily in the form of a quadratic equation. In such cases, linear programming fails to provide optimal solutions to problems.
- **Constant values of the objective function and constraints:** Linear programming assumes the values of the objective function and constraints to be constant over a period of time. This is not possible in real business situations.
- **No scope for fractional value solutions:** The solution of an LPP is often quantified to an integer. In case linear programming provides fractional-varied answers, then these answers are rounded off to the next integers. In such cases, solutions obtained using linear programming may not be optimal ones. For example, the number of men or machines required to perform a particular task cannot be expressed in a fraction.
- **Inflexibility:** It becomes difficult to make changes in the system once the objective function and constraints are quantified and linear programming tools are applied. However, the real world business scenario is subject to constant changes.

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Formulation of linear programming problems

In technical terms, linear programming can be defined as a technique of optimising (maximising or minimising) a linear function for different constraints expressed in the form of linear equations. To solve a problem using linear programming, it is important to express the problem in an algebraic form. The following are the steps to formulate an LPP:

1. **Defining the Objective Function:** It refers to the first step for solving a problem. For solving any problem, it is important to identify the goal in terms of the objective function (maximisation or minimisation).
2. **Defining the Constraints:** These refer to another requirement of LPP. As discussed earlier, managers need to make sound decisions by considering all constraints that come in the way. Therefore, to solve a problem, it is important for a manager to clearly define constraints.
3. **Ensuring Non-Negativity Condition:** This refers to a condition required for getting the more realistic solution to a problem. It is possible that the solution of linear programming contains a negative value, which is not possible in the real world. Therefore, to avoid such situation, non-negative approach is adopted.

It should be noted that all decision variables should be represented in an alphanumeric form. For example, decision variables, such as 1, 2, and 3, can be represented as x_1, x_2, and x_3, respectively.

Methods to solve linear programming problems

An LLP can be solved by using various methods. The two major methods that provide a feasible solution to a problem considering all constraints are shown in Fig.7.2:

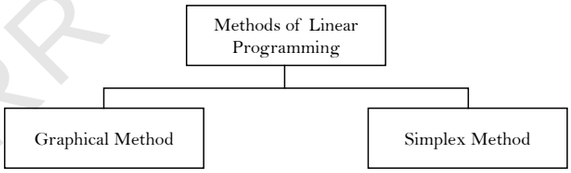

Fig. 7.2: Methods to Solve Linear Programming Problems

Let us discuss different methods of solving an LPP:

- **Graphical Method:** Graphical method is considered to be the simplest method for solving linear programming problems. This method can only be used when there are two variables involved. The following are the steps to be performed for solving an LPP using the graphical method:
  - Identifying the problem, which includes all decision variables, the objective function, and the constraints
  - Drawing a graph that includes all constraints and identifying the feasible region
  - Obtaining the point on the feasible region that optimises the objective function or provides an optimal solution
  - Interpreting the results

  Let us understand the graphical method with the help of an example.

- **Example: Maximisation Case:** An organisation produces x_1 and x_2 units of products M and N. In this case, the objective function and the constraints are expressed as follows:

  Maximise $Y = 50x_1 + 60x_2$ Profit

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Subject to

$4x1 + 2x_2$ 800 Raw material constraint

$2x_1 + 5x_2$ 1000 Labour hours constraint

x_1, x_2 0 Non-negativity condition

Let us plot the constraint lines on a graph by calculating the values of x_1 and x_2 with the help of terminal points. The calculation of x_1 and x_2 values with the help of terminal points are shown as follows:

Suppose for constraint equation $4x_1 + 2x_2 800$, $x_1 = 0$,

Then, $x_2 = 800/2$

$x_2 = 400$

In case, $x_2 = 0$,

Then, $x_1 = 800/4$

$x_2 = 200$

Similarly, for constraint equation $2x_1 + 5x_2 1000$, $x_1 = 0$,

Then, $x_2 = 1000/5$

$x_2 = 200$

In case, $x_2 = 0$,

Then, $x_1 = 1000/2$

$x_1 = 500$

Let us plot the calculated equations of x_1 and x_2 on a graph, which is shown in Fig. 7.3:

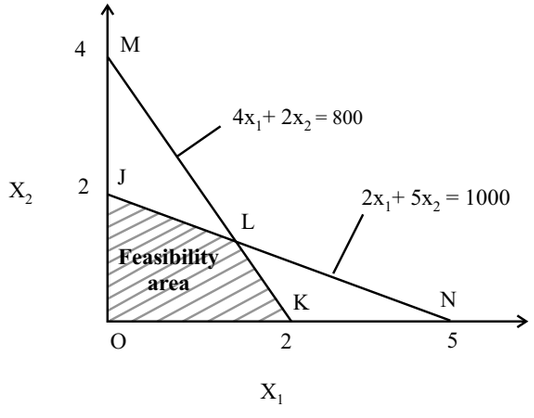

Fig. 7.3: Graphical Representation of Constraints

In Fig. 7.3, the shaded area, JLKO represents the points that satisfy all the conditions and assumptions of linear programming. The profit would maximise at point L with the available constraints.

At point L, the value of $x_1 = 1.5$ and $x_2 = 1.8$,

NOTES

Therefore, the maximum profit would be:

$$Y = 50x_1 + 60x_2$$

$$Y = 50*1.5 + 60*1.8$$

$$Y = \text{Rs. } 183$$

Simplex Method: This method is used for solving linear programming problems having more than two variables. It uses a repetitive computational procedure (called iterative procedure) until an optimal solution of a problem is achieved. Let us understand the simplex method with the help of an example.

Example: Shivam Confectionaries produces two types of candies, namely candy A and candy B. The production of candy A requires 3kg of raw material and 4 hours of labour, while candy B requires 4 kg of raw material and 3 hours of labour. However, the total availability of raw material is 120 kg per month and available labour time is 108 hours per month. The profit generated from one unit of candy A is Rs. 40, whereas the profit generated from one unit of candy B is Rs. 30. Assume that the organisation produces x_1 and x_2 units of candy A and candy B respectively. Let the total profit is represented by Z. Determine how many units of each candy the organisation should produce to earn maximum profit using the simplex method.

$$\text{Max. } Z = 40\,x_1 + 30\,x_2$$

Subject to

$$3\,x_1 + 4\,x_2 \leq 120 \text{ and}$$

$$4\,x_1 + 3\,x_2 \leq 108$$

And,

$$x_1, x_2 \geq 0$$

To formulate constraints, inequalities ($\leq, \geq$) are used as the whole lot of resources may not be fully consumed during production. In the simplex method, these inequalities are converted to equalities by adding variables, which represent resources that are not consumed. This process is termed as augmentation and the variables are called slack variables. In the present case, the constraints after augmentation are shown as follows:

$$3\,x_1 + 4\,x_2 + S_1 = 120$$

$$4\,x_1 + 3\,x_2 + S_2 = 108$$

Let us assume one more inequality as $x_2 \leq 25$. This inequality is converted into equality as:

$$x_2 + S_3 = 25$$

Now, let us rewrite the entire simplex problem again in its modified form as follows:

$$\text{Max. } Z = 40\,x_1 + 30\,x_2 + 0S_1 + 0S_2 + 0S_3$$

Subject to

$$3\,x_1 + 4\,x_2 + S_1 = 120$$

$$4\,x_1 + 3\,x_2 + S_2 = 108$$

Notes

$x_2 + S_3 = 25$

$x_1, x_2, S_1, S_2, S_3 \geq 0$

To solve the problem simultaneously, the number of equations and the number of variables must be the same. Here, you have three equations and five variables. Thus, you cannot solve this problem simultaneously. So, let us represent the equations in a tabular form. These tables are known as simplex tableau. The format of an initial simplex tableau is shown in Table 7.2:

Table 7.2: Format of Initial Simplex Tableau

Basic Variables (B.V.)	Contribution per unit (Cj) → ↓						
		x_1	x_2	S_1	S_2	S_3	b_i (constraint values)
S_1							
S_2		{ Coefficient values from the constraint equations }					
S_3							
Solution (z_j)							
$\Delta j = c_j - z_j$							

In the initial simplex tableau, all the slack variables are termed as basic variables and the coefficient of these variables would be 0. The initial simplex tableau for the present problem is shown in Table 7.3:

Table 7.3: Initial Simplex Tableau for Maximisation Problem of Shivam Confectionaries

(B.V.)	Cj	40	30	0	0	0	
		x_1	x_2	S_1	S_2	S_3	b_i
S_1	0	3	4	1	0	0	120
S_2	0	4	3	0	1	0	108
S_3	0	0	1	0	0	1	25
Solution (z_j)							
$\Delta j = c_j - z_j$							

After setting up the simplex tableau, the identity matrix and the variables involved in it are identified. The identity matrix is a square matrix in which all the values in a diagonal are ones and all other values are zeros. The variables other than basic variables are termed as non-basic variables.

As shown in Table 7.3, S_1, S_2, S_3, are basic variables while x_1 and x_2 are non-basic variables. For determining the initial solution, x_1 and x_2 are assigned a value of 0 and S_1, S_2, S_3 are assigned values 120, 108, and 25, respectively. A solution for LPP in which all variables are non-negative is termed as Basic Feasible Solution (BFS). In the present example, the solution $x_1 = 0, x_2 = 0, S_1 = 120, S_2 = 108$, and $S_3 = 25$ is the basic feasible solution. By putting the values of all variables in the objective function, you get:

$$Z = 40 * 0 + 30 * 0 + 0 * 0 + 0 * 0 + 0 * 0 = 0$$

NOTES

According to this solution, the organisation should produce 0 units of candy 1 and 0 units of candy 2 to obtain an overall profit of 0. Now, the simplex tableau is tested for optimality by using Δj ($=c_j-z_j$) values. The value of z_j is calculated by summing up the products of the each element in columns with the corresponding value of the coefficient. Table 7.4 shows the values of c_j,z_j, and Δj:

Table 7.4: Calculating the Values of cj,zj, and Δj

(B.V.)	Cj	40	30	0	0	0	
		x_1	x_2	S_1	S_2	S_3	b_i
S_1	0	3	4	1	0	0	120
S_2	0	4	3	0	1	0	108
S_3	0	0	1	0	0	1	25
Solution (z_j)		0	0	0	0	0	
$\Delta j = c_j - z_j$		40-0 = 40	30-0 =30	0-0 = 0	0-0 = 0	0-0 = 0	

The row that contains the values of Δj is called Net Evaluation Row (NER). After getting the values of Δj, the test for optimality of the solution can be conducted as follows:

- **Test of optimality in case of maximisation:** If all the values of Δj in the NER are zero or negative, the optimal solution is attained.
- **Test of optimality in case of minimisation:** If all the values of Δj in the NER are zero or positive, the optimal solution is attained.

In Table 7.4, the values of Δj are still positive; therefore, this is not an optimum solution. Therefore, the process of determining the optimal solution needs to be continued. For determining the next solution, the variable that corresponds to the highest positive value of Δj is selected. The variable that has the highest positive value of Δj is called the incoming variable, which enters the next simplex tableau. To indicate the incoming variable in the Δj column, an arrow is marked under it. The column to which the incoming variable belongs is termed as the key column or the pivot column. After deciding the key column, divide the values in the b_i column by the corresponding key column values. The values that come after this division are called the b_i/ a_{ij} values. Next, the variable corresponding to the least non-negative b_i/ a_{ij} values is selected. This row is called the key row or pivot row. The variable corresponding to the key row is the outgoing variable, which is represented by an arrow. On the intersection of the key row and the key column lies the key element. The key column and the key row are represented in Table 7.5:

Table 7.5: Determining the Pivot Row in Simplex Tableau

(B.V.)	Cj	40	30	0	0	0		
		x_1	x_2	S_1	S_2	S_3	bi/ aij	
S_1	0	3	4	1	0	0	120/3 = 40	
S_2	0	key element (4)	3	0	1	0	108/4 = 27	out-going variable (key row) ←

Notes

Table 7.5: Determining the Pivot Row in Simplex Tableau							
(B.V.)	Cj	40	30	0	0	0	
S_3	0	0	1	0	0	1	25/0 = N.D.
Solution (z_j)		0	0	0	0	0	
$\Delta j = c_j - z_j$		40-0 = 40	30-0 =30	0-0 = 0	0-0 = 0	0-0 = 0	
		incoming variable (key column) ↑					

In the present example, the incoming variable is x_1 and the outgoing variable is S_2. To construct a next simplex tableau, the outgoing variable and its corresponding coefficient are replaced by the incoming variable and its corresponding coefficient. After this, the values of the key row are derived and the remaining row elements are modified accordingly. This can be done by adopting the following steps:

1. Find the values of the row that has to be replaced called as replacement row. The replacement row is found by dividing each element of the key row by the key element to derive the new row or the replacement row.
2. For all other rows (other than the key row), the values of their elements can be determined by using the following formula:

New Row Element = Old Row Element – (Row Element in the Key column – Corresponding Replacement Row Value)

Table 7.6 shows the steps to derive the new simplex tableau:

Table 7.6: Obtaining New Simplex Tableau							
(B.V.)	Cj	40	30	0	0	0	
		x_1	x_2	S_1	S_2	S_3	bi/ aij
S_1	0	0	7/4	1	-3/4	0	40
x_1	40	1	3/4	0	1/4	0	27
S_3	0	0	1	0	0	0	N.D.
Solution (z_j)		40	30	0	10	0	
$\Delta j = c_j - z_j$		40-40 = 0	30-30 =0	0-0 = 0	0-10 = -10	0-0 = 0	

All the values in the NER are now 0 or negative; it means that the optimum solution has been attained. The optimum solution is obtained from the basis as:

$x_1 = 40,\ x_2 = 0, S_1 = 0, S_2 = -10, S_3 = 0$

For this set of solution, the value of the Z is:

$Z = 40 * 40 + 30 * 0 + 0 * 0 + 0 * -10 + 0 * 0$

$Z = 1600$

In the above example, the optimum solution could be achieved in a single iteration. However, in most cases, an optimal solution is not achieved in a single iteration. Therefore, the process is repeated until an optimal solution is obtained.

The linear programming model for minimisation problem using simplex table is as follows:

Min. $Z = 100\ x_1 + 200\ x_2$

NOTES

Subject to

$$30\ x_1 + 70\ x_2 \geq 2100$$

$$60\ x_1 + 100\ x_2 \geq 3600$$

$$x_1, x_2 \geq 0$$

In the case of a minimisation problem, the inequalities are converted into equalities by introducing variables called surplus. The surplus variables indicate the surplus of what is generated over what was required; therefore, you introduce the surplus variables that are always represented with a negative sign. The problem is represented in the following form:

$$\text{Min. } Z = 100\ x_1 + 200\ x_2 + 0S_1 + 0S_2$$

Subject to

$$30\ x_1 + 70\ x_2 - S_1 = 2100$$

$$60\ x_1 + 100\ x_2 - S_2 = 3600$$

$$x_1, x_2, S_1, S_2 \geq 0$$

As you did in the maximisation example, if you take the values of x_1 and x_2 equal to 0, you would get the values of S_1 and S_2 as -2100 and -3600, respectively. However, you know that this will be violation of the non-negativity constraint. In addition, you will not get an identity matrix in the starting simplex table because the coefficients of the surplus in the constraint equations are negative.

7.4.2 Transportation model

The term 'transportation' is associated with the movement of individuals or products from one place to another through various mediums such as airplanes, trains, buses, trucks, and ships. The transportation model is primarily concerned with minimising the costs associated with the transportation of products. Transportation models (which are a special case of linear programming) are used by aggregate planners to solve aggregate planning problems by identifying and minimising inventory costs, regular time, and overtime costs, etc.

Some of the important features of transportation models are as follows:

- Minimise transportation costs incurred on transferring input or output from one location to another
- Determine the most feasible or lowest-cost location for a new factory, warehouse, and outlet, of an organisation
- Formulate a minimum-cost production schedule that meets the demand and supply constraints of an organisation
- Allocate men and material, such as vessels and weapons, at different locations

From the discussion so far, you can conclude that a transportation problem usually consists of the following elements:

m = Source (supply centres)

n = Destination (demand centres)

s_i = Supply of a good available at source i

d_j = Demand for the good at destination j

c_{ij} = Cost of transporting one unit of the good from source i to destination

A transportation matrix is formed with the help of all the aforementioned elements. The matrix is shown in Table 7.7:

NOTES

Table 7.7: General Format of Transportation Matrix

	D_1	D_2	D_3	…	D_n	Supply	
	C_{11}	C_{12}	C_{13}	…..	C_{1n}	s_1	S_1
	C_{21}	C_{22}	C_{23}	…..	C_{2n}	s_2	S_2
Source	C_{31}	C_{32}	C_{33}	…..	C_{3n}	s_3	S_3
	:	:	:	:	:	:	:
	C_{m1}	C_{m2}	C_{m3}	…..	C_{mn}	S_m	
S_m	d_1	d_2	d_3	……	d_n		
Demand							

Q1. A firm is scheduling (allocating) its January-March production capabilities. Part of the decision involves scheduling overtime work. A unit produced at the cost of overtime costs an extra ₹ 300, and a unit made one month prior is needed. The inventory carrying cost is ₹ 100. For two months, it is ₹ 200.The deliveries are as follows:

- January - 80 units
- February - 120 units
- March - 150 units
- Formulate the production scheduling problem as a transportation problem.

	Regular Time	Overtime
January	100	50
February	100	40
March	100	30

Solution:

		Demand for				
Supply from		January	February	March	Unused capacity (dummy)	Total capacity available (Supply)
January	Regular	80	20			100
	Overtime		50			50
February	Regular		50	50		100
	Overtime			40		40
March	Regular			60	40	100
	Overtime				30	30
Demand		80	120	150	70	420

Q2. The production planner of XYZ ltd. derived the following level output aggregate plan for the next four periods. Compute the anticipated beginning and ending inventory for each period. Please note that back orders will be shown by a negative number.

Period	Demand Forecast	Planned Production	Beginning Inventory	Ending Inventory
1	40,000	48,000	9,000	
2	70,000	48,000		
3	30,000	48,000		
4	55,000	48,000		

NOTES

Give a chase demand strategy which will increase gradually, and show the effect of the level of inventory to 14,000 units at the end of period 4. Inventory is increased by 1250 units in each period: (14,000 - 9,000)/4

Period	Demand Forecast	Planned Production	Beginning Inventory	Ending Inventory
1	40,000	41,250	9,000	10,250
2	70,000	71,250	10,250	11,500
3	30,000	31,250	11,500	12,750
4	55,000	56,250	12,750	14,000

Solution:

Period	Required Work Force	Required Number of Employees	Available at the End of Previous Period	ire	ayof
1	41,250/4,000 = 10.3	10	10		
2	71.250/4,000 = 17.8	18	10	8	
3	31,250/4,000 = 7.8	8	18		10
4	56,250/4,000 = 14.1	14	8	6	

Self-Assessment Questions

11. Name the two most commonly used techniques to aggregate planning.

12. _____ assumes a linear relationship between input and output of production.

a. Continuity
b. Linearity
c. Proportionality
d. Constant Price

13. _____assumes that variable and their numerical values are not dependent on other variables.

14. Find the logical sequence for arranging the steps to be performed for solving an LPP using the graphical method:

i. Drawing a graph that includes all constraints and identifying the feasible region
ii. Identifying the problem, which include all decision variables, the objective function, and the constraints
iii. Interpreting the results
iv. Obtaining the point on the feasible region that optimises the objective function or provides an optimal solution

a. II, I, IV, III
b. IV, III, I, II
c. II, IV, III, I
d. I, IV, III, II

15. _____ method is used for solving linear programming problems having more than two variables.

16. The total number of products manufactured by a particular factory and the total number of products stored by an outlet keep changing. (True/False)

17. Transportation models minimise transportation costs incurred on transferring input or output from one location to another. (True/False)

18. Transportation models allocate _____ and material, such as vessel and weapon, at different locations.

Notes

Activity

Give an example in which the transportation method has been used to minimise the cost involved.

7.5 Summary

- Aggregate planning involves the planning of quantity and timing of output over the intermediate time horizon (three months to one year).
- Aggregate planning is a systematic way of developing an aggregate production plan of an organisation.
- There are two types of aggregate planning
  - Manufacturing aggregate planning
  - Service aggregate planning
- Master production schedule helps in:
  - Translating aggregate plans
  - Evaluating alternative master schedules
  - Identifying material requirements
  - Determining capacity requirements
  - Processing information
- One of the requisites of aggregate planning is the estimated costs of various alternatives and resources.
- Estimated costs of various alternatives and resources are one of the most important requisites of aggregate planning.
- Aggregate planning process involves a number of steps which are:
  - Forecasting demand
  - Identifying planning variables
  - Formulating the aggregate plan
  - Implementing the aggregate plan
- Linear programming and transportation model are the two most commonly used techniques to aggregate planning.
- Linear programming is used to select the best alternative from a set of feasible alternatives in situations when the objective function and the constraints are expressed in linear forms.
- Certain assumptions, made for solving optimisation problems with the help of linear programming are:
  - Linearity
  - Continuity
  - Independence and additivity

NOTES

- Proportionality
- Constant Price

- Two major methods that provide a feasible solution to linear programming problems considering all constraints are graphical method and simplex method.
- An organisation may face transportation problem while transferring men and raw material from one location to another or while distributing products from warehouses to end users.

7.6 Glossary

- **Aggregate Production Planning:** The planning the number of units of the products on a weekly basis for the coming 6-18 months.
- **Capacity:** A facility's maximum productive capability usually expressed as volume of output per period of time.
- **Cost Optimisation:** The process of finding alternative with the most cost-effective performance under given constraints.
- **Service:** The maximum level of value-added

7.7 Terminal Questions

1. Discuss the concept of aggregate planning.
2. What are the various functions of master production schedule?
3. Explain the costs of aggregate planning.
4. Briefly explain the process of aggregate planning, using the example of a bakery shop.
5. Discuss the various assumptions that are made for solving optimisation problems with the help of linear programming.
6. Explain the transportation model.

7.8 Answers

Q.	Self Assessment Questions
1.	Aggregate planning
2.	True
3.	c. It facilitates the possibility of changing only the demand variables.
4.	Service aggregate planning
5.	Master production schedule
6.	Aggregate plan and MPS are closely related to each other as MPS is derived from aggregate plan. MPS is a plan developed for individual products to be produced in a particular time period. On the other hand, the aggregate plan is a broad schedule formulated for the whole family of products.
7.	True

Notes

8.	Demand forecasting
9.	b. Identifying planning variables
10.	False
11.	Linear programming and transportation model are the two most commonly used techniques to aggregate planning.
12.	b. Linearity
13.	Independence and additivity
14.	a. II, I, IV, III
15.	Simplex
16.	False
17.	True
18.	men
Q.	**Terminal Questions**
1.	Aggregate planning refers to a process of planning quantity and timing of output for 3 months to 1 year. Refer to section **7.2 Concept of Aggregate Planning.**
2.	The various functions of master production schedule include translating aggregate plans, evaluating alternative master schedules, identifying material requirements, determining capacity requirements, and processing information. Refer to section **7.2 Concept of Aggregate Planning.**
3.	Costs of aggregate planning include cost of hiring and laying off employees, cost of excess inventory and backlogs, etc. Refer to section **7.2 Concept of Aggregate Planning.**
4.	Aggregate planning is a systematic approach that involves a number of steps such as forecasting demand, identifying planning variables, formulating the aggregate plan, and implementing the aggregate plan. Refer to section **7.3 Aggregate Planning Process.**
5.	Certain assumptions made for solving optimisation problems with the help of linear programming are linearity, continuity, independence and additivity, proportionality, and constant price. Refer to section **7.4 Aggregate Planning Techniques**.

7.9 Case Study: Cost Minimisation by ABC Organisation

Established in 1996, ABC organisation produces two products, namely P and Q. In the recent past, the organisation analysed its balance sheet and found that its cost of transportation has been increasing continuously for past few years. Therefore, it decided to hire an agency that can provide the best solution for optimising the output. This would help the company to minimise its costs and maximise its profits. It called upon STU Research Agency for this purpose.

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The research agency found that the organisation has three production facilities S_1, S_2, and S_3 with production capacities of 8, 10, and 20 units of goods respectively. These units are transported to four demand points D_1, D_2, D_3, and D_4 with the requirement of 6, 8, 9, and 15 units of goods respectively. The costs (in rupees) for transporting goods from production facilities to demand points are shown in the following table:

Table: Costs Incurred for Transporting Goods

Depot / Unit	D_1	D_2	D_3	D_4	Supply
S_1	2	3	5	1	8
S_2	7	3	4	6	10
S_3	4	1	7	2	20
Demand	6	8	9	15	38

The research agency provided the analysis report to ABC. In the report, the agency mentioned that the output can be optimised when the total transportation cost is minimised.

Discussion Questions

1. Which method can be used for solving the cost minimisation problem?

   (Hint: North West Corner Method of transportation model can be used for solving the given problem.)

2. Formulate the linear programming model for the problem given in case study.

   (Hint: The linear programming model for the given problem is as follows:

   Minimise $Z = 2x_{11}+3x^{12}+5x_{13}+x_{14}+7x_{21}+3x_{22}+4x_{23}+6x_{24}+4x_{31}+x_{32}+7x_{33}+2x_{34}$

   Subject to:

   Supply/capacity constraints

   $$x_{11}+ x_{12} + x_{13} + x_{14} = 8$$

   $$x_{21}+ x_{22} + x_{23} + x_{24} = 10$$

   $$x_{31}+ x_{32} + x_{33} + x_{34} = 20$$

   Demand/requirement constraints

   $$x_{11}+ x_{21} + x_{31} = 6$$

   $$x_{12}+ x_{22} + x_{32} = 8$$

   $$x_{13}+ x_{23} + x_{33} = 9$$

   $$x_{14}+ x_{24} + x_{34} = 14$$

   With a restriction $x_{ij} \geq 0$ for i and j

   In the above LP model, there are $m \times n = 3 \times 4 = 12$ decision variables, $m + n = 7$ constraints, where m is no. of rows and n is no. of columns in a general transportation matrix.)

Notes

7.10 References and Suggested Readings

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CHAPTER

8

Concept of Quality

Structure

Notes

Learning Objectives

After completing this chapter, you will be able to:

- define quality and explain its meaning
- describe the quality characteristics of goods and services
- describe the evolution of Quality Management
- discuss the Deming philosophy of quality management
- explain the principles of Total Quality Management
- list the barriers to the implementation of TQM in organisations
- list the different costs of quality
- discuss meaning of service quality

8.1 Introduction

The previous chapter discussed about the aggregate planning in detail. In this chapter, you will learn the concept of quality. Quality is a standard measure of how well a product or service conforms to the specified standards to meet the requirements of the customers. It is a crucial parameter that differentiates an organisation from its competitors in a competetive business scenario.

Quality is perceived by people with various parametres or expectations. For customers, quality is all about how a product or a service meets their requirements and expectations such as functionality of the product, material, durability, timely delivery, service, and implied necessities. On the other hand, from the perspective of manufacturers, quality is about how efficiently a product or a service is produced as per the pre-defined standards. To manage and improve quality, organisations implement quality management.

Quality management is an achievement oriented process of recognising and managing the activities that result in fulfilling the desired standards and quality objectives.

Stiff competition and liberalisation have forced organisations to practice the concept of Total Quality Management (TQM), which is a systems approach to manage quality. There have been many management philosophers, mainly from the USA and Japan, who have contributed in a big way towards the development of TQM and its implementation. These experts, who gave us various theories, principles, and techniques of quality management, can aptly be called quality gurus because many businesses have seen great success because of their phenomenal contribution in this field.

Quality management involves ensuring that an organisation's product and services are consistent in quality. It not only aims to deliver quality but also focuses on the ways to achieve quality. However, managing quality cannot happen with the effort of a single individual, but requires the support of all the areas of an organisation.

In this chapter, you will study about quality and the concept of quality management. You will also study the major principles of TQM. Further, you will be familiarised with the philosophies of quality management given by different quality gurus. Finally, you will study about the role of quality in different organisational areas.

NOTES

8.2 Meaning of Quality

The business term "quality as a discipline" guarantees that clients will receive the highest quality products. It is your expectation as a consumer that the goods and services you buy will live up to your standards. Businesses are under pressure to provide high-quality goods and services due to consumer expectations for variety and product comparisons. As a result, the majority of businesses guarantee that their clients will receive high-quality goods and services.

Quality has been described in a variety of ways by quality management pioneers and specialists, including:

- Quality is meeting all criteria. tailored to meet the needs of clients.
- To what extent does performance live up to expectations is the measure of quality.
- Quality is the degree to which a product or service meets or exceeds the expectations of its target market.

That being said, quality has been defined in a variety of ways over the years. Some quality gurus have proposed the following definitions of quality:

According to W. Edwards Deming, *"Quality is a predictable degree of uniformity, at low cost and suited to the market."*

According to Joseph M. Juran, *"Quality is fitness for use."*

According to Phillip B. Crosby, *"Quality is conformance to requirement".*

According to Genichi Taguchi, *"Quality is the minimum loss imparted by a product to society from the time the product is shipped."*

According to Kaoru Ishikawa, *"Quality is a companywide issue and must be an all-pervasive influence on the way every issue of business is conducted".*

ISO 9000:2005 has defined quality as *"the degree to which a set of inherent characteristics fulfils requirements. Degree indicates the extent to which, you can rate the quality of a product or services such as poor, moderate, good, excellent, etc."*

You can assess the quality of a product or service from poor to moderate to good to excellent, and so on, with degrees indicating the extent to which. Quality can also be defined as the extent to which a service or good meets the requirements laid out. To achieve this goal—or better—of satisfying customers, businesses operate according to quality standards. A company's product or service quality standards could include more than one criterion. Among these characteristics are the product or service's pricing, availability, performance, dependability, and promised delivery date.

It is important for any organisation to identify the needs and expectations of its customers. Apart from identifying needs, an organisation must also measure and understand its own ability to meet those needs. Quality as the language of business impacts the culture of the organisation and imbibes it as a value through its products and services. Organisations need to look for a holistic approach and make quality as all pervasive in all processes. Quality must also be the concern of all departments and at all levels of management. Total quality management is supported by management and employees and all the departments with effective tools.

Notes

Quality aims to serve the following purposes:

- Customer satisfaction
- Quality output
- Involvement of people
- Continual improvement

8.2.1 Quality characteristics of goods and services

When customers evaluates the quality of a product/service offered by an organisation they compare the perceptions of the quality received with the expectations. Customers are satisfied only when the perceived quality meets or exceeds their expectations. On the other hand, they are dissatisfied when they feel the quality falls below their expectations.

Certainly, there is a close relationship between quality and happy customers. But how exactly these two ideas relate to one another remains a mystery. There are those who think that happy customers make for good quality, while others hold the view that happy customers make for good quality. Furthermore, the connection between quality and customer satisfaction, as well as the relationship between these two ideas and consumer behaviour, is still mostly unknown. A fair explanation is that when customers are happy, they are more likely to change their minds about the quality. Here are the arguments in favour of this stance:

- When a customer has no background or experience with a company, his or her impressions of that company's quality will be based on those impressions.
- The customer goes through the process of disconfirmation and updated perceptions of quality as a result of further interactions with the organisation.
- Customers' impressions of the company's quality are either revised or reinforced with each subsequent interaction.
- Changes to customers' views of the company's quality impact their propensity to buy from them in the future.

On the basis of the aforementioned points, you can conclude the following characteristics of quality:

- **Reliability and Continuity:** In terms of quality, these two aspects are paramount. If a company consistently provides high-quality items and services, consumers will have faith in those offerings. So, for a business to provide high-quality goods and services, it has to keep all the processes that contribute to quality consistent and credible. In order to maintain a competitive advantage and client loyalty, quality-focused businesses must constantly innovate and provide superior products and services.
- **Customer Satisfaction:** When a service or product meets the expectations of its target audience, we say that it is of high quality. As a result, one of quality's most important characteristics is its capacity to satisfy customers.
- **Long-term and Overall Evaluation of Performance:** Immediate metrics do not constitute a valid evaluation of quality. When a product or service reliably meets or exceeds specified quality criteria over an extended length of time, we say that it is of high quality. Since quality is an attitude developed via long-term, comprehensive evaluation of performance, most experts concur that customer pleasure is a transaction-specific, short-term metric.

- **Conformance to Certain Standards:** Quality is an integrated approach that is implemented at each level of production. For this, organisations follow certain standards to maintain the desired level of quality. Without standard guidelines, implementing quality is not possible.
- **Assurance:** A product/service of an organisation is considered to be of good quality, if it provides basic assurance of good performance to the customers. Quality assurance can be in terms of guarantees, warranties, and return policies.
- **Empathy and Tangibility:** Quality, especially in case of services, is considered as good, if it involves elements of empathy and tangibility in it. Tangibility is shown from the appearance of store, factory, salespeople, and empathy is evaluated in terms of personalised services, receipts of notes and e-mails, and recognition by name.
- **Responsiveness:** It is another major characteristic of quality. An organisation should understand that delivering high quality to customers depends a lot upon being responsive to customers' demands, feedback, and complaints. Returning calls, e-mails, and giving prompt services are a few examples of responsiveness that assure quality.

From the preceding characteristics, it is evident that:

- The entire organisation must focus on delivering a consistent set of satisfying experiences that can build into an evaluation of high quality.
- The needs of the consumer must be understood specifically with conformance to quality standards
- Organisations must be focused on quality and the system must be designed to support that mission by being controlled and delivering, as it was designing to do.

8.2.2 Evolution of quality management

Over time, the idea of quality management developed. In the 1990s, when quality assurance was still a relatively new concept, the word "term" was often linked to inspection. Checking that the product meets the requirements set out by a company is what an inspection is all about. However, the main drawback of inspection was that it used to be carried out after the product was completely manufactured. This incurred huge cost for organisations as the defective products require a big amount to be spent on rework. Apart from this, the inspection process led to many other problems, such as lack of training of inspectors. These problems led to the evolution of the concept of quality management and various quality standards.

In the 1920s, quality acquired statistical connotation. Shewart, Dodge, Romig, and Nelson contributed to the development of statistical control charts, sampling methods etc. . Later on Dr. Edward Deming contributed to the evolution of modern day quality management to a large extent. He also devised 14 points related to quality management in an organisation (which are discussed in next section).

Quality management is a vast concept that requires the participation of every employee working in an organisation. In today's competitive marketplace, it has become important for every organisation to produce superior quality products. Moreover, an organisation should mention its quality standards in its mission and vision statements.

Notes

8.2.3 Fourteen points of Dr. Edward Deming for quality

Deming's philosophy can be explained in his fourteen points. These points provide guiding information to the organisation in explaining the significance of building customer awareness. These points also help the organisation to make efforts in the direction of continuous improvements. The 14 points of Deming's philosophy are explained as follows:

1. **Create and publish the aims and purposes of the organisation:** The management of an organisation must aim at surviving in a business by setting the long term goals. The commitment towards the aims and objectives must be visible to investors, customers, suppliers, employees and community. To achieve the goals, the organisation must concentrate on the effective allocation of resources for research, training and education. The organisation must also promote innovation to prevent a product or service from becoming obsolete. The organisation must work towards promoting the philosophy of making everyone integral to it.

2. **Learn new philosophy:** To achieve TQM in an organisation, everyone in the orgaisation must be acquainted with the new philosophy. Organisations must work for the continual improvements and should not accept non-conformance in any form. Customer satisfaction must be the ultimate aim for the organisation. Therefore, the organisation must endeavour towards defect prevention. For that, everyone in the organisation must be aware of the concept of quality and must be involved in the process of achieving total quality.

3. **Understand the purpose of inspection:** It is important for management to understand that inspection involves costs and are not reliable at all the times. Therefore, the organisation must strive to build quality in its processes. The aim of the organisation must be the reduction in inspection and use statistical control methods to inspect not just products but process.

4. **Select supplier based on quality and not on price:** The organisation must choose supplier on the criterion of quality and and not price. The organisation must emphasise on building a long term relationship of trust and loyalty with the supplier. Suppliers must be educated about statistical process techniques to improve the quality in products and services. They must be made aware of the customer specifications and requirements and must also be provided feedback regarding quality.

5. **Improve constantly and forever:** Continuous improvement must be the aim of an organisation. Management must work constantly to detect problems and methods to correct them, and consequently bring reduction in costs. The organisation must use control charts and assign responsibilities to the teams to make improvements in the ongoing process.

6. **Institute training:** Organisations must institute training programmes to educate employees about the changes. Training is one of the best ways to communicate and educate employees about the changing trends in quality and how these changes can play an important role in the improvement of processes. The methods of training should be monitored to check the efficiency of trainings.

7. **Teach and institute leadership:** The management is responsible for the improvement of supervision in the organisation. Supervisors must be trained to be supportive and need to be optimistic to promote the workmanship in the organisation. Therefore, they must be educated about the 14 points of Deming's philosophy. There should be clarity in the communication from upper management to the lower levels of management.

8. **Drive out fear, create trust, and create a climate for innovation:** Open communication must be given a priority. Performance appraisals, job security, poor supervision and lack of job knowledge have often been the reasons for the cause of fear among the employees. Management must work upon removing these fears from the minds of employees. So, adequate tools, training and supervision must be provided to the workers, so that they can perform their job with ease. Management must strive for creating a fearless and amiable environment and treat all the employees with respect and dignity. Such an environment will lead to rise in involvement of employees for improvement.

9. **Optimise the efforts of teams, groups, and staff areas:** In an organisation, customers, departments, staff areas, work groups, and teams; all play an important role. Often due to poor communication, various types of impediments arise among departments, within departments, with suppliers and customers. The reason for these impediments can be jealousy, fear, competition, or even personal grudges, which affects the work. In order to remove these barriers, the organisation must promote open communication and teamwork. The management can organise multifunctional teams and train them adequately.

10. **Eliminate exhortations for the work force:** The employees should be aware of what they have to do, how they have to do and what is expected of them. Therefore, management must set realistic and achievable goals for long term success. To improve the process, management must equip the employees with adequate tools.

11. **Eliminate numerical quotas for the work force and management by objective:** The organisation must focus upon quality rather than quantity. The numercial goals of the workforce should be eliminated so that workforce can focus on quality rather than quantity of goods and services. The management should learn the capabilties of the processes and their scope of improvement.

12. **Remove barriers that rob people of pride of workmanship:** People working in an organisation often feel deprived of pride of workmanship due to many reasons like their inability to relate to mission of the organisation, poor design of work, inadequate allocation of resources to perform, etc. The management must understand the importance of pride of workmanship and make efforts to restore the pride among employees. People in the organisations must be provided an understanding of their role in the process so that they can work together for the common well-being.

13. **Encourage education and self-improvement for everyone:** An organisation must serve the needs of education to make improvements on an ongoing basis to meet the requirements of the changing environment. It must keep the Deming's philosophy as the basis for developing the education and training programs for their employees.

14. **Involve everyone in the process of transformation:** In order to achieve perfection in quality, the organisation must involve all the people related to it in the transformation process. Adequate methods should be adopted to implement the change successfully.

The above mentioned 14 points holds relevance in today's environment too. These points act as a guide for those organisations who wish to achieve total quality.

8.2.4 Importance of better quality

To survive in today's competitive marketplace, it has become essential for an organisation to provide quality products or services to its customers. The significance of better quality is depicted in Fig. 8.1:

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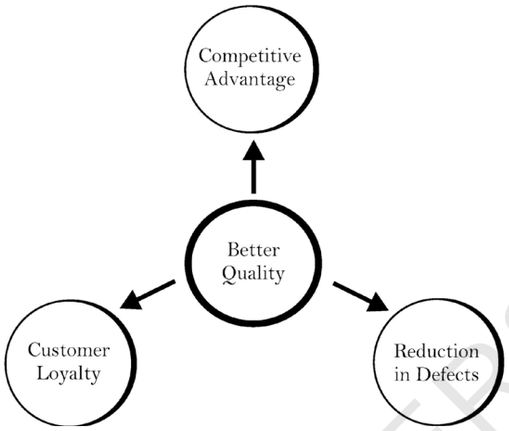

Fig. 8.1: Significance of Quality

The significance of quality is explained as follows:

- **Competitive Advantage:** It indicates the fact that superior quality products and services works as strength for an organisation and allows it to achieve an edge over its competitors. This is because customers are aware that quality products are more durable, reliable, and have an ability to deliver performance.
- **Reduction in Defects:** It implies that superior quality helps an organisation to reduce defects in products or services. In addition, superior quality enables an organisation to overcome the risk of rework or scrapping of products or services, which, in turn, results in the efficient utilisation of time and money of the organisation.
- **Customer Loyalty:** It refers to the fact that customers always prefer to purchase high quality products and services. An organisation that provides superior quality products or services is able to achieve a high level of customer satisfaction and loyalty.

Self-Assessment Questions

1. Without standard guidelines, implementing quality is not possible. (True/False)
2. Quality is the degree to which _____ meets expectations.
3. The quality standards can be a combination of attributes of an organisation's product or service. What are the attributes.

8.3 Quality Assurance

In order to guarantee that a product or service is of high quality, quality assurance is a general practise. As a result, difficulties and product faults can be avoided.

A number of businesses develop their own procedures, while others use industry standards like ISO or the Capability Maturity Model Integration (CMMI) (CMMi). Methods like CMMi make it possible for businesses to establish and stick to their own internal procedures.

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When it comes to improving quality processes, there are a lot of instruments that quality assurance functions use. From basic methods to complex software systems, these tools cover it all. Quality assurance experts should also receive certification after completing official industrial trainings. In software development houses, this is particularly useful for quality assurance duties.

Organisational quality assurance teams are always looking for ways to improve product and service quality through process optimisation and innovation.

Self-Assessment Questions

4. ISO stands for _____

5. _____is a broad practice used for assuring the quality of products or services.

8.4 Total Quality Management

As a customer you decide to buy products or services that meet your expectations in terms of price, quality, and availability. Apart from functional requirements, you seek quality and endurance of the products and services of their purchases. For example, you may not prefer to buy mobile phones from a company that is not well-known for high-quality products.

Organisations recognise that quality can give them a significant competitive advantage in products and services over their competitors. For this, they implement the concept of quality management to ensure good control over quality, for a successful business.

Quality management is a comprehensive process wherein an organisation manages its resources in such a way that the quality of its products and services can be maintained, thereby, fulfilling the needs and expectations of customers. By monitoring quality, organisations strive to maintain the standards and fulfil expectations in production and service. It helps an organisation to reduce costs and identify defects in products or services, before they reach customers.

Consequently, modern businesses place a premium on enhancing the quality of their offerings on an ongoing basis. Companies like IBM, Toyota, Motorola, and Hewlett-Packard (HP) use a technique called Total Quality Management (TQM) to manage quality as a culture (TQM).

Total Quality Management (TQM) is a method that uses best practises to enhance product or service quality while incorporating an organisation's deeply ingrained culture. In the 1950s, Professor W. Edwards Deming created the concept of Total Quality Management (TQM). Deming (1989) argues that TQM may be applied in any setting, whether it be a corporation, government agency, or educational institution. The cornerstones of Total Quality Management include dedicated leadership, a focus on process improvement in tandem with the rate of change, and active teams that work together to achieve goals. In addition to this, below are a few popular explanations of TQM:

According to **Sashkin** and **Kiser,** TQM may be defined as, *"creating an organisational culture committed to the continuous improvement of skills, teamwork, processes, product and service quality, and customer satisfaction."*

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According to **Harrington (1987),** *"TQM can be defined in terms of fundamental principles, such as doing the right things the first time, striving for continuous improvement, and fulfilling customers' needs."*

TQM is a proactive approach that is used by an organisation to satisfy all the needs and demands of customers. TQM includes the following three aspects:

- **Meeting the requirements of customers:** It means producing standard quality goods and services to fulfil the needs of customers.
- **Continuous improvement:** It means continuous modification in quality and product standards.
- **Employee involvement:** It means encouraging employees at every level to participate in quality management.

From the discussion so far, it can be said that TQM applies to every aspect of an organisation be it related to organisational functions, products and services, customer satisfaction and maximisation of profits. Apart from this, TQM calls for employee involvement for quality management. While implementing the concept of TQM, an organisation needs to take into consideration the following points:

- **Total Commitment of Employees:** It implies that the organisation should ensure the involvement of all employees working at different levels in quality management.
- **Training:** It implies that an organisation should conduct training for employees working at both managerial and non-managerial levels for the successful implementation of TQM.
- **Clear Goals:** It signifies that the organisation should have clear, measurable, and realistic goals related to TQM. To implement these goals, the organisation should have definite action plans and measure its performance from time to time.
- **Customer Oriented:** The basic goal of the organisation toward TQM should be the total satisfaction of customers; therefore, TQM should be customer driven and customer focused.
- **Continuous Improvement:** TQM should not be a one-time affair rather it should be an ongoing process since the requirements and expectations of customers are ever changing.

8.4.1 Importance of TQM

The main advantage of TQM is that it brings innovation in an organisation and makes it adaptable to changes. The importance of TQM is explained in the following points:

- **Producing quality products or services:** TQM helps an organisation to focus on main quality aspects while producing products or services. These aspects include durability, reliability, performance, and conformance with quality standards and aesthetics.
- **Achieving a high level of customer satisfaction:** By consistently delivering high-quality goods and services, TQM helps businesses increase customer satisfaction. When a company's goods and services consistently meet or beyond client expectations, we say that the company has exceptional quality. If the goods and services are of high quality, consumers will be more likely to buy from the company again or even become brand loyal.
- **Building reputation:** TQM helps the organisation to gain good public image by providing superior quality products and services.

- **Making efficient utilisation of resources:** TQM aims at making an optimum use of available resources by reducing defects in products.
- **Generating high revenue:** The TQM approach helps an organisation to reduce wastage, which, in turn, decreases additional costs and generates high revenue for the organisation.
- **Motivating employees:** Employees always prefer to be associated with an organisation that has good market image. TQM helps an organisation to build reputation in the market, which, in turn, motivates its employees to perform their jobs effectively.
- **To Achieve Objectives:** Reaching one's goals is the ultimate goal of any organisation. Organizational missions and objectives are defined by quality, in addition to profit and market survival. Companies need to make sure they follow quality standards that are reflected in their aim.
- **To Deal with Competition:** When you sell a product to the target customers, you face competition in the market. Poor quality may switch your target audience to your competitors. Therefore, to beat competition, organisations must focus on providing better quality to customers
- **To Generate Long-run Business Survival:** In the long term, satisfying clients is the goal of any firm. A company can stay in business and perhaps grow in the worldwide market if it sells high-quality products. Another bene fit is that organisations can gain customers' trust and confidence by consistently delivering high-quality work.

8.4.2 Barriers to the implementation of TQM

The implementation of TQM can be challenging for an organisation as it requires a number of activities to be performed and incurs huge cost for the organisation. Apart from this, there are various other barriers to the implementation of TQM. Some of these barriers are as follows:

- **Poor planning:** An organisation needs proper planning to implement TQM. Any inaccuracy in planning may have adverse effect on the results of TQM. Therefore, poor planning acts as a barrier to the implementation of TQM.
- **Resistance of employees:** As discussed earlier, TQM requires total commitment of employees. However, employees may resist the implementation of TQM due to various reasons, such as the absence of long-term objectives and targets, lack of coordination, and language barrier. Thus, the organisation should strive to eliminate these differences for the successful implementation of TQM.
- **Lack of proper training:** Lack of adequate training to employees may result in the misunderstanding of the quality management system. Thus, the successful implementation of TQM requires proper training of employees.
- **Lack of management commitment:** It refers to the absence of sense of responsibility on the part of management. The lack of management commitment can be due to various factors, such as inadequate knowledge, lack of training and experience, and hesitance. For example, sometimes the top management hesitates to introduce new methods or programs.

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- **Shortage of resources:** It refers to another roadblock in the successful implementation of TQM. The implementation of TQM requires a sufficient amount of resources, such as men, material, capital, and machine. Lack of any of these resources may hamper the implementation of TQM.

Self-Assessment Questions

6. The concept of TQM was introduced in the _____
7. _____ is a comprehensive process wherein an organisation manages its resources in such a way that the quality of its products and services can be maintained, thereby, fulfilling the needs and expectations of customers.
8. TQM stands for Total Quantity Management. (True/False)

Activity

List out any two organisations that follow Total Quality Management (TQM) for managing the quality of products and services.

8.5 Costs of Quality

Companies pay a hefty price for quality management. "Cost of quality" is a phrase that people constantly misunderstand. The amount spent on manufacturing high-quality goods and services is unrelated to the cost of quality; rather, it is linked to the faults in those goods and services. Companies incur more expenses as a whole due to the necessity to rework defective items. Reprocessing a loan procedure, reassembling a tool, or retesting the assembly are all examples of tasks that might be involved in product rework. Philip Crosby, Dr. Armand V. Feigenbaum, and other quality experts have all proposed various definitions of quality cost. For others, the price of quality is the same as the price of getting quality. Conversely, the word has been associated by some with additional expenses caused by subpar product quality. On the other hand, some have equated the term with the extra costs incurred due to poor quality of the product. However, most of the quality experts widely accepted thing that, *"Quality cost is the extra cost incurred due to poor or bad quality of the product or service".*

Organisations estimate quality costs for the following reasons:

- To quantify the impact of problem and take effective measures
- To identify opportunities for cost reduction
- To find out the way of reducing customer dissatisfaction and risk associated with product saleability

Understanding the significance of quality costs in production enables an organisation to develop quality conformance in a competitive business environment. Organisations also adapt a quality costs program for determining the magnitude of quality cost and its direct impact on the business. In addition, practice of quality cost program also guides how to control and minimise the costs involved in waste, scrap, and rework. This program helps an organisation to identify the requirement of quality costs in the current business practices. An effective quality cost program involves the following steps:

1. Establish a quality costs measurement system
2. Build a result oriented long-range trend analysis

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3. Set an annual development goals for total quality costs
4. Develop short-range trend analysis that aligns the annual goals
5. Compare the progress with the goal and take corrective action for better quality

Different types of costs of quality are shown in Fig. 8.2:

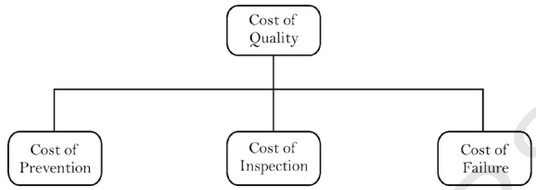

Fig. 8.2: Costs of Quality

Let us disuss the different costs of quality.

8.5.1 Cost of Prevention

Prevention costs are incurred to produce error-free output to the customers. Prevention cost is essentially planned to support such activities that are meant to mitigate the occurrence of defects. Keeping in mind the concept of prevention costs, today, organisations apply various techniques to safeguard a product from defects.

The cost of prevention is associated with the prevention of defects in products and services. A product is said to be defective if it does not match with the quality standards set by an organisation. This type of cost is incurred for:

- Formulating various quality-related specifications
- Designing and procuring different equipment for producing superior quality products
- Reviewing a new product or service
- Conducting supplier capability surveys
- Conducting quality improvement programs

An organisation may use various techniques to prevent defects in products, such as statistical process control, quality circles, quality engineering, and benchmarking.

8.5.2 Cost of Inspection

The cost of inspection is incurred for ensuring whether an organisation's products or services are in compliance with quality standards and performance requirements. This cost is incurred for:

- Testing the purchased material
- Conducting product, process, or service audits
- Measuring the performance of equipment
- Conducting in-process and final inspections

Most of the organisations have a separate team of inspectors to ensure the conformance of quality standards.

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8.5.3 Cost of Failure

Failure costs are those costs, which are incurred when a product falls short of conforming to its design specifications. In other words, the cost of failure is incurred when an organisation's products or services are below the specified standards. It can be further divided into two categories, which are as follows:

- **Internal failure costs:** These charges are made prior to the actual shipment of a product to the buyer. In order to determine why products were rejected due to flaws, these expenses must be met. It is possible to find a product's flaws on the inside throughout the evaluation process. Consequently, the likelihood of discovering flaws prior to shipment to clients increases in proportion to the amount of assessment operations conducted. Internal failure costs also include the costs incurred for scrap, re-examination and testing, re-welding, re-working of defective products, fault investigation, trouble-shooting, wastage of labour and energy etc. For example, you have manufactured 100 mobile phones, out of which 65 were found defective and rejected. To inspect these issues, some additional costs are incurred in terms of rework, testing, time and efforts. These costs are referred as internal failure costs.
- **External Failure Costs:** Repairs, replacements, and warranty coverage are all expenses that arise when a consumer receives a product that is not up to par. These expenses are spent by nearly every product category due to the high rate of consumer returns due to product defects. Customer complaints are seen as valuable feedback that organisations may use to fix or replace products with problems, which helps them evaluate external failure costs. Organisations should take in to account the Service Level Agreement (SLA) to fulfil its commitment to customers against such external failures. For example, you have purchased a 183 litre refrigerator with two years of warranty. After 15 months, you find some issues with its compressor and claim for the warranty coverage. The costs incurred during repairing the refrigerator comes under external failure costs.

Self-Assessment Questions

9. Which of the following costs are incurred to produce error-free output to the customers?

a. Appraisal costs

b. Prevention costs

c. Error costs

d. Failure costs

10. _____ are incurred when a product falls short of conforming to its design specifications .

11. The greater the application of appraisal activities, lower is the chance of catching the defects before shipping the products to the customers. (True/False)

8.6 Service Quality

Service can be defined as "an act of satisfying customers' needs and wants through representatives of service providers, who directly interact with them". Services are often intangible in nature. Other notable examples of services are welfare services, health services, education services, etc.

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The quality of service is judged by how well the customer is satisfied with the service. In other words, service quality is determined by comparing performance with the customer expectations. Service quality is the combination of core services and facilitating services. For example, in banks, the core service is to check the account, while operating accounts through internet and phone is facilitating service. Facilitating services act as value addition to core services.

The success of business is dependent on the type of service it offers to its customers. A business that aims at achieving an edge over its competitors works hard to improve the processes and set realistic measures for performance and customer satisfaction. As service requires customers' participation, therefore, service providers must adopt an amiable and responsive approach while interacting with the customers.

Exhibit

Distinguishing characteristics of service quality

Some of the important distinguishing characteristics of service quality are as follows:

a. Approach of service provider

b. Image of organisation in the market

c. Difficulty in measuring the performance

d. Difficulties in applying variations and acceptance range

e. Customer's interaction during the performance of service process

The key to retain customers is to understand their needs and fulfill them. Increasing the customers' loyalty towards a brand and making them buy the services repeatedly requires focus on quality dimensions of services. These dimensions help an organisation to add unique features to the quality, making it more reliable and satisfying. There are five dimensions of service quality, as shown in Fig. 8.3:

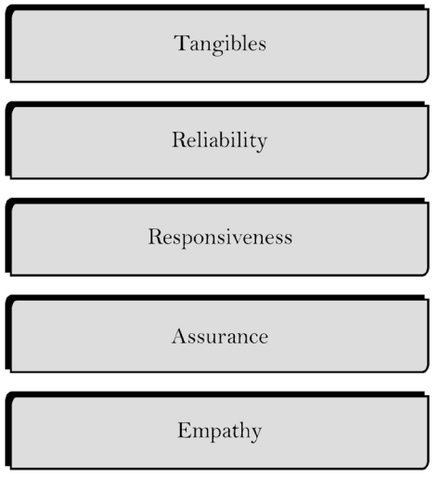

Fig. 8.3: Dimensions of Service Quality

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The dimensions of service quality are as follows:

- **Tangibles:** The tangible dimension of quality is related to the surroundings in which the service is provided to the customers. For example, when you enter a restaurant, the first thing you notice is the aesthetics employed in seating arrangement, interior décor, lighting system etc. All such things are known as tangible aspects of services. By focusing on tangibility, an organisation can improve its service and create a long lasting impression on its customers. Therefore, an organisation must ensure that it catches the attention of their existing customers as well as the first time customers by offering them a nice ambience and feel about the surroundings.
- **Reliability:** Reliability refers to the dependability of customers on services. In other words, if services offered are in consistency with customers' needs then these are reliable. To make the services reliable, they must be verified for their consistent performance prior to their commencement. An organisation must offer what it promises to its customers. For example, in 2010 Pizza Hut launched "hot on dot" system in India to indicate that pizzas delivered at door step are hot. Similarly, Indigo airlines in India have proved to be low cost airlines with high quality.
- **Responsiveness:** Responsiveness refers to the time taken by a service provider to respond. The service delivery time must be quick. Delays in response are not welcome by the customers and often leave them disgruntled. Service employees must show excitement while serving customers and must actively solve customers' problems and needs. Also, employees must be well trained to handle customers. For example, executives at Airtel Broadband Services respond to customer complaints within 24 hours.
- **Assurance:** This dimension of service quality is related to the competence of service employees. The employees must be competent to gain the trust of customers. The competence of employees is visible to customer at the time of performing the services. Therefore, service personnel must acquire adequate knowledge and skills about their work. For example, CA firms who provide auditing requires qualified and experienced professionals to conduct correct audits to give the client complete knowledge of financial accounts.
- **Empathy:** Empathy refers to caring attitude that an organisation shows towards customers. By adopting this dimension in service quality, an organisation gives individual attention to its customers and makes them feel special. For example, various hotels research about their guest's likes, dislikes, preferences etc. and provide individual attention to them making them feel special to the hotel. Service employees are encouraged to interact with customers, ask relevant questions and try to resolve their problems at the earliest.

Self-Assessment Questions

12. _____refers to the dependability of customers on services.

13. The employees must be competent to gain the trust of customers. (True/False)

NOTES

8.7 Summary

- Quality is a standard measure of how well a product or service conforms to the specified standards to meet the requirements of the customers.
- Customers are satisfied when the perceived quality meets or exceeds their expectations.
- Quality shows various characteristics such as reliability and continuity, customer satisfaction, long-term and overall evaluation of performance, assurance, empathy and tangibility, and responsiveness.
- All the cost elements that affect the total cost for controlling and sustaining quality are termed as 'cost of quality' or 'quality cost'.
- Quality management involves ensuring that an organisation's services are consistent in quality.
- TQM is a process of working with the deep-rooted culture of an organisation and directing it towards the improved quality of products or services, by employing the best practices.
- Quality management is needed to achieve objectives, deal with competition, bring customer satisfaction and loyalty, and generate long-run business survival.

8.8 Glossary

- **Competence:** It is the possession of the essential skills and understanding required to perform an activity
- **Prevention Costs:** Are the costs that generate to produce error-free output to the customers.
- **Quality:** It is the superiority or excellence of a product or a service in terms of features, prices, and durability.
- **Quality costs:** The cost incurred to maintain the quality and reduce the defects of a product.
- **Total Quality Management:** It is an act of managing the quality of an organisation's products, services, processes, and operations as a whole

8.9 Terminal Questions

1. Explain the meaning of quality. Discuss view of Dr. Edward Deming on quality.
2. Explain TQM. What are the barriers to its implementation?
3. Explain costs of quality.
4. What do you mean by service quality?
5. Explain quality assurance.

Notes

8.10 Answers

Q.	Self Assessment Questions
1.	True
2.	Performance
3.	The attributes include price, availability, performance, reliability, and commitment to delivery time of a product or service.
4.	International Organization for Standardization
5.	Quality assurance
6.	1950s
7.	Quality management
8.	False
9.	b. Prevention costs
10.	Failure costs
11.	False
12.	Reliability
13.	True
Q.	**Terminal Questions**
1.	Quality is a standard measure of how well a product or service conforms to the specified standards, to meet the requirements of the customers. Refer to section **8.2 Meaning of Quality** and sub section **8.2.3 Fourteen points of Dr. Edward Deming for quality**
2.	TQM is needed to achieve objectives, deal with competition, bring customer satisfaction and loyalty, and generate long-run business survival. Refer to section **8.4 Total Quality Management** and sub section **8.4.2 Barriers to the Implementation of TQM**
3.	Different types of quality costs are cost of prevention, cost of inspection and cost of failure. Refer to section **8.5 Costs of Quality**
4.	The quality of service is judged by how well the customer is satisfied with the service. Refer to section **8.6 Service Quality**
5.	Quality assurance is a broad practice used for assuring the quality of products or services. Refer to section **8.3 Quality Assurance**

8.11 Case Study: Quality Concern in the Food Industry

Quality is the prime concern in today's food service industry worldwide. Therefore, customers want no compromise with quality of food products they buy or eat. In rapid growing lifestyles, people spend both money and time at various food chain stores in the city. Therefore, the demand for food service is gaining its popularity gradually. It has resulted in the requirement of adopting quality control tools by different established market leaders.

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In addition to the ready-made food servicing organisations, various grocery food stores like Kroger, Meijer, etc. have also became more concerned about their quality output. The organisations that deliver quality products and services are most preferred by customers. As a result, they are able to sustain competitive business environment. Apart from the giant food stores, customers also prefer to buy products from small restaurants, bakeries, and grocery stores to taste fresh and quality items.

Today, most of the food service organisations aim to provide fresh and hygienic food items to the target audience. To examine the quality of food items, organisations employ various quality experts who prioritise the concept of TQM. The quality experts are responsible for examining the effectiveness of products in terms of its attributes, prices, quality standard, and availability. So that, customers can also experience good services along with quality products. TQM professionals evaluate the areas and the extent to which, the quality is lacking for a particular product or service. Some of the common quality issues identified in food services include inadequate shipment of food products and poor refrigeration of the foods. Some of the processed food items also lack quality due to the use of unsafe metallic containers. Thus, quality is also considered as providing a safe product to the end users. No food should be delivered to customers that fail to meet the required standard of quality. In many cases, food service industries are blamed for distributing the expired products. However, the reality is different. To gain huge profits, many small retailers sell products that are bad in quality. It threats users in terms of safety and healthiness of products. Therefore, in the long run, no such products are preferred by customers.

To guard against such circumstances at any stage, the Indian Ministry of Food Processing Industries has also adopted the Total Quality Management Approach. In this approach, the desired quality standards are set as per ISO14000, ISO22000, HACCP (Hazard Analysis and Critical Control Points), GMP (Good Manufacturing Practices), and GHP (Good Hygiene Practices). The organisations in this industry are required to abide by the guidelines mentioned in the quality standards.

Discussion Questions

1. Why quality is considered as the prime concern in the food service industry? (**Hint:** to avoid health problems)
2. In Indian food markets, what standards are to be followed by a food service provider? (**Hint:** ISO14000, ISO22000, HACCP)

8.12 References and Suggested Readings

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CHAPTER

9

Quality Control

Structure

Notes

Learning Objectives

After completing this chapter, you will be able to:

- explain the concept of quality control
- explain the various tools and techniques for quality control and improvement
- discuss the concept of Six Sigma and its application
- explain the concept of quality circles

9.1 Introduction

In the previous unit, you studied the concept and applications of Total Quality Management (TQM) and its various aspects. In this unit, let us discuss in detail how quality can be controlled in organisations.

Whenever you hear the term quality, the first thing that strikes your mind is an outstanding product or service. To sustain and improve the required standards of quality, organisations use various processes and techniques, referred to as quality control (QC).

Initially, the term quality control included everything that ensured delivery of defect-free products – though primarily it meant just inspection of the prescribed standards. It soon became apparent that quality control should also involve establishment of highly capable processes that reduce the need for inspection and rework. This resulted in the design of statistically capable processes and quality control tools that can assure high quality products.

The practice of quality control creates an environment where both the management and personnel endeavour to achieve quality standards by controlling and minimising defects. The quality control process is all about prevention of quality problems through planned and systematic strategies. It is a proactive measure to ensure excellence in products and services. It also attempts to develop and test processes to get defect-free outputs.

In this chapter, you will learn about the concept, significance, scope, and process of quality control. The chapter also covers the basic tools for quality control and improvement. You will also study the concept of Six Sigma and its application. Towards the end, the chapter explains the concept of quality circles.

9.2 Concept of Quality Control

Quality control is a process that helps in ensuring the desired level of quality in a product or service. In simple terms, it can be defined as a process of reviewing the quality of all factors involved in production. Quality control aims at preventing defects in the final output and taking corrective actions during the production process and services. There are various definitions of quality control. A few examples are as follows:

Definition by Alford and Beatty: *"Quality control is the mechanism by which products are made to measure up to the specifications determined from the customer's demand and transformed into engineering and manufacturing requirements. It is concerned with making things right than discovering and rejecting those made wrong."*

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Definition by Bethel, Atwater, and Stackman: *"Quality control refers to the systematic control of those variables encountered in a manufacturing process, which affect the excellence of the end product. Such variables result from the application of materials, machines, and manufacturing conditions. Only when these variables are regulated to the extent that they do not detract unnecessarily from the excellence of the manufacturing process as reflected in the quality of the finished product, can the quality said to exist."*

The above definitions indicate that quality control is a process of examining specific outputs against the desired standards. The quality control system monitors and tests the final outputs and generates a report. The management of an organisation reviews the quality control report and then decides whether to accept or reject the release of a product.

For example, pharmaceutical organisations follow special precautions and measures to examine the purity of all the ingredients used for manufacturing drugs. A wrong combination of ingredients may turn fatal. These organisations primarily focus on quality control to ensure defect-free products.

Exhibit

Quality Control in Toyota

In the mid-1940s, many Japanese manufacturers introduced and implemented the concept of quality management. Toyota was one of them. In a few years, Toyota revised and re-developed its basic quality control approach.

Toyota considers quality as an essential objective to provide standard quality output to customers. It prioritises customer satisfaction as a key quality control activity. The company's quality control unit involves members from various departments, from research and development to manufacturing to sales and to services.

Considering the changing trends in customers' buying habits, the company has developed an innovative quality control approach called company-wide quality control. This approach defines roles for all the members in assuring quality. This ensures that only the best quality work is transferred to the next level of the manufacturing process, and there is a minimum possibility of repetitive defects or failures.

The company relies on the flexibility and proficiency of its workforce. With an innovative quality control approach and standard quality procedures for continuous improvement and Kaizen, Toyota retains its role as a trend-setter in quality.

The key objectives of quality control are:

- To create value for customers by providing them quality products and services
- To control the overall cost by reducing defects or errors
- To maintain an optimum level of quality at a low cost
- To identify and prevent errors during operations
- To adopt corrective measures for delivering zero-defect outputs

9.2.1 Functions of quality control

The main goal of quality control is to meet customers' requirements by producing quality output. To ensure the quality of output, quality control undertakes three main functions, which are as follows:

- **Acceptance function**: This function is about the inspection of products. The products that fulfil quality standards are accepted, whereas the ones that fail to fulfil quality standards are rejected. Fig. 9.1 shows the acceptance function of quality control:

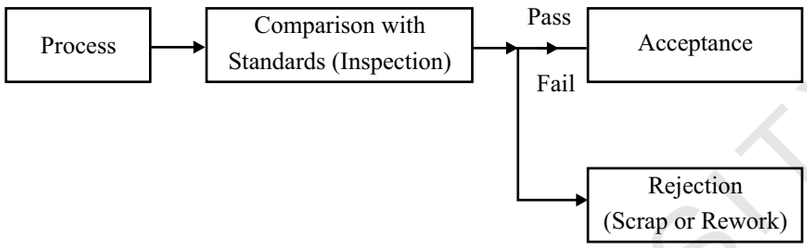

Fig. 9.1: Acceptance Function

- **Preventive function**: It is about identifying defects in raw materials, components, and processes. The defects at the early stage are checked to avoid defects at the later stage (when the goods are produced). This can be done by using various techniques, such as failure statistics analysis and method study.
- **Assurance function:** This is a quality function involves verifying quality for meeting pre-determined performance standards at each stage in the production cycle. This verification is done on the basis of customers' complaints, quality audit, and executive reports on quality.

9.2.2 Significance of quality control

When you buy a product from a market, you can easily find the contributions made by an organisation to sustain the quality of its products.

An example of such a contribution is the quality of plastics and other materials used in packaging of a product. An organisation conscious of quality control will package its products in safe plastic containers instead of hazardous materials like tin and iron. In addition, it provides user manuals or instructions for the convenience of customers.

Without quality control, there will be a possibility of defective products, which will require rework leading to wastage of resources. Quality control not only improves the standards of quality, but also increases productivity. Some of the benefits of practicing quality control are as follows:

- It produces high quality products and thereby achieves high levels of customer satisfaction.
- It ensures if raw materials are of the required standards of quality.
- It mitigates defects in the final output.
- It saves time and resources by minimising rework.
- It minimises the cost of labour and materials, as defects are reduced.
- It attains uniform quality and reliability of a product.
- It reduces the costs of inspection and production.
- It controls customer complaints.
- It increases quality consciousness among customers.

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9.2.3 Process of quality control

Quality control is a systematic approach to control various factors that affect the quality of products. It involves a number of steps, which are shown in Fig. 9.2:

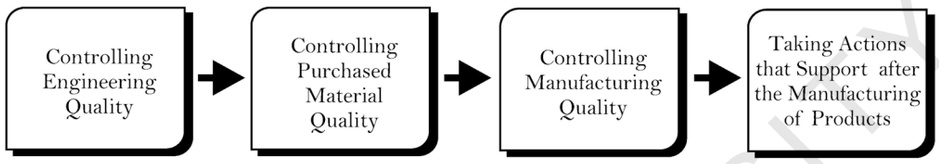

Fig. 9.2: Process of Quality Control

The steps involved in the process of quality control are discussed as follows:

1. **Controlling engineering quality:** This is the first step of quality control in which product specifications are developed. This step involves various sub-steps, which are as follows:
   a. Evaluating customers' requirements to have a clear understanding of product quality objectives
   b. Reviewing product design documents for conforming to design standards
   c. Validating the accuracy of design proof tests
   d. Auditing the release and distribution of design documents
   e. Taking reference of how quality problems were handled in the past
2. **Controlling purchased material quality:** One of the most crucial steps of quality control in which an organisation verifies whether the purchased materials are of good quality. This step involves the following sub-steps:
   a. Identifying potential suppliers
   b. Checking the accuracy of purchase orders
   c. Verifying whether the purchased materials are in conformance to the ordered materials
   d. Taking corrective actions in case materials are defective
3. **Controlling manufacturing quality:** This step involves controlling the quality of overall manufacturing process. The step includes the following sub-steps:
   a. Evaluating the quality of manufacturing equipment
   b. Inspecting different production activities
   c. Taking a corrective action for out-of-control conditions
   d. Conducting a follow-up for assuring that the corrective action is accomplished in a timely manner
4. **Taking actions that support after the manufacturing of products:** It involves checking the quality once the products are manufactured. This step involves the following sub-steps:
   a. Assuring that product and service specifications are clear and correct
   b. Assuring that spare parts conform to the quality requirements
   c. Assuring that repairs are performed according to quality requirements

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9.2.4 Scope of quality control

The scope of quality control depends on how effectively an organisation practices its functions and processes to deliver quality outputs to its customers. The scope of quality control is to:

- Prepare quality standards and specifications
- Exercise control over inputs
- Exercise control during manufacturing
- Perform inspection before delivery of products to customers
- Take deterrent actions at the right time on the product and process
- Establish the cause of rejections by periodic analysis of inspection reports
- Apply statistical methods of quality control
- Initiate quality circles
- Suggest schemes for improving quality
- Create quality consciousness in the organisation
- Conduct quality specific training programmes

Self-Assessment Questions

1. Define quality control.
2. What among these is not a key objective of quality control
   a. To control the overall cost by reducing defects or errors
   b. To maintain an optimum level of quality at maximum cost
   c. To identify and prevent errors during operations
   d. To adopt corrective measures for delivering zero-defect outputs
3. _____ is about identifying defects in raw materials, components, and processes.
   a. Acceptance function
   b. Assurance function
   c. Preventive function
   d. Rejection function
4. Practicing quality control increases the costs of inspection and production. (True/False)
5. Product specifications are developed at which of these stages of quality control process?
   a. Controlling manufacturing quality
   b. Controlling purchased material quality
   c. Taking actions that support after the manufacturing of products
   d. Controlling engineering quality

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Activity

Conduct a research on a quality control scenario in Indian companies. Write a paragraph on it. You can take help of publicly available sources, such as the Internet.

9.3 Tools and Techniques for Quality Control and Improvement

Parameters of both products and processes can benefit from quality control and improvement strategies. Process quality control and improvement is concerned with process capabilities; whereas, product quality control and improvement is concerned with finding and validating project outputs. Quality assurance makes use of the results of process quality control and improvement.

In this section, you will learn about some of the basic tools and techniques for quality control and improvement. Fig. 9.3 shows these tools:

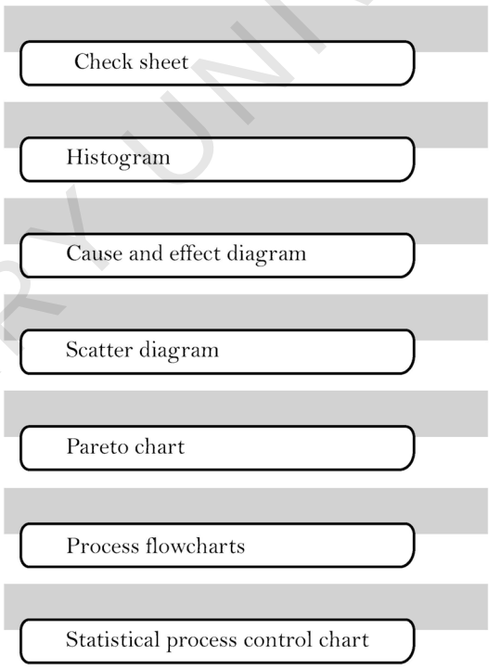

Fig. 9.3: Tools for Quality Control and Improvement

Let us now discuss these tools for quality control and improvement.

9.3.1 Check sheet

In order to pinpoint quality problems, product failure causes, and overall quality improvement initiatives, businesses must gather massive amounts of data. If a mobile phone maker wanted to know why their phones were malfunctioning, for instance, they would have to gather information about the manufacturing process, the materials utilised, and so on. The company would then examine the data to determine the cause(s) of the hardware problem or technical difficulty. Consequently, quality control relies heavily on data collecting and analysis. An

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essential tool for quality control and data collection in any organisation is the check sheet. To rephrase, check sheets are individualised, user-friendly instruments that make data collection for quality issues much easier. The frequency of various phenomena under observation is typically documented in tabular form on check sheets.

Fig. 9.4 shows a sample check sheet as follows:

Check Item/Defect	Day 1	Day 2	Day 3	Day 4	Day 5	TOTAL
Missing Paperwork	𝍸	𝍸	II	𝍸	II	22
Missing part number/ identification	I	II			𝍸	8
Damaged packaging				𝍸		10
Part damage – scratch	III	III	III	I	II	12
Part damage – dent					I	1
					Grand Total	53

Fig. 9.4: Showing a Sample Check Sheet

Various sorts of product problems identified on different production days are displayed on the check sheet. The use of tally marks to count the frequency of an occurrence is evident on check sheets. Tally markings are a counting method that involves drawing four horizontal lines or marks to indicate a count up to four, and then drawing one mark across the four lines to indicate five occurrences of an event. Consequently, on day-1, there are three cases of missing documentation and on day-5, there are five instances, as shown in Figure 9.4. For organisations that rely on manual data collecting, check sheets are ideal. So, the information gathered can be qualitative or quantitative. Furthermore, the data is deciphered by comparing the quantity of marks to the number of occurrences of flaws on the sheet. In order to identify potential product flaws, businesses choose a subset of items and document them using defect checklists. Data gathered from check sheets is then subjected to additional analysis in order to uncover valuable trends. The results of the analysis are used to take informed decisions about the product and the company's future.

A check sheet simplifies the data collection process in an organisation. However, the following things should be considered before collecting data through check sheets:

- **Training Staff:** Data collection staff should be properly informed about the relevance of data collection. The location and mark of data needs to be specifically explained along with the objective of data collection. This is because the final analysis of the data would depend upon the quality of the data collected. For example, if the data collection staff records wrong frequency of occurrence of different types of defects of products, it would not be possible to find out the reasons of the defects on the basis of the data. Therefore, the data collection staff should also be trained on how to fill the check sheets.
- **Allocating Enough Time:** Sufficient time and resources should be allocated for staff to collect data, otherwise; data collection staff might record wrong data because of lack of time.

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9.3.2 Histogram

Karl Pearson first proposed using a histogram to depict a continuous variable's expected distribution. The primary function of this tool, similar to other TQM tools, is to display data graphically. Histograms can alternatively be described as bar graphs that show how data is distributed. With a histogram, you can see how often each data class appears as bars.

Fig. 9.5 shows a sample histogram, as follows:

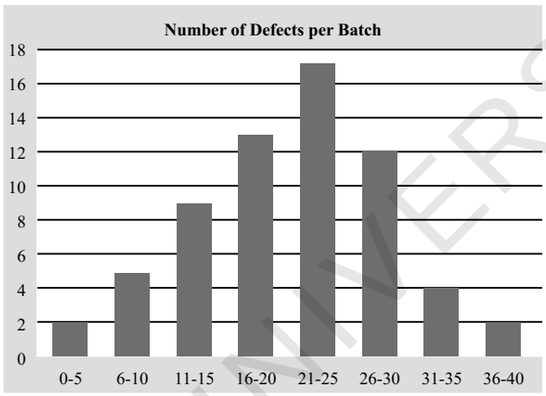

Fig 9.5: Showing a Sample Histogram

The histogram shows, graphically, the number of defects per batch over various class intervals. It is easy to see that the class interval from 21 to 25 has the highest amount of faults. Thus, it is clear that the histogram aids in the detection and control of quality issues through its simplification of data presentation.

Here are some common situations where histograms are employed in quality control:

- When hard numbers on quality metrics (such defect count) are at hand
- When determining if process outputs are adequate to satisfy consumers' needs
- When looking at when a process change could have happened
- When sharing and presenting high-quality data with others

9.3.3 Cause and effect diagram

Like any other real-world problem, quality concerns in organisations are just a series of causes and effects. Therefore, quality control relies heavily on identifying and addressing the root causes of product failures and similar issues. It is easier to determine what went wrong with a process when it is less complicated. However, pinpointing the causes of quality failures can be challenging for manufacturing organisations dealing with complicated and sophisticated goods like commercial aircrafts. To get to the bottom of these kinds of issues, you need reliable methods and instruments. Kaoru Ishikawa, a professor from Japan and an advocate for quality management principles, first used the cause and effect diagram in 1968. Ishikawa diagrams are another name for cause and effect diagrams. His work in the Kawasaki shipyards laid the groundwork for quality management, and he later became a prominent figure in the field. His book, "Introduction to Quality Control," presented the cause and effect graphic.

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One tool that may be used to find quality problems in a company is a cause and effect diagram. As its name implies, this graphic organises all possible or actual sources of quality issues in a hierarchical fashion based on their relative relevance. This is a fishbone diagram, which is a schematic depicting the anatomy of a fish. Figure 9.6 depicts a fishbone or cause and effect diagram:

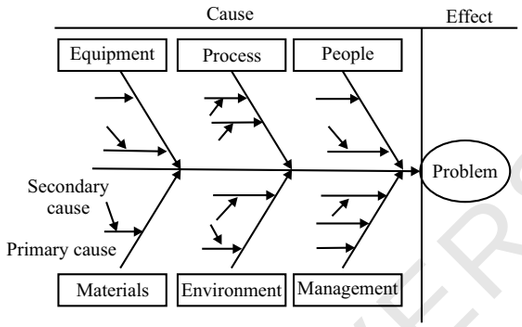

Fig 9.6: Fishbone Diagram

Before studying how to develop a cause and effect diagram, let us study the general causes of quality issues in organisations. The following are the main causes of quality issues in organisations:

- **People:** It refers to the workforce involved in the production process. The efficiency, knowledge and the motivational levels of the men involved in the production process affects the quality of the products. For example, the quality and functionalities of the software of a software company would depend on the expertise of the engineers of the organisation.
- **Methods:** These refer to the process of production of goods and services. There are different methods of production available in organisations. Some of the methods are capital extensive and others are labour-intensive. The selected method of production affects quality of goods and frequency of defects or errors in the goods. For example, Maruti suffered a loss of Rs.2690 million in 2011 due to quality and productivity issues. In the next year, the company started the "Challenge 50 initiative" to alter the manufacturing methods by collaborating with the vendors, and incorporate value analysis and value engineering initiatives. As a result, their quality and productivity substantially improved and the organisation posted a net profit of ` 1045 million (icmrindia.org, 2013).
- **Machine:** It refers to tools and equipment used in the production process. The sophistication of the machine used in the production process affects quality. For example, a manufacturer with a more modern and sophisticated machine will naturally be able to produce items with less number of product defects.
- **Material:** The type of raw materials used in the production process affects quality to a great extent. For example, if a mobile phone manufacturer uses low quality metals or plastics in the body of mobile phones, the phones would get physically damaged.
- **Measurement:** It helps in quantifying defects and quality issues in products and addressing the issues by using TQM tools. For example, measurement techniques helps an organisation counting number of defects or other quality issues, find the pattern of their occurrence, prioritise the quality issues according to their relative importance and take the most suitable course of action to correct the issues.

- **Environment:** It involves conditions, such as location, time, temperature, and culture in which an organisation operates. These factors affect quality to a great extent. For example, historically Japanese organisations have focused on quality improvement intensely. Therefore, most of quality improvement techniques have been developed in Japan; and Japanese organisations pioneered the applications of these techniques. This is because Japanese culture inculcates strong work ethics and dedication among the workers who in turn produce world-class products.

9.3.4 Scatter diagram

You saw in the preceding sections that quality concerns are mostly caused by a variety of variables. Nevertheless, businesses are never able to pin down the exact reasons of quality problems. Scatter diagrams come in handy when trying to figure out what the connection is between those two variables. These diagrams can be useful for determining whether two variables are related, but they cannot prove a cause-and-effect link. If you were to examine two variables, such as the quantity of product defects and the price of materials, for instance, the scatter diagram would reveal whether or not the two variables were related. Put simply, a scatter diagram shows how several variables are correlated with one another. Take, for instance, a shoe manufacturer's production and cost, where the former is plotted along the x-axis and the latter along the y-axis. Positive (increasing), negative (decreasing), or null correlations are all possible (uncorrelated).

When you look at a scatter plot, you'll see that the values of two variables are displayed side by side on the horizontal and vertical axes, respectively. A rise in one variable is correlated with an increase in the other, as seen by a general trend of dots heading up and to the right after plotting the varied values of the variables. If the trend is rightward and downward, then a rise in one variable will cause a fall in the other. The factors are unrelated if there is no discernible trend. There are hints for process improvement in the scatter diagram.

Fig 9.7 demonstrates these different relationships of variables as indicated by scattered diagrams:

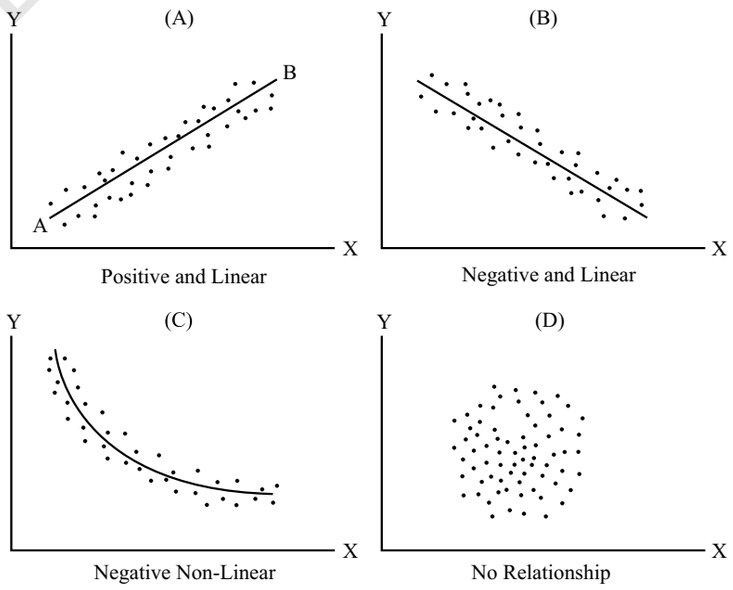

Fig. 9.7: Scatter Diagrams

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9.3.5 Pareto chart

It was the Italian economist Vilfredo Pareto who first proposed the Pareto chart. To better prioritise quality issues, a Pareto chart can be useful. It is commonly employed for the purpose of analysing data gathered from check sheets. The graphs in this chart are made up of lines and bars. In a bar graph, data are shown in decreasing order, whereas cumulative frequency is shown via a line graph. So, from left to right, the bars form a descending order in the chart. The values on the left are thus more important than those on the right, according to this interpretation.

A Pareto Chart is shown in Fig 9.8 as follows:

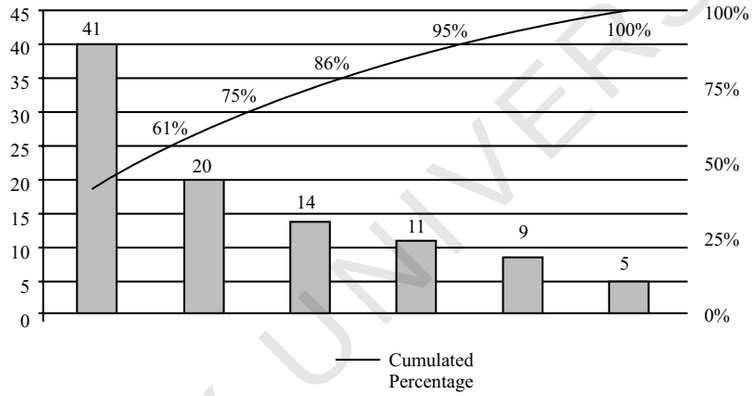

Fig. 9.8: Pareto Chart

The above chart is drawn on the basis of the following figures shown in Table 9.1 as follows:

Table 9.1: Reported Damages in Cars

Reported damages in Cars	Percentage of occurrence	Cumulative Percentage
Burning out of bulbs	41	41%
Battery discharge	20	61%
Blown fuse	14	75%
Damage in brake pads	11	86%
Flattening of tires	9	95%
Others	5	100%

The 80/20 rule, upon which a Pareto chart is built, states that just 20% of causes account for 80% of issues. To put it another way, according to the Pareto principle, just 20% of the causes of product defects or other quality concerns are responsible for 80% of the occurrences. In other words, the problems are weighted against the number of occurrences of flaws. Consequently, it helps in determining which factors are most influential on the system. A simple spreadsheet software can create a Pareto graphic. If you want to know what the biggest causes of product faults are, a Pareto chart can help. To put it simply, this chart simplifies a large problem by identifying its key components and drawing attention to the places that need it most in light of the defects. Not only that, but the graphic also shows how organisations can make the most efficient use of their limited resources. If companies didn't have access to Pareto charts, they would have to devote the same amount of time and resources to investigating every possible cause of product faults. There would be a lot of work and expense involved with this. Companies can then prioritise their efforts to address the most important causes.

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In addition to the product defects, Pareto principle recognises that:

- 80% of the customer complaints are related to 20% of the products or services.
- 80% of the production delays take place because of 20% of the possible reasons of delays.
- The causes that account for 80% of system problems are rather small. Thus, it is clear that Pareto charts can be applied to analyse various quality issues, such as product defects and system glitches in manufacturing and quality control. And services like banking, telecom, and travel use Pareto analysis to determine service quality and profitability.

9.3.6 Process flowchart

In 1921, Frank Gilbreth, a pioneer of motion study, introduced the concept of flowcharts. Gradually, flowcharts made a mark on various industrial and engineering projects. Quality guru Kaoru Ishikawa defined a flowchart as one of the key tools of quality control in addition to histograms, Pareto charts, check sheets, control charts, cause-and-effect diagrams, and scatter diagrams.

A flowchart is a graphical or symbolic representation of a process and the order of activities involved in the process, which are connected with arrows. It is a **snapshot of your business process**. The key purpose of using a flowchart is to analyse, design and manage a process.

Initially, flowcharts were confined to illustrating a solution to a given problem related to computers, software development, and programming. With the changing requirements of business practices and quality improvement processes, flowcharts entered into various fields such as engineering, Mathematics, IT, Computer Science, and Quality Management.

A flowchart helps to identify the current status of a process and how it can be improved. It identifies redundant steps in a process diagram. In quality management, you can use a flowchart to design your plan and strategy in the orderly manner. You can pinpoint the exact stages in a process that are causing problems. A flowchart summarises the responsibilities of each unit under every individual phase of a process.

Flowcharts also represent the composite business processes so that you can follow the process direction. They are also used in process documentation, training materials, workflow management, continuous improvement, troubleshooting guides, and programming.

Exhibit

Flowchart Shapes and Symbols

There are various symbols used in flowcharts, and each symbol is different in shape and represents different process of a flowchart. For example, the diamond symbol represents the decision phase, while the rectangle is used to indicate the process steps.

Some of the commonly used flowchart symbols are termed as terminator, process, and decision. Let's get acquainted with these symbols with the help of the following scenario:

As the project manager of a small organisation, you have initiated a plan. Accordingly, you have checked the availability and quality of the resources. Next, you start monitoring the production process (inputs into outputs). Having followed these steps, you are left with two options, and you have to select one.

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How will you represent the whole scenario using symbols and a flowchart? Consider the following Fig. as the answer:

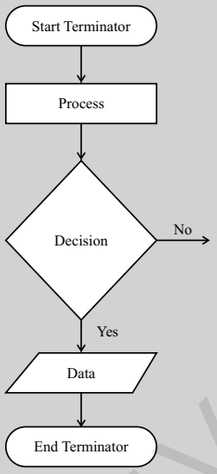

Fig.: Common Flowchart Symbols

Here, the **Start Terminator** (oval shape) indicates the initial phase of a project process where you have made the project plan. The next symbol used in the fig. is for a **process (**rectangular shape)**.** This signifies the production process where all inputs are converted to outputs. The **decision** (diamond shape) phase signifies the choice you made. In many cases, you may face a **Yes/No** situation while making a decision. If your answer is **No,** then the chart concludes here. If the answer is **Yes,** then you need to go for further analysis, report, and data input **(parallelogram).** The final symbol used in the flowchart is an **end terminator** (oval shape), which represents the end point of the flowchart.

The arrows used in the flowchart are meant for connectivity between each symbol and phase of the process. The following Fig. shows the various shapes used in flowcharts and the process they depict:

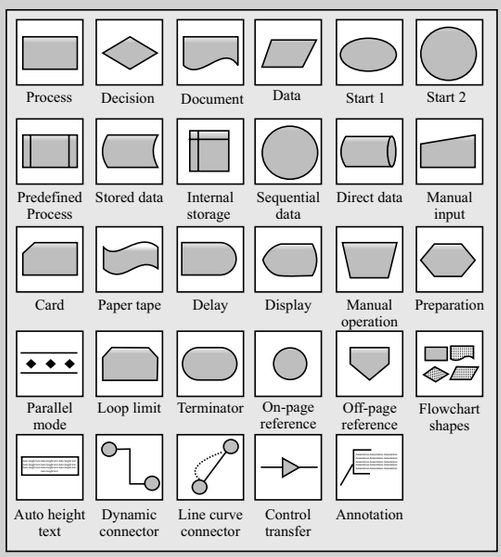

Fig.: Flowchart Shapes and Symbols

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9.3.7 Statistical process control chart

One of the most useful statistical tools for quality control is statistical process control, or SPC. Although it has its roots in manufacturing, the idea may be used to analyse, control, and enhance any type of repetitive process.

Statistical process control charts show the evolution of data by plotting points on a line over time. Walter Shewhart first suggested these diagrams in 1924. They show how the data has changed over time, how consistently it has occurred, or whether there are extreme outliers in the data. Looking at data variance is the main emphasis of monitoring performance over time. These graphs differentiate between variations with a common cause and those with a specific cause. The foundation of statistical process control for organisations is statistical process control charts.

Attribute control charts and variable control charts are the two main types of control charts. As an example, the quantity of items that do not meet the standards can be measured using a control chart for attributes. Variables like height, weight, temperature, pressure, and so on can be measured using control charts. The two most common kinds of control charts for variables are multivariate control charts and univariate control charts, which are based on the number of variables to be watched. While multivariate control charts take into account many variables, univariate control charts only take into account one variable's characteristic. You can use the univariate chart to show the average of different sets of operations or the values of individual observations. Nonetheless, a multivariate chart is employed in situations where the simultaneous monitoring of multiple variables or observations is required. This is due to the fact that it consolidates all process-related data into a single screen.

There are several varieties of control charts for variables, including univariate and multivariate control charts:

- **X-bar Chart:** Plotting the average value of the variables allows one to regulate the average of the variables in this form of control chart.
- **R Chart:** The sample ranges of the variables' values are presented in this form of control chart to limit the variable's range.
- **S Chart:** A control chart that plots the standard deviations of the variables to control their
- **S**2 chart:** To control the variability of the variables, this sort of control chart plots its variances.

The mean value of the process variable is depicted by the centre line of a control chart. Another pair of horizontal lines, the upper control limit (UCL) and the lower control limit (LCL), are also displayed on the graph. The three boundaries of a control chart—the centre line, the upper limit, and the lower limit—are illustrated in Figure 9.9:

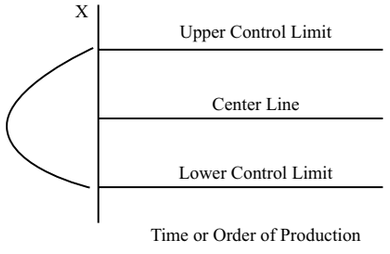

Fig. 9.9: Showing a Generic Control Chart

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In case if the data points fall inside these two limits, the process is considered to be in control. However, if the data points fall outside the control limits, the process is said to be out of control.

Let us now study how control chart helps in quality control. Suppose a production system can perform efficiently, only when it operates in a particular range of temperature, say within 20 degree Celsius to 55 degree Celsius. Product defects occur if the operating temperature falls below the lower limit of the range (20 degree C) or crosses the upper limit of the range. If the temperature remains within the range, the control chart would show that the system is in control. Fig. 9.10 shows the control chart of an 'in control' system:

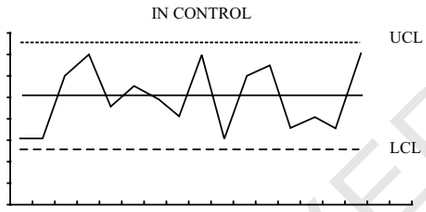

Fig. 9.10: Control Chart of an 'In Control' System

In case the system does not operate in the suitable temperature range, the control chart shows that the system is out of control. Fig. 9.11 shows the control chart of an 'out of control' system:

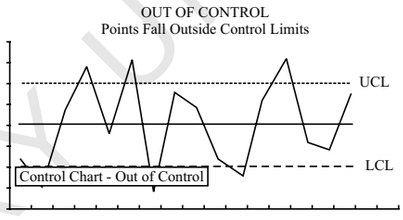

Fig. 9.11: Control Chart of an 'Out of Control' System

Out of control situations may follow a particular pattern. Therefore, the pattern (if any) needs to be detected to identify the special cause(s) of variations. An out of control system or process is allowed to run little longer to identify the pattern.

Self-Assessment Questions

6. The process quality control and improvement focuses on the _____.

7. _____ is a bar graph depicting the distribution of data.

8. How does cause and effect diagram work?

9. What are the main causes of quality issues in organisations?

10. The scatter diagram provides clues on how to improve the process. (True/False)

11. Describe the Pareto principle.

12. A _____ is a graphical or symbolic representation of a process and the order of activities involved in the process, which are connected with arrows.

13. _____ and _____ are two broad categories of control charts.

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14. _____ is a type of control chart in which sample ranges of the values of the variables are plotted in order to limit the range of the variable.

    a. R Chart

    b. X-bar Chart

    c. S Chart

    d. S**2 chart

15. A centre line of a control chart represents the _____under consideration in a process.

Activity

Meet the quality manager of a service provider company where quality control and improvement techniques are implemented and discuss with him/her about the applications of the quality control tools in the organisation.

9.4 Six Sigma and its Application

The Six Sigma methodology's development ranks high among quality management's most significant accomplishments. What exactly does Six Sigma imply? Six Sigma is a data-driven quality management methodology that places a priority on establishing and maintaining high quality standards, gathering and analysing data, and minimising product and service defects. Put another way, it is a strategy for making goods and services better and less prone to mistakes.

Motorola was the first to propose the Six Sigma methodology. During the early to mid-1980s, engineers from Motorola discovered that quantifying flaws at a level didn't give them enough information about quality issues. They settled on a failure rate per million opportunities metric. As part of the necessary culture shift, Motorola developed the new standard, built the quality measurement, and put it into action. Here we have a corporate philosophy and method that constantly and statistically checks the process. It is a quantitative approach that aims to optimise processes and reduce variation in the organisation. The overall process's performance is examined through the application of Six Sigma. After its implementation at Motorola was so fruitful, Six Sigma quickly gained traction as a popular approach to quality management. Consequently, Six Sigma has been adopted by numerous world-renowned companies, such as Honeywell, Allied Signal, and General Electric.

According to the **UK Department for Trade and Industry**, Six Sigma is *"A data-driven method for achieving near perfect quality. Six Sigma analysis can focus on any element of production or service, and has a strong emphasis on statistical analysis in design, manufacturing and customer-oriented activities."*

The Greek letter Sigma, denoted as 'σ' signifies the degree of variation from a particular set standard. For example, take an analysis of the variation in the radius of pipes in a pipe manufacturing plant. In order to achieve Six Sigma, an organisation cannot produce more than 3.4 defective products per 1 million products. The philosophy behind Six Sigma is that in order to eliminate product defects and achieve near-perfection in production, organisations need to measure the number of defects in the products and services. This ensures that there is minimal variation and products are defect-free. That is why Six Sigma is known as a data-based methodology.

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Now, the performance of any product or service has an acceptable average level and an acceptable level of variation. For example, in a restaurant customers may accept to be served within 15 minutes of placing the orders. In such a case, if the customer is served within 15 minutes, the customer would be satisfied. However, in case where the customer needs to wait, for say, 45 minutes, they would be dissatisfied and might think of never visiting the same restaurant again. Therefore, the restaurant needs to meet the expectations of the customers and do not cross the acceptable limit of the customers` expectations, i.e. the minimum variation level. In other words, the deviation of the actual service performance from the customers` expectations needs to be eliminated. Six Sigma helps in virtually eliminating this deviation.

The concept of Six Sigma originated from manufacturing with statistical modelling. Sigma rating is done on the basis of the yield of process producing percentage of defect free products. A Six Sigma process is a process which produces the 99.99966% of the products free of defects (3.4 defects per million).

Many Six Sigma methodologies have been developed all over the world based on different management philosophies and tools. The following features of Six Sigma are different from various quality control tools:

- Emphasis on attaining quantifiable results
- Focus on strong top management leadership
- Infrastructure inclusive of Champions, Master Black Belts etc. for Six Sigma implementation.
- Commitment for making decisions on the basis of statistical and verifiable data.

9.4.1 Benefits of Six Sigma

The main idea behind Six Sigma is to identify defects in the process and improve them. The following are some of the main benefits of Six Sigma:

- Producing defect-free products
- Reducing warranty and production costs
- Achieving better reputation in the market place
- Lowering down inspection costs
- Boosting employee morale
- Achieving higher customer satisfaction

9.4.2 Principles of Six Sigma

The ideas of Six Sigma originated from a statistical field called process capability. You can define process capability as the ability of a system to be able to produce the output according to the given specifications.

Six Sigma is based on the following principles:

- Thinking in terms of core business processes and customer requirements
- Focusing on corporate sponsors who are responsible for support team activities and

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obtain resources

- Emphasising on quantification i.e. DPMO defects per million opportunities
- Emphasising on extensive training by project team to improve profitability and reduce non value adding activities and cycle time reduction
- Creating highly qualified process improvement experts like green belt, black belt, master black belt who can apply improvement tools
- Setting up of stretch objectives for improvement

The fundamental areas of business which can be improved by using Six Sigma include:

- Improvement in organisational processes
- Improvement in products and services
- Improvement in investors relation
- Improvement in suppliers relation
- Improvement in designing methodologies
- Improvement in employee productivity and performance

9.4.3 DMAIC and DMADV framework-a Six Sigma methodology

DMAIC process is an improvement system for existing processes in an organisation which aims to enhance the quality standards and bringing down the defects in products. This mechanism represents five stages, which are shown in Fig. 9.12:

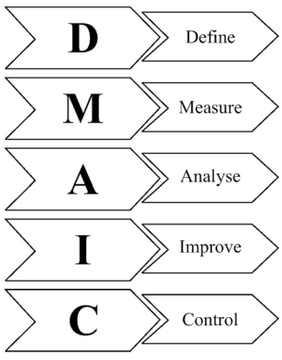

Fig. 9.12: DMAIC- Six Sigma Framework

- **Define:** This strategy involves defining the goals at different levels of the production process. These goals can be related to minimising defects in products, thereby increasing customer satisfaction. This stage involves the following activities:
  - Defining customers' requirements
  - Determining resources to meet those requirements
  - Developing a project plan

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- **Measure:** This strategy involves measuring the performance of the existing process of the organisation and setting the baseline performance. Some of the tools used at this stage are trend charts, Pareto charts, and process flowcharts.
- **Analyse:** This step helps in identifying the root cause of the defects and determining whether the process can be improved or redesigned. The different statistical tools used at this stage are hypothesis testing, regression analysis, and fishbone diagram.
- **Improve:** This strategy improves the process by eliminating defects. A process is improved by finding creative, faster, cheaper, and better ways. The statistical tools used at this stage are Design of Experiments (DOE) and Analysis of Variance (ANOVA).
- **Control:** This step involves controlling the performance of the improved process as well as the new ones. A process is monitored continuously to correct deviations on time. At this stage, SPC is used for monitoring processes.

The DMADV process is an improvement approach used to develop new or products or processes. It can also be implemented if current process requires breakthrough improvement. DMADV has the five phases, which are shown in Fig. 9.13:

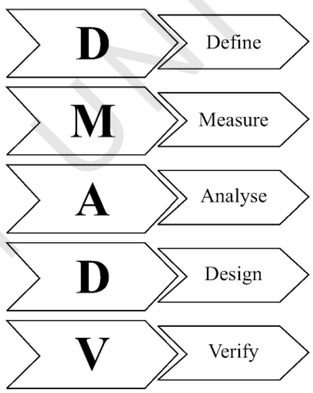

Fig. 9.13: DMADV- Six Sigma Framework

- **Define:** This step involves the formulation of goals and objectives that are consistent with customer needs and the corporate strategy of the organisation.
- **Measure:** This step identifies factors which are critical to quality like product capabilities, process capability, and risks analysis.
- **Analyse:** Processes are analysed to develop and design alternatives.
- **Design:** An alternative is designed by using any improvement strategy as per analysis done in the previous step.
- **Verify:** The design is verified by setting up pilot projects, or implementing the production process.

It should be noted that DMAIC methodology is mainly used to improve existing systems; whereas, the DMADV methodology is used while installing new systems or processes. General Electric (GE) achieved a number of breakthroughs by introducing DMADV and DMAIC methodologies in its existing and new systems and processes. Till 2000, GE saved more than 6.6 billion dollar by implementing Six Sigma.

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Self-Assessment Questions

16. In Six Sigma, the Greek letter Sigma, denoted as 'σ' signifies the degree of _____from a particular set standard.

17. In order to achieve Six Sigma, an organisation cannot produce more than 3.4 defective products per 1 million products. (True/False)

18. _____process is an improvement system for existing processes in an organisation which aims to enhance the quality standards and bringing down the defects in products.

19. The 'analyse' stage of DMADV model aims at _____.

9.5 Quality Circles

Several New Delhi-based vocational schools are under the umbrella of Vision Group of Institutes. A central library serving all of the group's institutes in the city was to be promoted by the company's administration. The personnel had the enormous burden of improving and competently organising the library. Also, because it was a brand-new library, there were a lot of operational issues that needed fixing, like lost volumes, books of different categories going missing, problems with purchases, and confusion over who was responsible for what. To solve these issues, the management organised a brainstorming session. Finally, the management created a group of five staff members to study and observe these issues for 2 weeks and identify the reasons behind the issues and to find permanent solutions. At the end of the two weeks period, the group submitted a report to the management detailing the reasons of the issues and their solutions. The suggestions of the group included classifying and locating books with the help of Radio-frequency Identification (RFID) technology, using software to regulate issuance, return/renewal of books, notifying arrivals of new books through SMS or email to the students and faculty members etc. The suggestions of the group were implemented and most of the issues were solved within a period of one month. In quality management, the group of library staff of Vision Groups is called as quality circle.

A quality circle by principle operates on the employee and management participation in making decisions and solving problems to improve the quality issue in an organisation. Quality circle is not just a technique or a solution for all the problems, or a decision making body. It is designed to identify the quality issues on a regular basis, conduct meetings, discuss issues and provide suggestions, and take concrete steps towards solving the issues. These also focus on optimum utilisation of available resources, for a smooth flow of the product in the supply and manufacturing chain keeping the customer satisfaction as the backdrop of all solutions and suggestions.

According to **Edwin B. Flippo, (1984)** quality circle refers to a *"self-governing group of workers with or without their supervisors who voluntarily meet regularly to identify, analyse and solve problems of their work field"*. These workers meet at certain intervals in order to discuss the problems of quality and find out solutions for improvement. Quality circles are usually small and autonomous in nature and led by a supervisor or facilitator. This facilitator is responsible for bringing cohesiveness in the group.

The concept of quality circle was developed by the Union of Japanese Scientists and Engineers. In India, however, he concept of *'***Gun Mandal***' (*meaning quality circle) was there for ages

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to promote the '**Satvic Qualities**', such as urge for excellence and knowledge mutual trusts and confidence, and self-actualisation. The concept of quality circle emphasises on this notion of problem solving through participation of different individuals in a group. Hundreds of Indian organisations, such as TVS, Maruti have adopted the concept of quality circles.

9.5.1 Objectives of quality circles

The main objectives of quality circle is to identify quality issues, find out the root causes of the issues and solve the issues to improve overall quality in an organisation. For example, the objective of Quality circles in **BHEL** is to *"achieve and sustain a reputation for quality at competitive prices in national and international market for the entire product range."*

Let us study the main objectives of quality circles in the following points:

- Developing problem solving skills, leadership skills, and supervisory skills among the employees
- Utilising the human resources effectively and efficiently
- Improving the quality of products, services
- Reducing the cost of production
- Utilising the imaginative, creative and innovative skills of the employees through participation, cooperation and mutual trusts
- Encouraging teamwork in the organisation
- Boosting employee motivation
- Developing cordial relationship between managers and employees
- Improving the flow of communication within an organisation
- Reducing absenteeism and grievances

9.5.2 Structure of quality circles

A quality circle is composed of the following elements, as shown in Fig. 9.14:

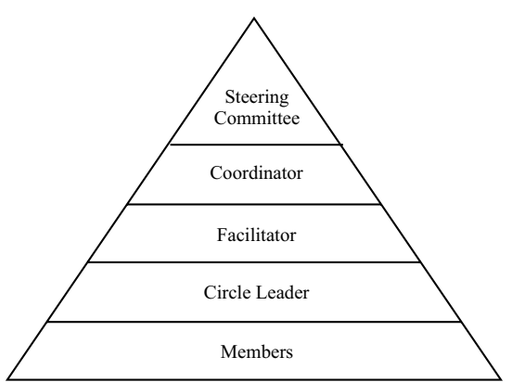

Fig. 9.14: Showing the Composition of Quality Circles

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Let us study about the elements of quality circles in more detail:

- **Steering Committee:** It consists of representatives of the top management, representatives of human resource department and representatives of workers in an organisation. The steering committee forms the quality circles consisting members from various departments and takes their suggestions.
- **Coordinator:** Generally, the coordinator in the steering committee belongs to the middle level management. The coordinators keep coordination between the facilitators and the steering committee.
- **Facilitator:** It is the supervisory officer who manages a number of quality circles. Generally, the facilitator belongs to the quality control or production department.
- **Circle Leader:** He/she is responsible for organising and conducting circle activities and is generally from the lowest level of supervisors. The circle leader ensures periodic meeting and discussion on quality issues. He/she also reports to the facilitator regarding the quality issues and suggestions.
- **Circle Members:** These are workers in a quality circle who give their suggestions and ideas and actively participate in improving quality. It is the responsibility of each circle member to involve themselves in quality improvement. The circle members approach to the circle leader in case of issues and grievances.

Self-Assessment Questions

20. The concept of _____ emphasises on this notion of problem solving through participation of different individuals in a group.

21. _____ is responsible for organising and conducting circle activities and is generally from the lowest level of supervisors.

a. Facilitator

b. Coordinator

c. Circle leader

d. Circle members

9.6 Summary

- Quality control is a process of examining specific outputs against the desired standards.
- Quality control is significant because it not only improves the standards of quality, but also increases productivity.
- Quality control undertakes three main functions, which includes acceptance, preventive, and assurance function.
- A number of steps, involved in the process of quality control are:
  - Controlling engineering quality
  - Controlling purchased material quality
  - Controlling manufacturing quality
  - Taking actions that support after the manufacturing of products

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- The scope of quality control is to:
  - Prepare quality standards and specifications
  - Exercise control over inputs and during manufacturing
  - Perform inspection before delivery of products to customers
  - Take deterrent actions at the right time on the product and process
  - Establish the cause of rejections by periodical analysis of inspection reports
- Check sheet is an important quality control tool that is used for data collection in an organisation. In other words, check sheets are easy-to-understand and customised tools which facilitate in collecting data to resolve quality issues.
- Histogram is basically used to present data in a graphical manner.
- Cause and effect diagram is one such technique which helps in identifying the quality issues in an organisation.
- Scatter diagram shows if there is any relationship between two variables or not. In other words, a scatter diagram indicates correlations between variables.
- A Pareto chart is a tool that helps in prioritising quality issues. It is often used to analyse the data collected using check sheets.
- Process flow chart refers to the graphical representation of processes which is complementary to other process related diagrams. These diagrams represent processes of various steps with arrows and boxes.
- Statistical Process Control (SPC) is an important statistical quality control tool, applicable for analysing, controlling, and improving any kind of repeatable process.
- In statistical process control charts, data points are plotted on a line over time to provide a picture of data movement.
- Six Sigma is a data driven approach to quality management philosophy that emphasises on setting high quality benchmarks, collecting and analysing information and reducing defects in products and services.
- DMAIC process is expanded as define, measure, analyse, improve and control is an improvement approach for current processes not meeting the customer specification and looking for small incremental improvement.
- The DMADV process which is expanded as define, measure, analyse, design and verify is an improvement approach used to develop new or products or processes.
- A quality circle is designed to identify the quality issues on a regular basis, conduct meetings, discuss issues and provide suggestions, and take concrete steps towards solving the issues.

9.7 Glossary

- **Statistical Process Control (SPC):** A method used for ensuring the quality of a product during the transformation process.
- **Six Sigma:** A quality initiative that involves going from approximately 35,000 defects per million, which is average for most companies, to less than four defects per million in every single process of a company.

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- **Control Limits:** These are certain limits established inside the specification limits, in order to ensure that these limits are never exceeded.
- **Quality Circles:** A group of individuals who voluntarily take part in giving ideas for quality control.
- **Statistics:** The discipline of collection, organisation, analysis, interpretation, and presentation of data.

9.8 Terminal Questions

1. What do you mean by quality control? Explain the significance of quality control.
2. Elaborate on check sheets.
3. What do you mean by Pareto Chart?
4. Explain the uses of cause and effect diagrams in quality control.
5. Explain the applications of flow chart in quality control.
6. Discuss the concept of DMAIC and DMADV framework as a Six Sigma methodology.
7. Write a short note on the structure of quality circles.

9.9 Answers

Q.	Self Assessment Questions
1.	Quality control can be defined as a process of reviewing the quality of all factors involved in production.
2.	b. To maintain an optimum level of quality at maximum cost
3.	c. Preventive function
4.	False
5.	d. Controlling engineering quality
6.	Process capability
7.	Histogram
8.	Cause and effect diagram is a technique that explores all potential or real causes of quality issues and arranges them in a hierarchical diagram according to the relative importance of the causes.
9.	People, Methods, Machine, Material, Measurement, and Environment are the main causes of quality issues in organisations.
10.	True
11.	The Pareto principle suggests that 80% of the product defects or other quality issues arise because of 20% reasons.
12.	Flowchart
13.	Control charts for attributes and control charts for variables
14.	a. R Chart

Notes

15.	Mean value of the variable
16.	Variation
17.	True
18.	DMAIC
19.	Analysing processes to develop and design alternatives
20.	Quality circle
21	c. Circle leader
Q.	**Terminal Questions**
1.	Quality control refers to a process of maintaining a predefined level of quality of products or services. Quality control helps in reducing the number of defective products by establishing a standard for evaluating the quality of products at each level of production. Refer to section **9.2 Concept of Quality Control**.
2.	Check sheets are easy-to-understand and customised tools which facilitate in collecting data to resolve quality issues. Refer to section **9.3 Tools and Techniques for Quality Improvement**.
3.	A Pareto chart is a tool that helps in prioritising quality issues. It is often used to analyse the data collected using check sheets. Refer to section **9.3 Tools and Techniques for Quality Improvement**.
4.	Cause and effect diagram is a technique that helps in identifying the quality issues in an organisation. Refer to section **9.3 Tools and Techniques for Quality Improvement**.
5.	Flow chart refers to the graphical representation of processes which is complementary to other process related diagrams. Refer to section **9.3 Tools and Techniques for Quality Improvement**.
6.	As a Six Sigma methodology DMAIC is mainly used to improve existing systems; whereas, the DMADV methodology is used while installing new systems or processes. Refer to section **9.4 Concept of Six Sigma and its Application**.
7.	The elements of quality circles include steering committee, coordinator, facilitator, circle leader, and circle members. Refer to section **9.5 Quality Circles**.

9.10 Case Study: Pyro Systems Services Ltd.

The improvement team at Pyro Systems Services Ltd. was working in a particular area, which was creating a problem. Whenever service engineers were called out to perform emergency servicing for a customer, they took the spares and equipment along with them, which they thought would be necessary to repair the system. Engineers could never guess what was likely to be needed and took a range of spares and equipment, which would cover most eventualities. However, very often, the engineers would find that they needed a spare or piece of equipment, which they had not brought with them, and therefore, they would have to return to the depot in order to collect the required equipment. To aggravate the situation, sometimes the required spare part would not be in stock, and so the customer would have to wait until it was brought

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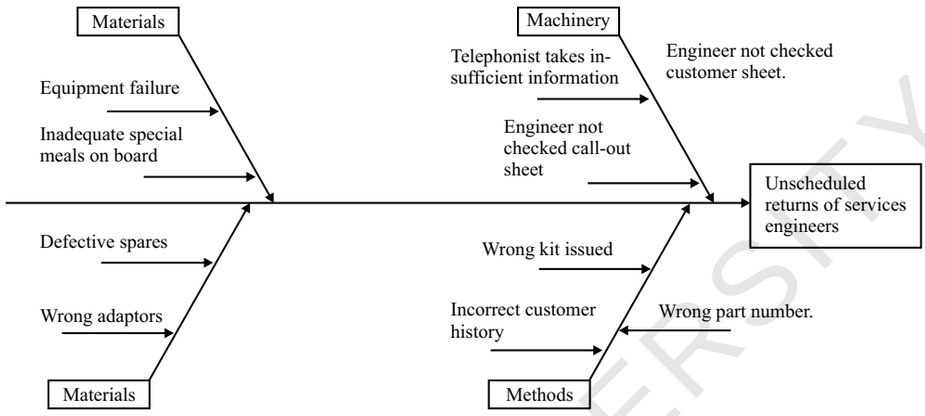
from another part of the country. The cause-and-effect diagram for this particular problem, as drawn by the team, is shown below:



Cause-and-Effect Diagram

Discussion Questions

1. Critically analyse the causes and their effects as given in the above diagram.

   (**Hint**: The causes like equipment failure, defective spares, wrong adaptors, telephonist takes insufficient information, etc. finally led to a dissatisfied customer, which directly affects the profit of the organisation.)

2. Can you suggest any other plan to analyse the problem?

   (**Hint:** Process diagram can be used to determine the problems of Pyro Systems Services Ltd. at every stage of servicing the customers.)

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CHAPTER

10 Productivity Improvement Techniques

Structure

Notes

Learning Objectives

After completing this chapter, you will be able to:

- explain the concept of productivity
- discuss the concept of work study and job analysis
- explain the concept of method study.
- discuss the concept of work measurement
- establish relationship among time study, motion study, and work study

10.1 Introduction

In the last chapter, you learned about the concept of quality control and tools for improvement in quality. In this chapter, you will study the tools for improving the productivity of an organisation.

Productivity is a measure of the rate at which an output is produced per unit of input. It depends on many factors, such as availability of resources, change in business cycles, and government policies. Different industries measure productivity differently. For example, in the manufacturing sector, productivity is measured on the basis of number of hours taken by labour and power consumed by machines to produce the desired output. On the other hand, in the service sector, it is measured based on the total revenue generated by employees. Higher productivity leads to lower costs, improved competitiveness and high profits . Therefore, an organisation uses various methods to improve its productivity. Job analysis and work study are the two most commonly used methods for improving productivityin an organisation.

Productive employees not only provide more value to employers from their services but also provide better business results in terms of new product development, customer service and innovation. For increasing the productivity of the employees, job analysis is used which is a systematic study of the responsibilities, work activities, and tasks associated with a particular job. The main aim of job analysis is to allocate the right job to the right people, thereby improving the productivity of an organisation. To perform job analysis efficiently, an organisation needs to collect accurate data related to a particular job. This data can be accumulated by using various techniques such as interview method and questionnaire method. On the other hand, work study refers to a systematic approach to determine the best possible way to perform a job, which, in turn, helps an organisation in achieving a higher level of productivity.

The chapter begins by explaining the concept of productivity and various factors affecting it. After that, it discusses the two important methods for improving productivity, namely job analysis and work study. Job analysis encompasses a number of activities such as job description, job specification. On the other hand, work study includes method study, motion study, and work measurement. Toward the end, the chapter explains the relationship among time study, motion study and work study.

10.2 Concept of Productivity

Productivity is all about measuring how efficiently inputs are used to produce the desired output. According to **European Productivity Agency (EPG)**, *"Productivity is an attitude of mind. It is the mentality of progress, of the constant improvements of that which exists. It is the certainty of being able to do better today than yesterday and continuously. It is the continuous adaptation of economic and social life to changing conditions. It is the continual effort to apply new techniques and methods. It is the faith in progress."*

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So, basically, productivity is the ratio of output to input. It can be expressed mathematically as follows:

Productivity = Amount of Output/Amount of Input

In terms of productivity, output can be the total quantity produced. On the other hand, input can be total labour and machine hours, the amount of money spent, and the amount of raw materials consumed for producing the desired output. Therefore, in case of different inputs, productivity can be expressed as follows:

- **Labour Productivity** = Number of units of output/ Number of people employed in production

  Or

  Number of units of output/ Number of man hours

  Or

  Output at standard price/Total amount of wages paid for output
- **Capital Productivity** = Value added/Capital employed

  Or

  Total sales (in Rs.)/Depreciation of capital assets
- **Material Productivity** = Standard material usage/Actual material usage
- **Total Factors Productivity (TFP)** = Output at standard price/ (Labour + materials + overhead + capital invested)

According to **European Productivity Agency**, *"Productivity is an attitude of mind. It is a mentality of progress, the constant improvement of that which exists. It is the certainty of being able to do better today than yesterday and continuously. It is the constant adaption of economic and social life to changing conditions. It is the continual effort to apply new techniques and new methods; it is the faith in human progress."*

The concept of productivity can be further understood with the help of following Productivity Conceptual Model, shown in Fig. 10.1:

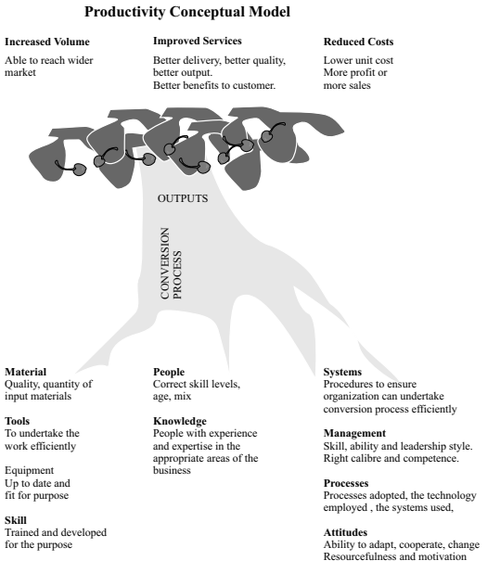

Fig. 10.1 Productivity Conceptual Model

Source: *http://www.accel-team.com/productivity/productivity_01_what.html*

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The roots in the model represent the inputs, the trunk is the conversion process and fruits are the outputs.

10.2.1 Factors affecting productivity

Productivity depends on a number of factors. These factors can be broadly classified into two categories, namely internal factors and external factors, which are explained as follows:

- **Internal factors:** These are the factors that can be controlled by an organisation. They are as follows:
  - Type of product produced
  - Effectiveness of manufacturing plant and equipment
  - Type of technology used
  - Amount of raw materials
  - Efficiency of human resource
  - Work methods used
  - Style of management followed in the organisation
- **External factors:** These refer to uncontrollable factors, which are as follows:
  - Economic factors, such as shift in employment and industrial competitiveness
  - Availability of natural resources such as land and raw materials
  - Government policies such as fiscal policies and five year plans

10.2.2 Ways to improve productivity

Organisations can learn a lot about their long-term success and where they might make improvements by tracking their productivity. This is in addition to the following ways in which it benefits a company:

- Increasing the reserve funds that can be used for expansion and modernisation
- Reducing overheads and various other costs per unit of output
- Improving the quality of products
- Increasing the competitive strength of the organisation
- Maintaining a fair compensation system

So, it's crucial for a company to boost productivity periodically. In general, businesses aim to increase their productivity by boosting output with the same or fewer inputs, or by decreasing inputs without sacrificing output quality or quantity. Fig. 10.2 shows the two most prevalent strategies it uses to accomplish this:

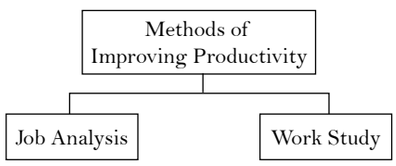

Fig. 10.2: Methods for Improving Productivity

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Activity

An organisation produces 1000 steel glasses and uses 200 square meters of steel sheet and 200 hours of labor. Calculate productivity if the glasses are sold for Rs. 100 each, the cost of steel sheet is Rs. 100 per square meter, and labor cost is Rs. 10 per hour.

Hint:

Inputs

200 square meters of steel sheet at Rs. 100 per square meter = Rs. 20, 000

200 hours of labor at Rs. 10 per hour = Rs. 2, 000

Output

1000 glasses are being sold Rs. 100 each = Rs. 1, 00, 000

Productivity = 100000/22000 =4.5

Self-Assessment Questions

1. _____ is all about measuring how efficiently inputs are used to produce the desired output.
2. External factors are controllable factors. (True/False)
3. Which of the following is not an internal factor that affects productivity?
   a. Type of product produced
   b. Type of technology used
   c. Amount of raw materials
   d. Availability of natural resources, such as land and raw materials

10.3 Concept of Job Analysis

The term "job analysis" refers to a methodical approach to gathering, assessing, and studying the tasks and obligations inherent in a certain position. Selection and recruitment, training and development, and performance evaluation are just a few of the human resources tasks that could benefit from its usage. Here are a few ways that famous authors have described job analysis:

According to **Michael J. Jucius,** *"Job Analysis refers to the process of studying the operations, duties and organisational aspects of jobs in order to derive specifications or as they are called by some, job descriptions."*

According to **Edwin B. Flippo**, *"Job Analysis is the process of studying and collecting information relating to the operations and responsibilities of a specific job."*

Fig. 10.3 shows the different methods and sources of data used to perform job analysis as well as the people responsible to conduct it:

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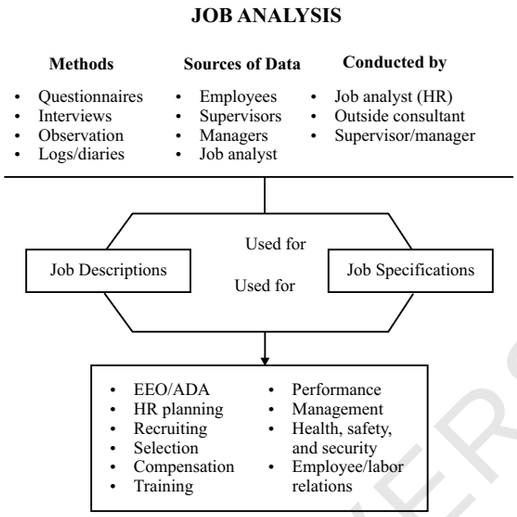

Fig. 10.3 : The Job Analysis Process

Fig. 10.3 shows the job analysis process where end-products of job analysis are job description and job specification. It also represents the fields where job analysis can be applied such as recruitment, selection, HRP, compensation, training, performance management, employee welfare management, industrial relations and Equal Employment Opportunity (EEO).

Job analysis is an important source of information for HRP and Human Resource Development (HRD). It provides information on the following aspects:

- **Skills required:** These refer to the information on skills, educational qualifications, experience, expertise, and training required to perform a particular job in the organisation. It helps the human resource department of the organisation to determine the skills and competencies required to perform a job and recruit the right candidates accordingly.
- **Structure and design of job:** This helps a jobholder to properly understand the responsibilities associated with the job, and enhance his/her performance. The job analysis process helps the organisation to design the job.
- **Human resource requirements and employees' career graph:** These help in conducting various HR activities such as external recruitment. Job analysis identifies and recognises the skills required to perform various jobs in future, which, in turn, helps the employees to realise career opportunities available in the organisation in future. In addition, it helps the organisation to select the sources of employment, namely, internal or external.
- **Information on selecting suitable employees:** This information helps to dentify the skills required to perform a particular job. Consequently, it becomes easy for the organisation to select appropriate employees for different tasks.
- **Established performance standards:** These standards indicate the specific standards that are used to measure the performance of employees. Job analysis defines the activities required to perform a particular job and accomplish organisational objectives.

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10.3.1 Process of job analysis

Human resource tasks like training and development, remuneration, health and safety, placement and induction, career and succession planning, and recruitment can all benefit from job analyses. Job analysts, outside consultants, and HR managers are the typical participants in a job analysis. The job analysis method is illustrated in Fig. 10.4:

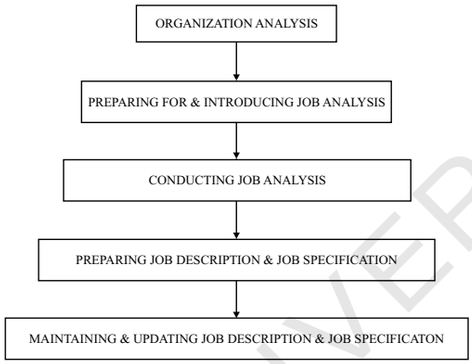

Fig. 10.4 : Job Analysis Process

The steps involved in the job analysis process (as shown in Fig. 10.4) are discussed as follows:

1. **Organisational analysis:** Keeping competent workers on staff and compiling a list of open positions inside the company are the primary goals of this component. Planning and organising the materials for the job analysis are the two primary steps. Assisting the company's upper management in determining the goals of job analysis is the purpose of this stage.

2. **Preparing job analysis:** Recognising representative roles and the reasoning for selection, reviewing current employment documents, and informing managers or employees of the approach are the three primary tasks involved. The first thing to do is conduct need research, where the organization's HR department or the job analyst determines which positions require evaluation. These tasks are chosen according to their importance, taking into account both the time and money constraints. Additionally, the HR analyst refers to the job description, specification, procedure manuals, and system flow diagrams to gather data regarding the present work design.

3. **Conducting job analysis:** There are two parts to this process: gathering data from job analyses and evaluating and compiling it. The collected data describes the profession's requirements, including the skills and qualifications needed to do the work properly. In addition, other criteria, including correctness, dependability, and relevance, are used to evaluate the gathered data. The onus is on the job analyst to verify that the data collection method is appropriate and dependable.

4. **Preparing job description and job specification:** Creating an outline of the job description and work specification, reviewing it with input from managers and employees, and finally, finalising the document with any relevant ideas are the three parts that make up this stage. A job description and set of requirements are developed using the data collected in the third stage. Everything that is involved in doing the work, from daily tasks to specific assignments, is detailed in the job description. Job specifications, on the other hand, outline what an ideal candidate for the position should be able to do.

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5. **Maintaining and Updating Job Description and Job Specification:** This phase entails keeping the job description and job specifications up-to-date and making any necessary adjustments to reflect the ways in which the organisation does business. If all the occupations are reviewed on a regular basis, we can prevent the differences between job specifications and descriptions.

Note

Job description is an organised factual statement that defines the type of the job to be performed, the way to perform it, and the individual responsible to perform the job.

Job specification or employee specification is a statement that summarises the main purpose of a particular job, as well as the experience, aptitude, educational qualifications, and skills required to perform it.

Self-Assessment Questions

4. _____ is a systematic process of collecting, evaluating, and examining the duties and responsibilities required to perform a job.
5. What are the end products of job analysis?
6. Job analysis is an important source of information for _____.
   a. Finance
   b. Marketing
   c. Human Resource Planning and Development
   d. Recruitment

10.4 Work Study

Work study is another important method for improving the productivity of an organisation. It involves finding out the better ways to perform different jobs. The main objective of work study is to make optimum utilisation of labour and materials by determining efficient work methods. Work study includes method study, motion study, and work measurement , discussed in next sections.

The following are some of the popular definitions of work study:

According to **Dr. Taylor**, work study is *"The greatest production results when each worker is given a definite task to be performed in a definite time in a definite manner."*

According to **British Standard Institution (BSI)**, *"Work study is a generic term for those techniques, particularly method study and work measurement, which are used in examination of human work in all its contents and which lead systematically to the investigation of all factors which affect the efficiency and economy of this situation being removed in order to effect improvement."*

According to **Russel Currie**, *"Work study is the systematic, objective, and critical examination of all the factors that govern the operational efficiency of any specified activity in order to effect improvement."*

According to **International Labour Organisation (ILO)**, *"Work study is a term used to embrace the techniques of method study and work measurement, which are employed to ensure the best possible use of human and material resources in carrying out a specific activity."*

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10.4.1 Objectives of work study

As discussed earlier, the main objective of applying work study in an organisation is to make optimum utilisation of labour and available resources. Apart from this, the following are some other objectives of work study:

- Analysing the existing work methods of the organisation
- Determining the standard time to perform a particular job
- Increasing the productivity of the organisation
- Achieving the desired quality at minimum cost of production
- Improving operational efficiency of the organisation

10.4.2 Process of work study

Work study is a systematic approach to increase the productivity of an organisation. It involves eight steps, which are as follows:

1. Selecting a job to be studied
2. Recording information related to the selected job using various charting techniques, such as operation process chart, flow process chart, and Simultaneous Motion (SIMO) chart
3. Analysing the recorded facts and determining the purpose, place, sequence, and existing methods for performing the job
4. Making a plan to develop a new method for performing the job
5. Measuring the work content to set a standard time for performing the job. Work content refers to responsibilities and duties involved in a job. To measure the work content, an organisation uses various techniques, such as time study, synthesis method, analytical estimating, and work sampling
6. Designing the new method for performing the job
7. Implementing the method in the organisation
8. Setting the new method as a standard method for performing the job

10.4.3 Benefits of work study

The following are the benefits of work study:

- Increases the production efficiency of an organisation
- Maintains a uniform production flow
- Reduces the manufacturing cost of the organisation
- Improves the employee-employer relationship by establishing standard methods for performing different jobs
- Increases job satisfaction among employees
- Provides better working conditions to employees
- Measures labour efficiency

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Self-Assessment Questions

7. Which of the following is not an objective of work study?
   a. Analysing the existing work methods of an organisation
   b. Determining the standard time to perform a particular job
   c. Increasing the productivity of the organisation
   d. Selecting the technology for production
8. The main objective of work study is to make optimum utilisation of labour and materials by determining efficient work methods. (True/False)

10.5 Method Study

Method study involves analysing different methods for performing a job and selecting the best one. The main objective of method study is to determine the best method for performing a job. Some of the popular definitions of method study are as follows:

According to **BSI**, *"Method study is the systematic recording and critical examination or existing and proposed ways of doing work as a means or developing and applying easier and more effective methods and reducing cost."*

According to **International Statistical Institute (ISI),** *"Method study is the systematic analysis and design of work methods and systems through the application of innovatory techniques to achieve improved utilisation of resources."*

Method study involves the study of work processes and working conditions. An organisation generally performs method study if it faces the following problems:

- High operating costs
- High wastage and scrap
- Extreme movement of materials and labour
- Extreme production blockages
- Extreme rejections and rework
- Complaints related to quality of products by customers
- Complaints related to poor working conditions
- Excessive overtime

The concept of method study is a development of Gilbreth's Technique of Motion Study. According to **Frank Gilbreth** method study is "the science of eliminating wastefulness resulting from ill-directed and inefficient motions". The main objective of the method study is to evolve the most economical method of doing a job and eliminate all wastages. Method study is also known as work simplification. It is based on a notion that *'there is always a better way of doing a job'.*

Method study is also known as methods engineering. According to the **Industrial Engineering Handbook**, *"The technique that subjects each operation of a given piece of work to close analysis to eliminate every unnecessary element or operation and to approach the quickest and best method of performing each necessary element or operation. It includes the improvement and standardization of methods, equipment, and working conditions: operator training; the determination of standard time; and occasionally devising and administering various incentive plans."*

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10.5.1 Objectives of method study

The following are the objectives of Method Study:

- Analysing the existing method for performing a job
- Formulating a new method to perform the job, thereby increasing productivity and reducing production cost
- Reducing excessive movement of materials
- Making effective utilisation of resources
- Eliminating unnecessary operations
- Standardising work methods and processes

10.5.2 Advantages of method study

The advantages of method study are as follows:

- Helps in simplifying different jobs
- Determines the best possible way to perform a job
- Provides better working conditions
- Reduces the cost of material handling
- Improves the workflow
- Helps in making optimum utilisation of available resources
- Ensures the safety of employees
- Reduces production cycle time
- Reduces wastage and material consumption
- Reduces the cost of production

10.5.3 Process of method study

The procedure of the method study involves the following steps:

- **Step 1:** The first step is to Select the work to be studied and define the objectives to be achieved. For example, an objective may be to reduce the manufacturing cost. There are a number of factors involved in selecting a job, which are:
  - Economical aspect
  - Technical considerations
  - Human reactions
- **Step 2:** Next step is to collect and **Record** all the relevant data about the existing method in details. To avoid the difficulties involved in reading and visualising the complex data, information is recorded in the graphical form taking the shape of charts, diagrams, motion and film analysis, andmodels.
- **Step 3:**The next step is to **Examine** all the recorded events critically and in sequenced manner. Critical examination requires a well-designed questioning pattern in an impartial and objective manner.

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The likely questions to be asked are:

- Purpose – What is achieved?
- Person – Who achieves it?
- Place/Location – Where it is achieved?
- Means – How is it achieved?
- Sequence/Frequency – When is it achieved?

An activity can be eliminated, simplified or combined with another on the basis of these questions.

- **Step 4:** Depending upon the alternatives generated for each question, next step is to **Develop** the best method and record it. The developed method should be practical, safe, effective and economical. Some commonly used approaches to develop methods are:
  - Eliminate unnecessary activities
  - Combine two or more activities
  - Re-sequence activities so as to reduce time and effort
  - Simplify process to reduce number of operations or effort
  - Removeconstraints which are preventing the method to perform better
- **Step 5:** Next step is to **Install** the best developed method as a standard practice. Installing involves:
  - Planning and arranging implies making necessary arrangements of resources, equipment, tools and instruction to workers
  - Implementing the method as standard practice
- **Step 6:** Last step is to **Maintain** the new method by regular routine checks. This step involves:
  - Ensuring proper functioning of the installed method
  - Checking for any deviations and finding the reasons for deviations

Self-Assessment Questions

9. _____involves the study of work processes and working conditions.

10. When an organisation generally performs method study. Give any two reasons.

10.6 Motion Study

Motion study is a technique that involves analysing the body movements of a worker while performing a job. This analysis helps in eliminating ineffective movements that do not add value to the job, thereby reducing the time taken for performing the job. The process of motion study involves the following steps:

1. Examining the existing method for performing a job
2. Conducting a deep analysis of every motion required to perform the job
3. Recording the collected information

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4. Developing an improved method for performing the job
5. Documenting the new method
6. Implementing the new method
7. Verifying the new method

Motion study helps an organisation in simplifying and standardising work methods by following a systematic approach. This approach makes work easier and effective. However, the implementation of motion study would be successful only if its principles are followed properly. Let us discuss the principles of motion study in detail in the next section.

Motion study is the systematic analysis of the human motions used to perform an operation. Objective of motion study is to:

- eliminate unnecessary motions
- identify the best sequence of motions for maximum efficiency
- job simplification

10.6.1 Principles of motion study

The principles of motion study were given by Frank Gilbreth, the father of motion study. These principles are studied under three headings, namely principle for the use of human body, principle for the arrangement of workplace, and principle for the design of tools and equipment. These principles are discussed as follows:

- Principle for the use of human body involves the following:
- Ensuring that the two limbs start their movement and complete it at the same time
- Ensuring that the two limbs are not idle at same time except for the rest period
- Making sure that the movement of limbs should take place simultaneously but in opposite directions
- Ensuring that a smooth and continuous motion is preferred over a straight line motion
- Ensuring that the movements of limbs are ballistic in nature as they are fast, easy, and accurate as compared to restricted movements
- Arranging tasks in a manner that it can permit easy and natural movements whenever required
- Ensuring that eye fixation is as close as possible

Principle for the arrangement of workplace: Involves the following:

- Keeping the tools and materials at a definite place near to their use
- Using gravity feed bins and containers for the transportation of materials near to the point of their use
- Using drop deliveries whenever required
- Locating the tools and materials effectively for ensuring the best sequence of motions
- Ensuring adequate conditions for seeing
- Placing the furniture as per the height of workplace
- Ensuring that the furniture (chairs) used by the worker is comfortable

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Principle for the design of tools and equipment: Involves the following:

- Using appropriate tools and devices, such as fixtures, jigs, and foot-operators, for performing a particular job.
- Combining the tools wherever required.
- Ensuring that the tools and materials are pre-positioned to the place of their use.
- Dividing the workload among different fingers. For example, during typewriting, each finger performs some specific movement.
- Locating levers, cross bars, and hand wheels in such a manner so that operators need not put extra efforts in moving them

10.6.2 Micro-motion Study

In certain operations, the production cycle is very short and involves rapid movements of men and materials. The activities involved in such operations cannot be recorded using direct observation as they are performed with greater speed. In such a case, it is difficult to identify unnecessary movements in these operations and develop the best method for performing them. Therefore, film and video cameras are used for recording the activities involved in such operations. The study of these operations is known as micro-motion study. The objectives of micro-motion study are as follows:

- Analyse the interrelationship among different work group members
- Study the relationship between an operator and a machine
- Record the time involved in completing an operation
- Study the method used for performing a job

Micro-motion techniques are based on the idea of segmenting human activities into divisions of movements or groups of movements. These divisions of movements are also called therbligs, which are given by Frank O. Gilbreth. These therbligs are shown in Table 10.1 :

Table 10.1: Therbligs and their Description

S. No.	Name of Therblig	Symbol	Color	Description
1.	Search	SH	Black	Finding an object.
2.	Find	F	Gray	Indicating the mental reaction at the end of search
3.	Select	ST	Light Gray	Picking one object from a group of objects
4.	Grasp	G	Red	Holding the object
5.	Hold	H	Gold Ochre	Retaining the object after grasping it
6.	Transported Load	TL	Green	Shifting an object from one place to another
7.	Position	P	Blue	Placing the object properly so that it can perform the work effectively

NOTES

Table 10.1: Therbligs and their Description				
S. No.	Name of Therblig	Symbol	Color	Description
8.	Assemble	A	Violet	Keeping one object with the other so that it can become the integral part of the later object
9.	Use	U	Purple	Moving the tool or equipment for performing an activity
10.	Disassemble	DA	Light Violet	Segregating one object from the other
11.	Inspect	I	Burnt Ochre	Analysing the object with respect to standard size, shape, and color
12.	Preposition	PP	Pale Blue	Placing the object in a predetermined place where it needs to perform a function
13.	Release Load	RL	Carmine Red	Letting go the object from the operator's hand
14.	Transport Empty	TE	Olive Green	Moving the empty hand to reach an object
15.	Rest	R	Orange	Providing a pause to the operator to overcome fatigue
16.	Unavoidable Delay	UD	Yellow	Signifying the delay that cannot be controlled by an operator
17.	Plan	PN	-------	Determining the way to perform the job

10.6.3 Memo-motion study

In 1946, M.E. Mundel delivered a lecture at Purdue University on memory and movement. He claims that the study of memo-motion is a subset of micro-motion. Using motion image cameras, memo-motion studies document the slow-motion movement of both people and items. Videos of such events are also known as motion pictures. Analysis of the industrial process, material handling, and human-machine interaction can be aided by these images. Memo-motion study enables to obtain motion films at lesser rates while still providing all the benefits of micro-motion study. In addition, it facilitates the visual examination of lengthy sequences of tasks with relative ease.

Having said that, memo-motion study is not without its drawbacks. It can be utilised only in situations where the job is contained to a specific area. The inability of motion picture cameras to capture steady footage becomes apparent when an item is constantly shifting positions.

Self-Assessment Questions

11. _____ is a technique that involves analysing the body movements of a worker while performing a job.

12. Memo-motion is a special form of micro-motion study. (True/False)

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10.7 Work Measurement

When methods are used to ascertain what constitutes a job, this is called work measurement. Measuring job content requires standardising the way the job is performed, which can be achieved through method study. Thus, it is said that technique study follows work measurement. According to **BSI**, 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."*

Work measurement, in its simplest form, is a method for estimating how long it will take an experienced worker to complete a given task. Job completion times are often referred to as standard time, work standards, labour standards, production standards, or simply standard time. Time is often measured in minutes or units of production per hour.

Work measurement is essential for planning and controlling the operations of an organisation. This is because unless the work content is measured, it is hard to identify the capacity level of a production plant. In addition, work measurement is also used for introducing incentive schemes and standard costs for budget control as well as for achieving a high level of labour productivity. The following are the major objectives of work measurement:

- Improving the planning and controlling of operations
- Making work handling more effective
- Providing indices to measure labour performance
- Enabling an organisation to control its labour cost
- Making the incentive schemes better

10.7.1 Benefits of work measurement

As discussed earlier, work measurement aids the planning and controlling of various jobs of an organisation. Apart from this, there are several other benefits of work measurement, which are discussed as follows:

- Comparing alternative methods developed in method study
- Preparing a work schedule by assessing work done by workers
- Establishing standards for measuring the efficiency of labour
- Comparing the time taken by labour to perform a job
- Aiding the estimation of labour cost
- Providing data with respect to approximation of tenders, fixation of selling price, and assessment of delivery schedule

10.7.2 Process of work measurement

The process of work measurement involves a number of steps, which are as follows:

1. Dividing the work into elements
2. Recording the time taken by each element to perform its work with the help of work measurement techniques, such as time study, synthesis method, and analytical estimating

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3. Setting a standard time for each element by extending observed time to normal time by applying a rating method
4. Assessing the relaxation allowance for personal requirements and physical and mental fatigue
5. Including the relaxation allowance in the normal time for every element to determine the work content
6. Identifying the repetition of an element in the job, multiplying the work content with a number of times the element is repeated, and adding the time taken to determine the actual work content of a job
7. Including the contingency allowance in the determined work content

10.7.3 Techniques of work measurement

Work measurement is a tool to determine the work content of a job by using various techniques. Some of the most commonly used work measurement techniques are shown in Fig. 10.5:

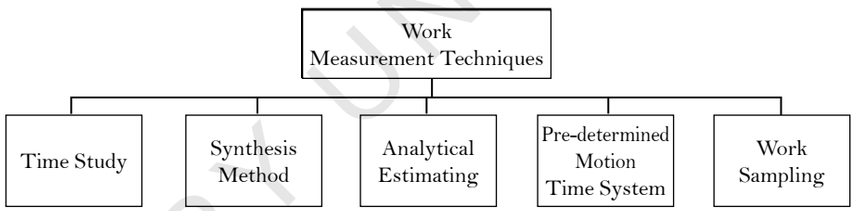

Fig. 10.5: Different Techniques of Work Measurement

Time study

Time study deals with the determination of time required to perform a job. It helps in calculating the standard time to perform a specific job. According to **International Labor Organisation (ILO)**, *"Time study is a work measurement technique for recording the times and rates of working for the elements of a specified job carried out under specified conditions and for analyzing the data so as to obtain the time necessary for carrying out the job at a defined level of performance."* Some of the objectives of time study are as follows:

Identifying the time required by an individual to perform a job

- Establishing a basis for comparing operational effectiveness
- Comparing different work methods to select the best one
- Determining the standard cost
- Providing a basis for setting incentive wages
- Setting the completion schedules for individual operations

Time study is generally performed with the help of stop watch, which can be started or stopped instantly. Thus, it helps in the measurement of accurate time taken for the completion of a job.

Notes

The process of time study conducted through stop watch includes the following steps:

1. Selecting a job that needs to be studied. A job is selected based on the following factors:
   - New job in the production
   - Modification in the method used for performing a job
   - Alteration in resources, such as materials and machinery, used for performing the job
   - Established standard time for performing the job
2. Selecting a worker who needs to be studied. Generally, a qualified worker is selected for establishing the standard time for performing a job. A qualified worker is one who has all the required skills, intelligence, and physical characteristics to perform a job at the same time meeting the standards of quality, quantity, and safety. However, all these characteristics are hard to find in an individual. Therefore, the best available worker is selected and the time taken by him/her to complete a job is calculated.
3. Calculating the time taken for performing a job, using stop watch. Determining the time taken to perform a job involves the following steps:
   a. Gather all information related to the job, worker, and working conditions.
   b. Record the work method used for performing the job and split it into different elements. A job is broken into different elements to be analysed thoroughly. An element can be of different types, which are discussed as follows:
      - **Repetitive element:** It indicates an element that occurs in every cycle of the job
      - **Occasional element:** This refers to an element that occurs after a regular interval of time
      - **Constant element:** It signifies an element whose normal time remains the same
      - **Variable element:** It indicates an element whose normal time varies
      - **Manual element:** It indicates an element that is performed manually
      - **Machine element:** Indicates an element that is performed with the help of machines
      - **Governing element:** It refers to an element that requires more time to perform as compared to other elements
      - **Foreign element:** It indicates an unnecessary element of a job
   c. Analyse the different elements of a job to determine the most effective work method for performing the job.
   d. Record the time taken by the qualified worker to perform each element of the job with the help of a stop watch.
   e. Determine the rating factor by comparing the actual speed of the worker with the standard speed of performing a job. The qualified worker is assumed to have a standard speed. Rating factor/scale can be expressed as follows:

      Rating factor = Rating of the observed worker/Rating of the qualified worker

      The rating scale can be of three types, namely 60-80 scale, 75-100 scale, and 100-133 1/3 scale.

f. Calculate the normal time taken by a worker to perform a job. After selecting the rating scale and calculating the rating factor, the normal time of the worker is calculated using the following formula:

Normal time = Observed time * Rating factor

For calculating the observed time, the time taken for performing the activities of an element is recorded. This action is repeated a number of times depending on the number of work cycles and their length. After that, the average observed time is determined as follows:

Observed time = Sum of element times/Number of cycles

g. Identify the time allowances given to the worker while performing the job. Such allowances are calculated by taking the percentage of normal time. The different types of allowances are explained as follows:

- **Relaxation allowance (RA):** This refers to an allowance that is provided to a worker to overcome fatigue, which is the result of physical exertion, posture, working conditions, and personal needs. Such type of allowance varies from 10% to 20% of normal time and is also known as Personal Fatigue on Delay (PFD) allowance.
- **Contingency allowance (CA):** This refers to an allowance provided for non-repetitive activities, such as getting materials from retail stores, polishing of tools, and consultation from a supervisor. This allowance is about 5% of normal time.
- **Process allowance:** This refers to an allowance given to the worker for his/her idleness, which is the result of the production process. For example, workers working on an automated machine get process allowance.

h. Calculate the standard time by the addition of related allowances to the normal time. Therefore, the standard time can be calculated as follows:

Standard time = Normal time + Relevant Allowances

Synthesis method

Synthesis method is a technique in which the standard time to perform a job is determined using either the previous time studies conducted on similar jobs with same elements or the standard data. Standard data is one that includes normal time values for different elements. It is prepared by assimilating the time of different standard elements. A catalogue of standard data can be prepared for different elements.

In synthesis method, the elements of the job to be studied are determined. After that, the time taken to perform these elements is identified from the catalogue of standard data. Further, the time values of different elements of the job are added to determine the standard time to perform the job. The following are the benefits of the synthesis method:

- Reduces the cost and time involved in determining the time required by an element to complete its work
- Helps in determining the labour time for preparing cost estimates for new jobs

Notes

The applications of synthesis method are as follows:

- Determining standard time for new jobs
- Estimating production time to decide the price of products to be sold
- Aiding the preparation of incentive schemes

Analytical estimating

Analytical estimating is one of the important techniques of work measurement. It is used to determine the time values of jobs having long and non-repetitive operations. These time values are obtained from the synthetic data or from the past experience of work study engineer. The process of analytical estimating involves a number of steps, which are as follows:

1. Determine the job details, such as dimensions of a job and standard procedures and conditions for performing it
2. Divide the job into different elements
3. Identify the time values for as many elements as possible
4. Assess the time values for the remaining elements through past experience
5. Add the time values of all elements to get the total time
6. Add the relaxation allowance, which can range from 10% to 20% of the total time depending on the kind of job and its conditions
7. Add other allowances if applicable to obtain the standard time for performing a job

There are several advantages of analytical estimating. Some of them are as follows:

- Makes the planning and scheduling of production easier
- Offers a basis for determining labour-rate for non-repetitive jobs
- Helps in improving control on labour

However, the main limitation of analytical estimating is that the standard time calculated depends on the judgment of the estimator. In such a case, the accuracy of time values is less as compared to time value calculated with the help of stop-watch.

Predetermined Motion Time System

Predetermined Motion Time System (PMTS) refers to a technique in which normal time values are established for basic human motions. These time values are used to determine the standard time for performing a job.

The standard time determined through PMTS is considered to be standard data for a number of human body motions such as move, reach, and position, which are common in several industrial operations. PMTS can be of three types, which are discussed as follows:

- **Methods Time Measurement (MTM):** It refers to PMTS in which time values for basic human body motions are expressed as Time Measurement Units (TMUs). TMUs can be expressed as follows:

  1TMU = 10-5 hour = 0.00001 hour = 0.0006 minutes = 0.036 seconds

NOTES

MTM can be applied to a number of operations. Some of these operations are as follows:

- Formulating effective work methods prior to the initiation of production cycle
- Refining the existing work methods
- Preparing standard time data
- Determining labour cost and time involved in performing a job

- **Work factor:** It refers to PMTS that classifies basic body movements in terms of arm movement and finger movement. These movements may take longer time due to resistance from certain factors, such as weight, change of direction, and manual control, thereby slowing down the work process. These factors are known as work factors.
- **Basic Motion Time (BMT):** It refers to PMTS in which time values are determined from labouratory experiments and are tested against a variety of factory operations before standardising them. BMT data is based on basic body motions, such as finger, hand, arm, foot, and leg movements. These motions are grouped into different categories, namely class A motions, class B motions, and class C motions, based on muscular control required to stop these motions. Class A motions can be stopped without muscular control while class B motions require muscular control to be stopped. However, class C motions need muscular control to slow down or stop completely.

PMTS is considered as an extension of motion study. It not only determines the best method but also identifies the standard time to perform a job. The method is regarded to be more economical than time study as well as an effective tool for measuring time for repetitive jobs having shorter duration. Therefore, it helps an organisation in several ways, which are as follows:

- Improves the work methods of an organisation
- Simplifies the determination of standard time for a job as the basic human body motions are predetermined
- Provides an accurate means for recording time to perform a job
- Does not interrupt the work routine of workers

PMTS also suffers from certain limitations, which are as follows:

- Does not include standard time values for all human activities
- Has limited application in non-repetitive jobs

Work sampling

Work sampling refers to a technique in which samples of work of one or more employees are collected at regular intervals. These samples help in determining the amount of time required for performing a particular activity.

Work sampling helps an organisation in the following ways:

- Identifying the allowances to be included in the standard time
- Signifying the type of work activities to be included in a work sample
- Estimating the percentage of utilisation of groups of similar machines
- Indicating the use of material handling equipment
- Providing a basis for indirect labour time standards

Notes

- Identifying the productive and non-productive utilisation of clerical operations
- Determining the standard time for repetitive operations

Work sampling can be done by adopting the following steps:

- Identify study objectives

1. Prepare a plan for the sampling process, which involves the following activities:
   - Estimating the time required to complete every phase of the activity
   - Establishing the accuracy level
   - Estimating the required number of observations
   - Determining the period of study and scheduling the number of readings for this period
   - Establishing the method for observation, route to follow, and recording data
2. Collect the data according to the defined method
3. Analyse the data and prepare results

The number of observations required in work sampling can be determined as follows:

$$\sigma_p = \sqrt{\frac{pq}{n}}$$

$$n = \frac{pq}{\sigma_p^2}$$

Where

= Standard error of proportion

p = Percentage of idle time

q = Percentage of working time

n = Number of observations

Self-Assessment Questions

13. _____refers to an application of techniques for determining the content of a job.
14. Work measurement is essential for planning and controlling the operations of an organisation. (True/False)
15. Name any two work measurement techniques.

10.8 Relationship among Time Study, Motion Study, and Work Study

As discussed earlier, time study refers to the quantitative analysis of a job. The main objective of time study is to set a standard time for performing a job. On the other hand, motion study is the qualitative analysis of a job with the aim of designing an improved work method. Work study involves determining the best possible way to perform a job and setting a standard time to perform that job. It should be noted that all the three methods focus on determining the

more efficient way to perform a job. Therefore, the three techniques, time study, motion study, and work study are closely related to one another. Fig. 10.6 shows the relationship among the three techniques:

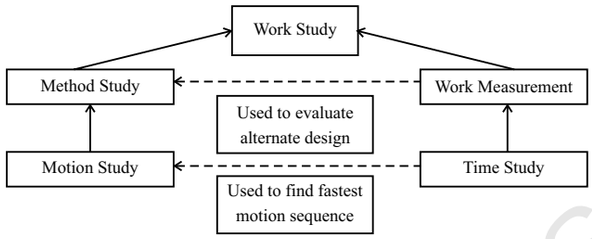

Fig. 10.6: Relationship among Time Study, Motion Study, and Work Study

Self-Assessment Questions

16. Time study refers to the qualitative analysis of a job. (True/False)

17. _____study is the qualitative analysis of a job.

10.9 Summary

- Productivity implies producing more with the help of same set of resources. The methods used for improving productivity are job analysis and work study.
- Job analysis implies a systematic process of collecting, evaluating, and examining the duties and responsibilities required to perform a job
- Work study measures work and defines performance standards. Work study includes method study, motion study, and work measurement.
- Method study aims at simplifying the jobs and developing more economical methods of doing it.
- Motion study helps to reduce the time taken for the activity.
- Work measurement technique of productivity improvement helps to determine how long it should take to carry out a task.

10.10 Glossary

- **Effectiveness:** The degree to which something is successful in producing a desired result.
- **Efficiency:** The comparison of what is actually produced or performed with what can be achieved with the same consumption of resources
- **Flow Process Chart:** A chart that provides a graphical representation of all the operations, transportation, delays, and shortages of a work process.
- **Outline Process Chart:** A chart that records only the important events of a job in a sequence.
- **Work study:** A systematic study of a job to determine the best possible way to perform it

Notes

10.11 Terminal Questions

1. What do you understand by productivity? Explain factors affecting productivity.
2. Explain the concept of work study.
3. Explain the process of method study.
4. Explain the concept of motion study.
5. Describe the process of work measurement.

10.12 Answers

Q.	Self Assessment Questions
1.	Productivity
2.	False
3.	d. Availability of natural resources, such as land and raw materials
4.	Job Analysis
5.	Job description and job specification
6.	c. Human Resource Planning and Development
7.	d. Selecting the technology for production
8.	True
9.	Method study
10.	High operating costs and extreme movement of materials and labour
11.	Motion study
12.	True
13.	Work measurement
14.	True
15.	Time Study and Synthesis Method
16	False
17.	Motion
Q.	**Terminal Questions**
1.	Productivity is a measure of the rate at which output is produced per unit of input. Refer to section **10.2 Concept of Productivity**
2.	Work study makes optimum utilisation of labour and materials by determining efficient work methods. Refer to section **10.4 Work Study**.
3.	Method study determines the best method for performing a job. Refer to sub section **10.5.3 Process of Method Study**
4.	Motion study eliminates ineffective movements that do not add value to the job. Refer to section **10.6 Motion Study**.
5.	Work measurement can be defined as a technique used to determine the time required to perform a job by a qualified worker. Refer to sub section **10.7.2 Process of Work Measurement**.

NOTES

10.13 Case Study: XMX Ltd.'s Productivity Efforts

The production department of a leading truck manufacturing company, XMX Ltd. is aiming at doubling the amount of trucks that they manufacture in a day. The plan is to optimise the resources while maintaining excellence in quality performance. The Improvement Team within the production department drafted an improvement project. The team laid importance on knowing the exact amount of time being spent on non-value activities at each assembly station of their plaint in Montreal, in order to optimise their operation.

XMX Ltd. evaluated value-added and non-value-added tasks using the time-honored method of using a stopwatch and a paper form. It was necessary to have a more effective method, the Senior Production Coordinator said.

Collecting task times with stop watches was a real pain because you had to hold the watch and jot down the information all at once. Both the findings and the data gathering process were flawed.

The Improvement Team considered all of their options before deciding to purchase UMT Plus, a piece of software that measures productivity using portable PCs.

The data collection procedure is made easier and more efficient using top-notch tools. Five portable computers should be loaded with the necessary information and distributed to staff, according to the Improvement Team's recommendation. After two hours of training, they were dispatched into the facility to assess seventy assembly workers in only three days. "With UMT Plus, it's as easy as clicking the right icon; your time is logged," the head of the improvement team remarked.

"Once the tasks have been correctly timed on the PDA, the results are transferred to the computer without having to perform any data entry, it's very simple," reports the Project Coordinator. Improving efficiency in our assembly operation by cutting out non-value-added tasks is easy to prove. The stopwatch system is more scary. We have found that using UMT Plus has greatly improved the accuracy and efficiency of our work measuring procedure.

Discussion Questions

1. Do you think it was essential for XMX Ltd to switch to high quality software from traditional technique of stop watch? Discuss why or why not.

   (**Hint:** as results were inaccurate, thus it is beneficial to shift)

2. Discuss how important it is for any organisation to concentrate on improving their productivity?

   (**Hint:** for cost reduction ; goodwill; profitability)

10.14 References and Suggested Readings

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CHAPTER

11 Maintenance Management

Structure

Notes

Learning Objectives

After completing this chapter, you will be able to:

- explain the concept of maintenance management
- explain the need for replacement of equipment
- explain the concept of total productive maintenance

11.1 Introduction

The efficiency of the production function is dependent on the reliability of the production facilities, which include the land, building, plants and equipment and tools, Facilities also include services such as the material handling, power plants, gas and steam lines and fire fighting facilities. Due to their usage, all these facilities are always subject to wear, hence require maintenance. The sole objective of the plant maintenance is to keep the facilities working. These functions involve the indirect cost of the production activity.

In a manufacturing organisation, maintenance is a function that aims at ensuring that all machines and equipment required for production are operating at their maximum efficiency. Maintenance focuses on increasing the effectiveness of a production system by creating a safe work environment and optimising the overall production cost. Therefore, it is essential for an organisation to manage its maintenance activities properly.

Maintenance management is all about planning and executing maintenance activities in a systematic manner. These activities include daily inspections, cleaning, lubricating, repair and replacement. Maintenance management aims at identifying potential failures and breakdowns in the production system and fixing them on time. It also helps in minimising the idle time of machines and equipment, thereby maintaining an uninterrupted flow of production and improving the quality of final output.

In this chapter, you will study about the concept of maintenance management. You will further study the need for replacement of the equipment and the factors responsible for replacement of equipment. Towards the end, the chapter will discuss the concept of total productive maintenance.

11.2 Concept of Maintenance Management

The various parts of a machine work in sequence to do their designated tasks. Consider a typewriter as an example: when the user presses a key on the keyboard, it mechanically strikes a ribbon, which in turn makes an impression on the paper that is positioned on the carriage. In preparation for the subsequent cycle, the carriage travels one space while the type linkage goes back to its initial position. The machine has some permanent parts and other removable parts. In order to keep these mechanical devices and their components running efficiently, regular maintenance is required. This includes cleaning, lubricating, fixing, and replacing parts. Ground, building power plant, material handling equipment, transportation vehicles, and water supply are all part of the plant's maintenance service. The supply of maintenance tools and the storage of repair components and materials are also part of this. Thus, practically all operations directly or indirectly connected to manufacturing fall under the purview of maintenance.

Notes

In other words, maintenance is not just a repair function. According to the British Standards Institute, maintenance "is a combination of many actions carried out to retain an item in, or restore it to an acceptable condition." This function keeps an eye on the entire production system and facilities. These days, National Productivity Council (NPC), is spreading the message of good maintenance management. In fact, these days a comprehensive tero-technology approach is adopted that looks after the physical assets right from design to discard stage through various angles—managerial, financial, technical, and maintenance.

An effective production system includes maintenance as one of its primary functions. By lowering operating costs and raising output quality and quantity, it aids in keeping plant facilities operationally efficient, which in turn increases income. Costs associated with maintenance, as a service activity, include salaries for maintenance crew members and other administrative staff, capital expenditures for maintenance equipment, and supplies for repairs and upkeep. But it gets expensive when anticipated maintenance service isn't there.

Machines break down and some production services don't work because there wasn't enough planned maintenance. This causes production to stop, which means more idle machine-time, more idle direct and indirect labour time, process relocation, lower product quality, more scrap, missed delivery deadlines, workplace accidents that could have killed workers, workers' morale taking a hit, etc. It is recommended to conduct the plant maintenance services with the cost-benefit analysis in mind. Because it is a service, it need to be offered at the most affordable price.

Ensuring that the manufacturing facilities and equipment remain in a standard operational state is the goal of the maintenance operation. Alternatively, when machinery breaks down, it affects the following:

- **Production capacity:** When machines break down, they can't create anything, which means the system's capacity decreases.
- **Production costs:** When workers aren't producing anything because machines aren't working, the cost per unit of labour goes up. As machines experience more frequent breakdowns, the maintenance cost rises. This cost encompasses the provision of repair facilities, repair crews, preventative maintenance checks, replacement components, and standby equipment.
- **Product and service quality:** Products of poor quality are the result of equipment that is not well-maintained. Inadequately maintained equipment fails to last long and fails to meet consumer expectations. Customers may experience subpar service, for instance, if airline, railway, and road transport fleets are not properly maintained.
- **Employee or customer safety:** Workers operating the faulty machinery run the risk of personal injury should it break down at any moment.
- **Customer satisfaction:** Work stoppages occur when production equipment fails, making it impossible to manufacture products in accordance with the master production schedules. As a result, consumers experience postponed product delivery.

11.2.1 Objectives of maintenance management

The main objective of maintenance management is to keep an efficient and reliable production system. Earlier, maintenance activities were performed by operators in a production plant. However, with the growing awareness of maintenance, many organisations have formed separate maintenance departments.

NOTES

Following are some of the major objectives of maintenance:

- Making sure that equipment failure doesn't eat into productive time
- Keeping repair time and costs to a minimum
- Keeping production stoppage losses to a minimum
- Helping maintenance staff and tools work together more effectively
- Decreasing wear and tear frequency
- Making sure all productive assets are always in top shape
- Getting the most out of available resources in order to maximise output while minimising waste
- Reducing the likelihood of accidents by keeping safety equipment maintained and repaired
- Keeping the overall cost of maintenance to a minimum by minimising repair expenses, preventative maintenance costs, and the costs associated with holding an inventory of replacement parts

11.2.2 Types of maintenance

Different organisations perform different maintenance activities depending on their requirements and budget. Based on the requirements of different organisations, maintenance is grouped into two categories, which are shown in Fig. 11.1:

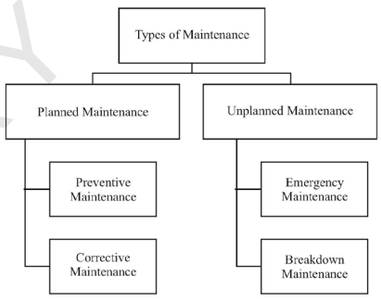

Fig. 11.1: Types of Maintenance

The two types of maintenance are:

- **Planned maintenance:** As the name suggests, planned maintenance entails maintenance activities that are predetermined within a time-bound schedule. These activities are performed in the way they have been planned when the actual production takes place. Planned maintenance follows a work cycle, which is shown in Fig. 11.2:

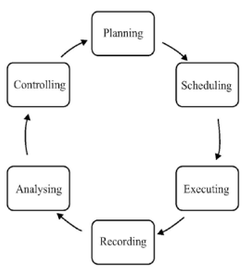

Fig. 11.2: Planned Maintenance Work Cycle

Notes

As shown in Fig. 11.2, planned maintenance involves six stages, namely, planning, scheduling, executing, recording, analysing and controlling. At the planning stage, all the maintenance activities to be performed are determined by an organisation. Next, at the scheduling stage, a sequence in which all the maintenance activities are to be performed is decided. Next, at the executing stage, the predetermined maintenance activities are put into practice when the actual production starts. At the recording stage, the organisation records the performance of machines and equipment after the execution of maintenance activities. At the analysing stage, these records are evaluated for identifying the gaps between the planned maintenance activities and the maintenance activities that actually took place during the production. At the controlling stage, if a gap exists, necessary changes are made in the existing maintenance plan to bridge such gaps.

There are two types of planned maintenance, which are discussed as follows:

- **Preventive maintenance:** This type of maintenance involves planning maintenance activities by anticipating failures that may take place when the actual production starts. In preventive maintenance, work is performed on a routine basis, irrespective of the condition or performance of a machine or equipment. The main objective of preventive maintenance is to reduce failures and ensure consistent performance of machines and equipment. The common activities performed under preventive maintenance include regular inspection, cleaning, oiling and repairing.

  Preventive maintenance can also be sub-divided into two parts, namely, running maintenance and shutdown maintenance. In running maintenance, preventive actions are performed while a plant is running. For example, inspecting and lubricating a machine while it is working. On the other hand, in case of shutdown maintenance, a plant is shutdown to perform maintenance activities to prevent failure while it is running. For example, repairing or replacing a machine when it is not in use.

- **Corrective maintenance:** It refers to a form of maintenance that is performed after a failure or fault has taken place. As a matter of fact, all the conditions cannot be foreseen, thus every failure cannot be precluded by performing preventive maintenance activities. Although preventive maintenance activities reduce the likelihood of failures to a remarkable extent, certain problems may still take place during the production process. Corrective maintenance aims at resolving these problems to restore machines and equipment back to their acceptable working conditions.

  The corrective maintenance process begins with finding out the reason for a particular failure which involves physical inspection of a machine or equipment. Once the cause is determined, corrective actions are taken to maintain machines and equipment at an acceptable level of performance.

- **Unplanned maintenance:** Unplanned maintenance is a type of maintenance work that is not planned in advance. Maintenance activities are mainly based on predictions. However, these predictions may not always hold true. There are various technical and non-technical factors that affect the production process. In this case, an organisation has some unplanned maintenance work. Unplanned maintenance can be divided into two types, which are as follows:

- **Emergency maintenance:** It involves performing maintenance for problems that need to be rectified urgently. However, since all kinds of failures in a production plant are considered urgent, they should be resolved as soon as possible. Emergency maintenance is performed for failures that are unforeseen or cannot be anticipated.

Notes

- **Breakdown maintenance:** It involves performing maintenance for problems that can be anticipated. However, maintenance activities for these problems cannot be planned. This is because an organisation cannot ascertain how and when these types of problems would take place in a plant.

Exhibit

Preventive versus Breakdown Maintenance

Preventive maintenance is a systematic, proactive process of inspecting, identifying, rectifying, and preventing incipient failures of assets. The preventive maintenance approach is based on the principle 'prevention is better than cure.' The main aim of preventive maintenance is to preserve and restore a machine's reliability through the replacement of worn-out components before they actually fail; thereby avoiding production halts. Preventive maintenance helps in achieving improved system reliability, decreased maintenance costs, and reduced downtimes. To be preventive maintenance effective, it is important for an organisation to develop a preventive maintenance program.

The main objectives of adopting preventive maintenance by organisations are to:

- Reduce machine breakdowns
- Increase assets' reliability
- Improve productivity
- Increase the life and utilisation of assets
- Reduce production stoppages and machine slowdowns
- Adhere to production and delivery schedules

Breakdown maintenance refers to repair or replacement of equipment after they have failed. Unlike the preventive and predictive maintenance strategies that focus on avoiding equipment failures, breakdown maintenance is typically employed when failures are already occurred. This policy is often used at times when a facility is scheduled to close or cease operations, or there are no plans to continue using the equipment afterward.

Preventive maintenance follows a proactive strategy, where inspections are typically carried out on a regular basis to avoid any catastrophic failures. However, in breakdown maintenance, a reactive or corrective strategy is applied, where any maintenance work is done after the breakdown of equipment or component. This is done to avoid the costs associated with inspections and pre-emptive repairs. Therefore, the breakdown maintenance approach allows the components to fail and then addresses the issue.

To survive in today's highly competitive business environment, organisations spend a huge amount on acquiring the latest machines and equipment to produce quality products. Therefore, organisations cannot rely only on breakdown actions wherein maintenance tasks are performed after a failure occurs.To deal with uncertainties,organisations need to adopt the measures that are successful in preventing failures even before their occurrence.

11.2.3 Maintenance policies for facilities and equipment

Different organisations can have different policies for maintaining facilities and equipment. However, the most important objective of formulating policies for maintaining facilities and equipment is to ensure on-time availability and high performance.

NOTES

The following are the important objectives of developing policies for facilities and equipment maintenance:

- To incorporate the latest production and maintenance techniques.
- To determine the level of output that can be produced from the existing facility and equipment under normal operating conditions.
- To assess the functioning of machines and equipment under abnormal conditions of working.
- To estimate the requirements of funds for the development and maintenance of facility and equipment.
- To ensure on-time recovery and restoration of facility and equipment.

A maintenance manager needs to formulate policies for facilities and equipment maintenance. Developing a maintenance policy is a systematic approach and involves a number of steps, which are shown in Fig. 11.3:

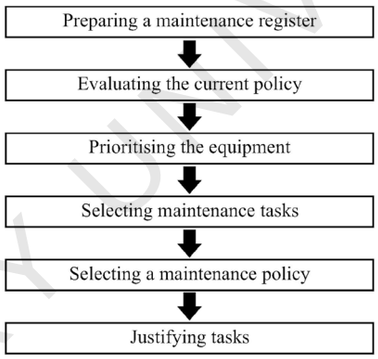

Fig. 11.3: Steps Involved in Developing a Maintenance Policy for Facilities and Equipment

Let us discuss these steps in detail.

1. **Preparing a maintenance register:** The first step in developing a maintenance policy for facilities and equipment is to create a maintenance register. A maintenance register records all the details of an organisation's assets, such as machineries' names, usage, and scheduled maintenance date. It helps maintenance personnel in identifying the facilities and equipment that require maintenance so that there can be no halts in the production process.

   Without a maintenance register, it can be difficult for an organisation to identify maintenance requirements and define maintenance jobs. Therefore, an organisation should have a comprehensive maintenance register containing accurate details of all facilities and equipment.

2. **Evaluating the current policy:** After creating a maintenance register, the next step is to review the existing policy for the maintenance of facilities and equipment. The review is done to determine the scope for improvement, which further helps a maintenance manager in establishing new maintenance policies. The correct and complete review requires the information about the following:

Notes

The percentage of planned maintenance work to determine whether all monitoring and control measures are in place.

The volume of backlog work and the measures taken to complete this work. This helps in producing the output at the given time and making on-time delivery of products.

The areas that require high costs. Identifying such areas would help in determining whether the expenditure is in line with the equipment priority.

3. **Prioritising the equipment:** After reviewing the current maintenance policies, the next step is to prioritise the equipment for maintenance tasks. Prioritisation is done based on criticality analysis, which is a process that involves deciding the type and amount of maintenance work to be performed for a particular asset. The main objective of performing criticality analysis is to find out the equipment that is likely to fail in the near future and may affect the business negatively. In order to perform criticality analysis, an organisation needs to:

   - Collect information about equipment through asset registers, equipment listings, process flow diagrams, etc.
   - Define equipment categories that have maximum relevance to the organisation.
   - Establish benchmarks to define the importance of consequences in case of failure of equipment.

   After that, an organisation needs to categorise equipment according to the functions performed by them and risks associated with their functions. These items are generally categorised based on the following four parameters:

   - Safety
   - Environmental
   - Production
   - Others

   By categorising equipment, the aims of maintenance function for each category can be defined easily. Table 11.1 shows the aims of maintenance for each category:

Table 11.1: Aims of Maintenance

Category of Equipment	Aim of Maintenance
Assets that are installed for ensuring safety by responding in emergency situations.	These assets must be available at the required time.
Assets that control the production process.	These assets reduce the risk of failures.
Assets that affect production directly.	These assets must be available at all the stages of production.
Assets that do not affect production, safety, and control directly.	Direct costs must be minimised.

The next step after categorisation is prioritisation of categories. Prioritisation is done in the following manner:

- **Prioritisation by cost:** In this approach, the aims of prioritising must be clearly indicated by the category. This could be listed in the following manner:

- Safety/environment category includes safety/integrity costs and safety accidents costs.
- Production category includes repair includes repair costs, lost production costs, and logistic costs.
- Others category includes repair and logistics costs.

◆ **Prioritisation according to the effect on production**: In this approach, categories are priorities in accordance with the effects they have on the production process. The methods used in this approach are subjective than the cost approach. However, the time taken by these methods is shorter.

4. **Selecting maintenance tasks:** With time, there has been greater emphasis on cost reduction and improvement in maintenance functions. This has led to advancement in design for reliability, design-out maintenance, condition-based maintenance, and failure finding tasks. In this step, the focus is laid on deciding appropriate maintenance tasks. The type and range of maintenance tasks that are gaining wide acceptance are shown in Fig. 11.4:

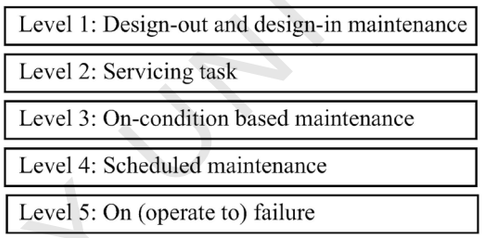

Fig. 11.4: Maintenance Tasks

Let us discuss each of these maintenance tasks in detail.

- **Level 1: Design-out and design-in maintenance:** In design-out maintenance, the main cause of failure is determined and rectified so that it can be prevented in the future. Design-out is a part of the continuous improvement process and has provision for modifying equipment. In design-in maintenance, emphasis is laid on building reliability and maintainability of equipment.
- **Level 2: Servicing task:** Servicing tasks are performed to keep a plant and equipment under operational conditions. These servicing tasks can be preserving, cleaning, draining, painting, and replenishing. These tasks must be performed at proposed intervals.
- **Level 3: On-condition based maintenance:** Condition-based maintenance is performed by monitoring the condition of a component. This type of maintenance is effective only if it detects the onset of failure so that corrective actions are taken at the right time. This approach has gained popularity over the years and forms the base for developing an asset strategy.
- **Level 4: Scheduled maintenance:** Scheduled maintenance, also known as fixed time maintenance, is performed in a planned manner for the maintenance of equipment. Scheduled maintenance usually includes repair, rework, and replacement tasks.
- **Level 5: On (operate to) failure:** Operate-to failure is also called reactive maintenance. In this maintenance, corrective actions are taken in response to

the failure of a component or equipment. Operate-to failure is least effective maintenance and thus less preferred in modern times.

5. **Selecting a maintenance policy:** In this step, an appropriate maintenance policy is selected. In the maintenance policy selection, the consequences of failures are analysed to justify maintenance tasks to be performed. The consequences of failures are mainly classified into four categories, namely hidden; safety/environment; production or operational; and non-operational. Based on the selected asset strategy, an equipment maintenance schedule is generated.

6. **Justifying tasks:** This is the last step in developing a maintenance policy. After selecting maintenance tasks, these tasks must be justified. Therefore, tasks are assessed on the basis of suitability, costs, and procedures involved in level 3, 4, and 5 (these levels are described earlier in this section).

11.2.4 Machine failure

In maintenance management, a failure is the cessation of normal operations of machines and equipment. For example, breakdown of equipment due to short circuits or loose connections resulting into cessation of operation is said to be equipment failure. Recurring failure of machines or equipment clearly indicates that the quality standards have not been met. Failed machines and equipment have a direct impact on the production cost and delivery of final products.

In simple words, machine failure can be defined as any event in a machine or any of its part or component that interrupts the normal functioning of the machine. Machine failures are also referred to as the loss of usefulness of a machine or equipment. For example, if a pump at an oil station is installed to drive 100 gallons of oil per minute but is able to pump only 50 gallons per minute, it is the loss of usefulness of the pump. The most common reasons for the failure of machines and equipment are faulty designs, material defects, and discrepancies in manufacturing and processing. However, reasons for machine failures have been broadly classified into two categories, which are shown in Fig. 11.5:

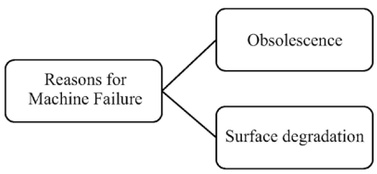

Fig. 11.5: Reasons for Machine Failure

Let us discuss these reasons in detail.

- **Obsolescence:** Every machine and equipment has a life cycle beyond which its performance is reduced drastically. Failures that take place due to the use of outdated machines are called failures of obsolescence. For example, a machine (having a life span of 10 years) that is capable of producing 200 units of cardboard boxes/hour may not be able to produce the same output after 10 years. Such a machine would lose its utility and would be replaced by the organisation to prevent halts in production. Therefore, organisations must keep track of the obsolete machines in the plant to avoid such failures.

NOTES

- **Surface degradation:** Surface degradation results in machine failure due to friction, wear and tear, or lack of lubrication. It can happen due to chemical degradation such as corrosion, or mechanical degradation, like abrasion of machine surfaces.

  For example, cyclic rollers on a loading machine rub against each other may get worn out due to friction and heat generated in the process. Thus, it is important for an organisation to perform maintenance activities like lubrication, replacement of parts, etc. on time to prevent further degradation of machines. Surface degradation is basically of two types, which are:

  - **Corrosion:** Machine parts are prone to corrosion, particularly in areas where water contamination is a problem. Iron surfaces rust when exposed to water, and oil oxidation speeds up when exposed to water, creating an acidic environment inside the component. When specific additives in oil react with water, acids are produced as a byproduct. Seal contamination can lead to a caustic atmosphere and corrosive wear. When yellow metals (copper, bronze, brass, etc.) come into touch with a strong extreme pressure additive, it causes corrosion.
  - **Mechanical wear:** It happens when the surfaces of machines wear down against one another mechanically. Abrasive wear, adhesive wear, and metal fatigue are three types of mechanical wear. The bulk of wear in an abrasive wear is caused by particle contamination. Surface fatigue or three-body abrasion, brought on by particles like dirt or wear debris, can cause surfaces to become pitted and scored. The process of adhesive wear occurs when two surfaces come into touch with each other, causing the transfer of material from one side to the other. This manifests in places where the lubricant is either completely depleted or cannot sustain the current load. The phenomenon known as metal fatigue is analogous to the effort required to cut a wire by hand. The metal's torque increases with each back-and-forth motion of the wire. The metal eventually turns brittle and breaks after enduring enough rounds of this stress. Machines go through the identical procedure. A rolling-element bearing's inner race might experience a stress riser due to a particle, for instance. The metal wears down after a while of continuous bending. A material spall results from this.

While there are several potential ways in which machines could stop working, the most common issue is the surface deterioration of machine components. Properly sealing machines, limiting particle infiltration, and ensuring that lubricants satisfy the operational demands of components can extend machine life and reduce overall failures.

Self-Assessment Questions

1. The _____operation tries to keep the production facilities and equipment in an acceptable operating condition.
2. What is the main objective of maintenance management?
3. _____maintenance entails maintenance activities that are predetermined within a time-bound schedule.
4. The main objective of preventive maintenance is to reduce failures and ensure consistent performance of machines and equipment. (True/False)
5. Preventive maintenance is sub-divided into two parts, namely, _____and _____.

Notes

6. _____ involves performing maintenance for problems that can be anticipated, but cannot be planned.

   a. Emergency maintenance b. Breakdown maintenance

   c. Corrective maintenance d. Preventive maintenance

7. Write the steps involved in developing a maintenance policy for facilities and equipment.

8. _____maintenance, also known as fixed time maintenance, is performed in a planned manner for the maintenance of equipment.

9. _____are referred to as the loss of usefulness of a machine or equipment.

10. Obsolescence results in machine failure due to friction, wear and tear, or lack of lubrication. (True/False)

11.3 Replacement of Equipment

A manufacturing organisation uses various types of machines and equipment for producing the final output. These machines and equipment are subject to depreciation in due course of time. Besides this, these machines and equipment also run the risk of obsolescence. A machine or equipment usually becomes obsolete when a new and improved technology is introduced in the market. In this way, the dynamic business scenario may anytime raise the need of replacement of machines and equipment irrespective of their current operational conditions.

Every organisation strives to achieve a cost advantage and strengthen its competitive position in the market. For this, it needs to implement the latest technology. However, it is not always possible for an organisation to replace the existing machines and equipment, as it incurs huge cost, time and efforts of the organisation. Therefore, before taking any decision related to the replacement of machines and equipment, an organisation needs to perform replacement analysis and understand the factors responsible for such a replacement. Depending on the situation, it may be necessary to replace the old equipment with a newer model that is functionally equivalent but offers improved performance, lower operating costs, lower power consumption, or other technological advantages. When it's time to replace some machinery, you might be wondering:

- How often should one check on a machine's condition, and when should one buy new machinery?
- When does it become necessary to replace equipment?
- When it comes time to replace equipment, what steps should we take to be ready?

The decision to replace should not be made until these and similar questions have been addressed. In order to make a replacement decision, all relevant elements are considered, whether subjectively or objectively; nevertheless, the importance of the objective factors is diminished. This is due to the fact that data is not processed and handled appropriately in order to obtain useful information that permits objective analysis and results in replacement at the lowest possible cost and in the shortest amount of time. To sum up, the operational cost should be considered first, before the thought of replacement is brought up, so that it can be most economically feasible. When deciding whether or not to replace an item of equipment, it is wise to compare its original cost with its current, realistic book value; in other words, to look forward.

NOTES

11.3.1 Factors responsible for replacement

The factors that are responsible for the replacement of machines and equipment in an organisation can be categorised under two heads, namely, technological factors and cost factors. These factors are discussed as follows:

- **Technological factors:** These refer to the factors that are not under the control of an organisation. Therefore, these factors are called uncontrollable factors. Technological factors include the following:
  - Depreciation of machines and equipment
  - Invention of advanced technology
  - Inadequacy of the existing machines and equipment due to the size of work, time of operation, reliability of usage, quality of output or consumption of power
  - Requirement of auxiliary operations
  - Need for automation
  - Safety of operation
  - Performance issues in terms of speed and accuracy
- **Cost factors:** These are the factors that are under the control of a manufacturing organisation to a certain extent. These factors include the following:
  - Delay in production caused due to change
  - Economic advantage of replacement
  - Quality improvement resulting in economic benefit
  - Less maintenance cost and space occupied with the replaced machinery
  - Expected economic durability of the new machine
  - The amount of investment required to install new machinery

Self-Assessment Questions

11. In what manner, an organisation can take the replacement decisions?
12. The factors that are responsible for the replacement of machines and equipment in an organisation can be categorised under two heads, namely, _____and _____.

11.4 Total Productive Maintenance

Total productive maintenance (TPM) is implemented to increase the production and the morale and job satisfaction of employees. It states that the maintenance is an integral part of the business. The primary goal of TPM is to keep emergency and unscheduled maintenance to a minimum. Various technological advancements have paved way for advanced production equipment, such as robots. Machines and equipment that can be used for super precise processing of micron size objects have also been developed for processing that requires speed, pressure and temperature. The primary concern of TPM is to bring the breakdowns and defects to zero. Once the breakdowns and defects have been eliminated, the operation rates improve, the costs get reduced, the inventory gets optimised and the labour productivity increases.

Notes

11.4.1 Objectives of total productive maintenance

TPM aims at achieving effective plant maintenance through total employee participation. Following are some of the main objectives of TPM:

- Satisfying global customers and achieving sustained organisational growth
- Monitoring and regulating the work in process critically
- Achieving enhanced manufacturing flexibility objectives
- Improving organisation's work culture and mind set
- Tapping cost reduction opportunity regarding maintenance related expenses
- Minimising investments in new technologies and maximising return on investment (ROI)
- Improving the production capacity of a plant
- Increasing the efficiency and effectiveness of a maintenance program
- Eliminating sudden breakdowns and failures of machines and equipment
- Making all employees to participate actively in routine maintenance activities
- Facilitating a defect-free, accident-free and breakdown-free production environment
- Making optimum utilisation of productive resources

11.4.2 Impact of total productive maintenance

As discussed so far, TPM focuses on improving the maintenance activities of an organisation. This results in a significant increase in the overall productivity of a production plant. TPM considers the following six parameters to improve the overall productivity of a production plant:

- Productivity
- Quality
- Cost
- Delivery
- Safety
- Morale

The above-mentioned parameters are also represented as productivity, quality, cost, delivery, safety and morale (PQCDSM) of an organisation. In this way, TPM aims at making timely delivery of high-quality products to customers at the minimum required cost. At the same time, it boosts employee morale by providing a safe working environment. This ultimately increases the productivity of an organisation.

Apart from this, TPM also reduces wastes during the production process, thereby achieving overall effectiveness. There are three major categories of organisational wastes, which are caused due to six different reasons. These organisational wastes are categorised as follows:

Waste of downtime caused by

- Time lost in correcting equipment failure and sudden breakdowns
- Time lost in setup and adjustment of equipment before operation

NOTES

Loss of speed caused by

- Machine idle time and temporary stoppage of operation due to abnormal functionality of sensors or blockage of work
- Reduction in the pace of operations due to inconsistency between the planned and actual speed of equipment

Loss in the form of defects caused by

- Defective process operations due to scrap, fall of quality and unreliable repair
- Reduction in the yield due to lifecycle cost of a machine or equipment

It is important for an organisation to identify and eliminate these wastes from its production system to maintain higher productivity. TPM outlines the following guiding principles that help in preventing wastes in a production plant:

- Prevention of over production
- Prevention of excess inventory
- Prevention of loss of productive hours
- Prevention of delayed time and loss of cycle time
- Prevention of breakdowns
- Prevention of loss in process capacity

11.4.3 Overall equipment efficiency

An important performance metric that takes all three of these factors into consideration is the overall equipment effectiveness (OEE):

- **Availability:** As a percentage, it represents the difference between the amount of time machines were available before and the amount of time they are accessible for scheduled production. The plant manager can then determine if the machine downtime problems are related to a regular timetable or if there is another long-term issue.

  The availability metric is determined by:

  Availability = Operating Time / Planned Production Time

- **Performance:** It is a measure of how many things a machine can really generate in a given amount of time as compared to its potential rates. A comparison is made between the actual rate and the performance standards that were set before production began. That way, a facility can evaluate its efficiency in relation to the available downtime. If a line is experiencing low production or excessive downtime, it will be shown.

  Numerically, the performance can be calculated as:

  Performance = Ideal Cycle Time / Operating Time

  OR

  Performance = Total Pieces / Operating Time / Ideal Run Rate

- **Quality:** It is the percentage of items that pass the first quality inspection. This process allows an operations manager to compare the consistency between machines and manufacturers.

NOTES

Quality is calculated as:

Quality = Good Pieces /Total Pieces

OEE takes into account all three OEE factors and is calculated as:

OEE = Availability × Performance × Quality × 100

By implementing a system that can measure and analyse OEE, manufacturers can improve equipment performance, operating procedures and maintenance processes. Following are the six categories of productivity losses:

- Breakdowns
- Setup and Adjustments
- Small Stops
- Reduced Speed
- Start-up Rejects
- Production Rejects

Optimal Equipment Effectiveness (OEE) is an effort whose overarching goal is to reduce waste and maximise productivity in a certain market. There should be varying degrees of individual performance for each OEE component. It is recommended that availability be at 90%, performance be at 95%, and quality be at 99%. When these components reach appropriate levels, manufacturers can resort to these criteria. Output, efficiency, effectiveness, and bottleneck constraint analysis can inform proactive decision-making with the help of OEE measures. Manufacturers can learn about the impact and trends of equipment faults by monitoring OEE. Visualising the outcomes of an organisation's endeavours to enhance its operations is also beneficial.

11.4.4 Pillars of total productive maintenance

The main objective of TPM is to optimise the efficiency and effectiveness of a production plant. TPM is based on eight pillars. Each pillar helps an organisation to achieve the objectives of TPM. These pillars are shown in Fig. 11.6:

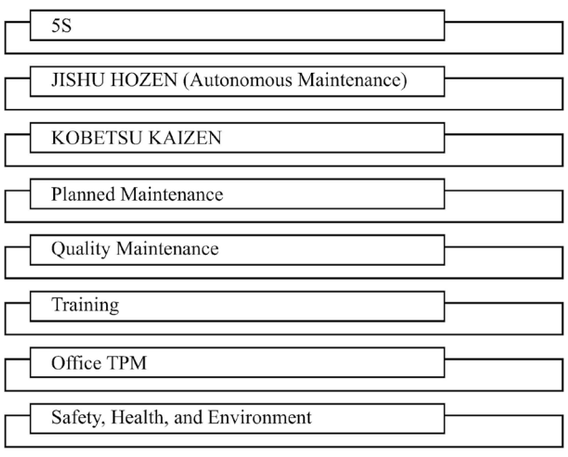

Fig. 11.6: Pillars of Total Productive Maintenance

NOTES

These pillars are discussed as follows:

- **Pillar 1 - 5S:** The pillars of TPM state a systematic process of housekeeping to achieve a good environment in the workplace, which involves employees with a commitment to implement the adequate housekeeping. The problems can be identified clearly if the workplace is unorganised. To identify the problem, visible is the first step of rectification. If the organisation overlooks the 5S, it has to suffer the 5D that is, Delays, Defects, Dissatisfied Customers, Declining Profits and Demoralised Employees. The pillars of 5S are shown in Fig. 11.7:

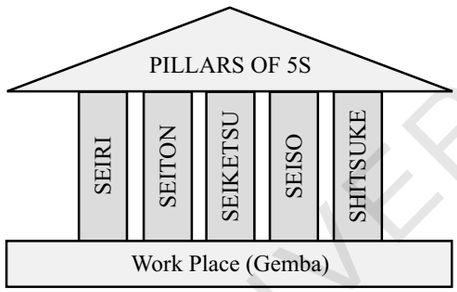

Fig. 11.7: 5S

The pillars of 5Ss are discussed as follows:

- **SEIRI — Sort out:** SEIRI refers to the sorting and organising of the items as critical, important, frequently used and useless. The items that are not desired can be scraped and the critical items may be kept nearby for current use. The items that are not to be used currently may be stored safely at some place.
- **SEITON — Organise:** It is always important to organise the tools of production, that is, the items should be placed back on the same place after use. In order to identify the items easily, we can use the name plates and coloured tags. Even the vertical racks can be used in which the heavy items are placed at the lower sections.
- **SEISO— Shine the workplace:** It is related to the cleaning of the workplace regularly.
- **SEIKETSU — Standardisation:** The operators are liable to decide on the standards for keeping the workplace neat and clean. These standards are then implemented and maintained for the whole organisation.
- **SHITSUKE — Self-discipline:** The concept of self-discipline includes wearing the badges, following the work procedure, maintaining punctuality and dedication, etc.
- **Pillar 2 - JISHU HOZEN (autonomous maintenance):** It is one of the eight pillars of TPM. The operators are themselves made responsible for the maintenance of the equipment they are using. This includes cleaning, lubricating and visual inspection.

The policies that are followed in this pillar are as follows:

- Ensuring uninterrupted operation of equipment
- Eliminating the defects at source through active employee participation

NOTES

Steps followed in JISHU HOZEN (JH) are as follows:

1. Preparation of employees
2. Initial clean-up of machines
3. Take counter measures
4. Fixing tentative JH standards
5. General inspection
6. Autonomous inspection
7. Standardisation

- **Pillar 3 - KAIZEN:** 'KAI' means change and 'ZEN' means good (for the better). KAIZEN is basically related to the small improvements that are to be performed at a continuous basis. KAIZEN helps to reduce the losses, which affect our efficiencies, by the use of detailed procedure in a systematic manner by using the tools of KAIZEN. The KAIZEN policies are as follows:
  - Trying to achieve the cost reduction for all the resources
  - Ensuring ongoing programs to develop the overall equipment effectiveness
  - Ensuring high level of analysis to eliminate the losses
  - Focussing on easy handling of operators
- **Pillar 4 - Planned maintenance:** It is targeted towards having the trouble-free machines and defect-free production for achieving total customer satisfaction. The whole process can be broken down into four groups or families, which are as follows:
  - Preventive Maintenance
  - Breakdown Maintenance
  - Corrective Maintenance
  - Maintenance Prevention

  The policies followed in this pillar are as follows:
  - Achieve and sustain availability of machines
  - Optimum maintenance cost
  - Reduces spares inventory
  - Improve reliability and maintainability of machines

  Main targets of this pillar are as follows:
  - Zero equipment failure and break down
  - Improve reliability and maintainability by 50%
  - Reduce maintenance cost by 20%
  - Ensure availability of spares all the time

  Steps followed in planned maintenance are:

  1. Equipment evaluation and recoding present status
  2. Restoring deterioration and improve weakness

NOTES

3. Building up information management system
4. Mapping out of the plan
5. Preparing the predictive maintenance system by using equipment diagnostic techniques
6. Evaluating planned maintenance

- **Pillar 5 - Quality maintenance:** The highest level of quality should be maintained by defect-free manufacturing. For this it is necessary to identify the probable causes of defects and then move on to the potential quality control. Quality control moves from the reactive to the proactive approach.

  Policies of this pillar are as follows:

  1. Defect free conditions and control of equipment
  2. Quality maintenance activities to support quality assurance
  3. Focus on poka-yoke, that is, a fool-proof system
  4. In-line detection and segregation of defects
  5. Effective implementation of operator quality assurance

  Targets of this pillar are as follows:

  1. Achieve and sustain customer complaints at zero
  2. Reduce in-process defects by 50%
  3. Reduce cost of quality by 50%

- **Pillar 6 - Training:** This pillar states that a multi-skilled employee with a high morale is able to perform all the said functions effectively and efficiently and a well-versed training program is able to do the needful. Here, the workers are educated for the "know-why" of the assigned job. The employees are trained to achieve the desired skills and reach the phases of skills. The phases of skills are as follows:
  - **Phase 1:** Do not know
  - **Phase 2:** Know the theory but cannot do
  - **Phase 3:** Can do but cannot teach
  - **Phase 4:** Can do and also teach

  Policies of this pillar are as follows:

  1. Focus on improvement of knowledge, skills and techniques
  2. Develop an environment for self-learning
  3. The curriculum and tools of training are conducive to employee revitalisation
  4. Main targets of this pillar are as follows:
     a. Achieve the zero level downtime
     b. Achieve the zero loss
     c. Aim for 100% participation in suggestion scheme

Notes

- **Pillar 7 - Office TPM:** The office TPM helps in increasing productivity and effective functioning of the administrative department. It also helps in identifying losses so that they can be eliminated. This will include the analysing process towards the increased office automation. The major losses of the office TPM are as follows:
  - Processing loss
  - Cost loss
  - Communication loss
  - Idle loss
  - Set-up loss
  - Accuracy loss
  - Office equipment breakdown
  - Communication channel breakdown, telephone and fax lines
  - Time spent on retrieval of information
  - Non-availability of correct online stock status

  How to start office TPM?

  1. Provide the TPM system to all the departments.
  2. Assist these departments to identify the P, Q, C, D, S and M in each function related to the plant performance.
  3. Identify the scope for improvement in each function.
  4. Collect the relevant data.
  5. Help them to solve problems in their circles.
- **Pillar 8 - Safety, health and environment:** The main targets of this pillar as follows:
  - Zero accident
  - Zero health damage
  - Zero fires

Here, a committee is made that comprises the representatives of the officers and workers as well. The senior vice-president (Technical) is the head of the committee and highest importance is given to the safety of the plant. The manager (Safety) looks after the functions related to safety.

Self-Assessment Questions

13. The primary goal of TPM is to keep emergency and unscheduled maintenance to a maximum. (True/False)

14. Name the six parameters that TPM considers for improving the overall productivity of a production plant.

15. _____ is a comparison between the theoretical machine rates and the number of items actually produced on a machine during its operating time.

a. Availability

b. Quality

c. Performance

d. Quantity

NOTES

16. What is the basic purpose of OEE initiative?

17. TPM is based on six pillars. (True/False)

18. The SEITON pillar of 5S stands for:

    a. Sort out

    b. Organise

    c. Standardisation

    d. Self-discipline

19. _____is basically related to the small improvements that are to be performed at a continuous basis.

20. The _____TPM helps in increasing productivity and effective functioning of the administrative department.

Activity

Give an example from the Indian manufacturing industry that has implemented the philosophy of "Kaizen."

11.5 Summary

- Maintenance is an important service function of any efficient production system.
- The plant maintenance pays more attention to the maintenance of machines and equipment due to their frequent usage and strategic position in the entire production function.
- Ensuring efficiency and reliability of the production system are the two main objectives of maintenance management.
- There are basically two types of maintenance, namely planned and unplanned maintenance.
- Planned maintenance is a type of maintenance in which maintenance activities are predetermined within a time-bound schedule.
- The two types of planned maintenance are preventive maintenance and corrective maintenance.
- Preventive maintenance involves planning maintenance activities in anticipation of failures that may take place when the actual production starts.
- Corrective maintenance refers to a form of maintenance that is performed after a failure or fault has taken place.
- Unplanned maintenance is a type of maintenance work that is not planned in advance and is mainly based on predictions.
- Unplanned maintenance can be divided into two types, emergency maintenance and breakdown maintenance.

Notes

Developing a maintenance policy is a systematic approach and involves a number of steps, which are:

- Preparing a maintenance register
- Evaluating the current policy
- Prioritising the equipment
- Selecting maintenance tasks
- Selecting a maintenance policy
- Justifying tasks

- Machine failure can be defined as any event in a machine or any of its part or component that interrupts the normal functioning of the machine.
- Reasons for machine failures have been broadly classified into two categories:
  - Obsolescence
  - Surface degradation
- To decide on replacement, all factors that affect the decision should be analysed subjectively and objectively.
- The factors that are responsible for the replacement of machines and equipment in an organisation can be categorised under two heads, namely, technological factors and cost factors.
- Total productive maintenance (TPM) is implemented to increase the production and the morale and job satisfaction of employees.
- The overall equipment effectiveness (OEE) is a key performance indicator, which accounts for the following three elements:
  - Availability
  - Performance
  - Quality
- TPM is based on eight pillars
  - Pillar 1 - 5S
  - Pillar 2 - JISHU HOZEN (autonomous maintenance)
  - Pillar 3 - KAIZEN
  - Pillar 4 - Planned maintenance
  - Pillar 5 - Quality maintenance
  - Pillar 6 - Training
  - Pillar 7 - Office TPM
  - Pillar 8 - Safety, health and environment

NOTES

11.6 Glossary

- **Breakdown:** It refers to the failure of a machine or equipment that hampers the production process.
- **Deterioration:** It refers to the harm caused to an asset due to usual wear and tear.
- **Kaizen:** It refers to the Japanese concept of continuous improvement in all aspects.
- **Poka-Yoke:** It is a quality management tool that helps in preventing defects in products.
- **Preventive Maintenance (PM):** It refers to the planned maintenance of plant and equipment so that the life of the equipment can be improved by preventing depreciation and impairment.
- **Reliability:** It refers to the probability how efficiently a machine or equipment can perform.
- **Scrap:** It is recyclable left over from the manufacturing of products.

11.7 Terminal Questions

1. Explain the concept of maintenance management.
2. Discuss the major types of maintenance.
3. Differentiate between preventive maintenance and corrective maintenance.
4. Discuss the major factors that are responsible for the replacement of machines and equipment in an organisation.
5. Explain the concept of total productive maintenance (TPM).
6. Write a short note on the overall equipment effectiveness (OEE).
7. Discuss the eight pillars of TPM.

11.8 Answers

Q.	Self Assessment Questions
1.	Maintenance
2.	The main objective of maintenance management is to keep an efficient and reliable production system.
3.	Planned
4.	True
5.	Running maintenance; shutdown maintenance
6.	b. Breakdown maintenance
7.	Developing a maintenance policy is a systematic approach and involves a number of steps, which are preparing a maintenance register, evaluating the current policy, prioritising the equipment, selecting maintenance tasks, selecting a maintenance policy, and justifying tasks.
8.	Scheduled

Notes

9.	Machine failures
10.	False
11.	The replacement decisions should be taken by comparing the economy of an existing realistic book value of the equipment with its original cost, that is, the replacement may take the futuristic view.
12.	Technological factors, and cost factors
13.	False
14.	TPM considers productivity, quality, cost, delivery, safety, and morale as six parameters to improve the overall productivity of a production plant.
15.	c. Performance
16.	The basic purpose of OEE initiative is to make the most efficient and effective manufacturer in a given market and minimise the losses.
17.	False
18.	b. Organise
19.	KAIZEN
20.	Office
Q.	**Terminal Questions**
1.	Maintenance management is an important service function of any efficient production system that pays attention to the maintenance of machines and equipment due to their frequent usage and strategic position in the entire production function. Refer to section **11.2 Concept of Maintenance Management**.
2.	The two types of maintenance are planned and unplanned maintenance. Refer to section **11.2 Concept of Maintenance Management**.
3.	Preventive maintenance involves planning maintenance activities in anticipation of failures that may take place when the actual production starts. On the other hand, corrective maintenance refers to a form of maintenance that is performed after a failure or fault has taken place. Refer to section **11.2 Concept of Maintenance Management**.
4.	The factors that are responsible for the replacement of machines and equipment in an organisation can be categorised under two heads, namely, technological factors and cost factors. Refer to section **11.3 Replacement of Equipment**.
5.	Total productive maintenance (TPM) is implemented to increase the production and the morale and job satisfaction of employees. Refer to section **11.4 Total Productive Maintenance**.
6.	The overall equipment effectiveness (OEE) is a key performance indicator that keeps a check on the availability, performance and quality aspects of machines and equipment. Refer to section **11.4 Total Productive Maintenance**.
7.	TPM is based on eight pillars namely, 5S, JISHU HOZEN (autonomous maintenance), KAIZEN, planned maintenance, quality maintenance, training, office TPM, and safety, health and environment. Refer to section **11.4 Total Productive Maintenance**.

NOTES

11.9 Case Study: Total Productive Maintenance in Toyota

Toyota Motor Corporation is the world's leading, multinational organisation that deals in the manufacturing of automobiles. The organisation is known for its effective production system called Toyota Production System (TPS). This system is basically a set of powerful production techniques, management policies and practices. TPS is the key ingredient of the high quality output of Toyota. The system helps the organisation to complete its production process on time and eliminate wastes. To build TPS, the organisation has combined a number of techniques, such as just-in-time (JIT), total quality management (TQM) and total productive maintenance (TPM).

TPM acts as the ground level pillar of TPS, as it helps the organisation in performing maintenance activities on time, thereby achieving continuous quality improvement. Moreover, it reduces the inventory levels of the organisation with minimum stoppage in production. It also prevents the loss of productivity due to equipment deterioration, thereby reducing defects in the final output.

To implement TPM, Toyota encouraged 100% participation of its employees in the maintenance work. The organisation also attempted to enhance the knowledge of its employees related to maintenance work. For this, it strived to remove communication barriers between operators and technicians. However, it was not easy for the organisation to maintain a free flow of communication between them. This is because operators were having machine operating skills, while technicians were appointed for maintenance work. To bridge the gap between operators and technicians, the organisation followed a centralised approach and cross-trained its employees.

After that, Toyota started collecting and analysing data related to the performance of all its machines and equipment for implementing TPM. The implementation of TPM at Toyota boosted the morale of its employees and increased the efficiency of its production system. After successful implementation, Toyota has shown a long-term commitment towards preventive maintenance and quality management.

Discussion Questions

1. What was the major challenge faced by Toyota while implementing TPM?

   (**Hint:** The major challenge for Toyota is to maintain a free flow of communication between operators and technicians.)

2. What are the objectives of TPM?

   (**Hint:** One of the objectives of TPM is to monitor and regulate the work in process critically.)

11.10 References and Suggested Readings

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Notes

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