Industrial Management
Tutorial Notes

1 OVERVIEW OF INDUSTRIAL MANAGEMENT

Learning Objectives

After reading this chapter, you will understand :

- Concept of Industrial Management
- Development of Industrial Management
- Difference between industrial management and production management
- Organisation of an industry
- Objectives of industrial management
- Application areas of industrial management
- Importance of industrial management
- Problems faced in industrial management
- Scope of industrial management

1.1 INTRODUCTION

The term "Industrial Management" is quite confusing as different authors deal it in different ways It has many synonyms and many other branches which have developed from it. Anyway, we will follow a simple method to develop an introduction to the subject. By the time you finish reading the third article of this chapter "Development of Industrial Management", the meaning, its nature, scope and application areas will be quite evident and crystal clear. Some of the discussion in these articles have been dealt in detail in the earlier courses of "Industrial Psychology/Sociology" and "Engineering and Managerial Economics". Here we will be giving only brief outlines. Those readers who are interested in detail may refer to the books on these subject by the author of this book. We have purposely avoided repetition of detailed subject matter here.

Industrial Management is the combination of two words—*Industrial* and *Management*. Industrial implies referring to industry. Industry may be defined as "the application of complex and sophisticated methods to the production of economic goods and services". The complex and sophisticated methods refer to the use of machines which improve the quantity and quality of production. In our

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context, "Industry" does not simply refer to activities related to manufacturing, trade or business. It has a broader meaning and includes all sorts of operating or working organisations such as business, educational, governmental and religious. On the other hand, management means planning, organising, co-ordinating, controlling, motivating and directing various activities in an organisation. According to Henry Fayol "Management is to forecast and plan, to organize, to command, to coordinate and to control". However, this definition attempts to describe management in terms of what a manager does and not what management is? According to Oliver Sheldon "the term management is commonly used to cover the formation of policy, its execution, the designing of the organisations and its employment". However, our simple *working definition* is "Management is a process used to accomplish organizational goals".

The combination of these two words results in a new branch of engineering. Industrial Management may be defined as :

"The branch of engineering that deals with the creation and management of systems that integrates people, materials and energy in productive ways."

1.2 CONCEPT OF INDUSTRIAL MANAGEMENT

Industrial management is the organizational process that includes strategic planning, setting objectives, managing resources, deploying the human and financial assets needed to achieve objectives, and measuring results. Being a management functions it also includes recording and storing facts and information for later use or for others within the organization. The concept of management planning involves direction, planning, adjustment, control and cooperation. It draws upon specialized knowledge and skill in the mathematical,

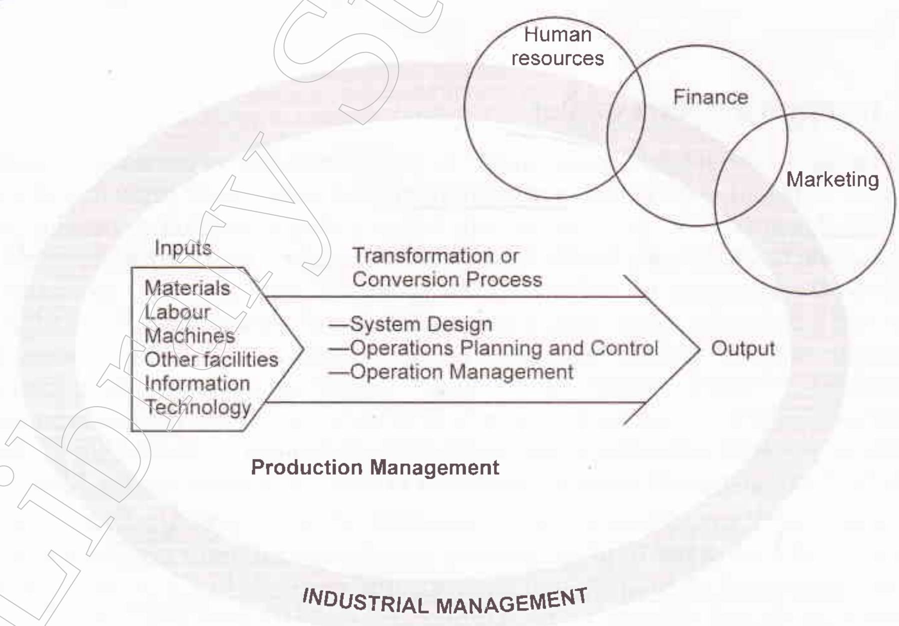

Fig. (1) Concept of Industrial Management

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physical and social sciences together with the principles and methods of engineering analysis and design. In this way it specifies, predict and evaluate the results obtained from such systems.

In its most comprehensive meaning, industrial management refers to the systematic management of all aspects of the industry (or factory). The techniques employed go beyond increasing productivity or controlling the mechanical cost factor. They also include organization structure, administration and human/labour problems. This has been shown in fig. (1).

Industrial management involves studying the performance of machines as well as people. *Specialists are employed* to keep machines in good working condition and to ensure the quality of their production. The flow of materials through the plant is *supervised* to ensure that neither workers nor machines are idle. Constant *inspection* is made to keep output up to standard. Charts are used for recording the accomplishment of both workers and machines and for comparing them with established standards. Careful accounts are kept of the cost of each operation. When a new article is to be manufactured, it is given a design that will make it suitable for machine production, and each step in its manufacture is *planned*, including the machines and materials to be used.

Essentially, the industrial management is concerned with the *design of a system* and its primary function is that of management. As such it provides a service function. Service function means to provide expert information. The facts are gathered, problems are subjected to analysis, tentative conclusions are made-compared-tested for various alternatives and finally the findings are presented with recommendations to the top management. For doing all this various tools and techniques of industrial management are employed.

Note : (1) Industrial Management is a branch of engineering. As such the person performing the functions of industrial management is an engineer by profession.

(2) Industrial Management and Industrial Engineering are synonymous terms.

(3) Industrial Management is different from production or operations management and is explained later on in detail.

1.3 DEVELOPMENT OF INDUSTRIAL MANAGEMENT

The term "industrial management" came into use in the United States around the turn of the twentieth century after the Industrial Revolution.

Industrial Revolution—The rise of factories

Before the Industrial Revolution people worked with hand tools, manufacturing articles in their own homes or in small shops. In the third quarter of the 18th century, steam power was applied to machinery. People and machines were brought together under one roof in factories, where the manufacturing process could be supervised. This was the beginning of *shop management*. In the next hundred years factories grew rapidly in size, in degree of mechanization, and in complexity of operation. However, the growth was accompanied by much waste and inefficiency. In the United States many engineers, spurred by the increased competition of the post-Civil War era, began to seek ways of improving plant efficiency.

The result of Industrial Revolution was :

- Machine power began to substitute for human power
- It led to mass production of economical goods
- Improved and less costly transportation systems became available which created larger market for goods
- Larger organizations developed to serve larger markets
- A need to understand work that had become complex was felt to improve plant efficiency.

Scientific Management

- The first sustained effort in the direction of improved efficiency was made by Frederick W. Taylor.
- His principles of scientific management resulted in :
  - Use of scientific method to define "One best way" for a job to be done.
  - Increased efficiency by selecting the right people for the job and training them to do it in one best way.
  - Motivation to workers due to incentive wage plans
  - Separation of managerial work from operative work.
- The husband-wife pair of Gilbreths developed "time and motion" studies
- Henry Ford introduced the division of labour in the factories.

Human Relations Movement

Little attention was paid to the motivational content of work. The accidental discovery of the importance of human relations was made by the Hawthorne studies from 1927 to 1932. The research was supervised by Elton Mayo. While conducting productivity studies at Western Electric, Mayo demonstrated that workers' efficiency depended on a wide range of relations within groups as well as on compensation. This finding led to an eventual split in the study of industrial management, with one branch emphasizing an understanding of organization theory and behaviour and the other emphasizing the mechanics of production,, also known as operations. While science continued to provide the basis for acedamic studies of both branches, the practice of management was increasingly recognized as a complex set of knowledge and skills. Later, increased specialization of management talents led to the dissipation of comprehensive studies in industrial management, with more attention paid to specialties like financial management, human resources management, and operations management.

Modern Trends

Following World War II, many of the dehumanizing aspects of factory life were a leading concern of both union movements and studies to improve quality of work life. Work design and socio-technical approaches to work became the focus of industrial management. By the 1960s, however, the U.S. economy had

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shifted to a service economy, with more than half of the labour in the country employed in services. This shift was to be followed by the information revolution and extraordinarily high rates of global competitiveness, changes that had dramatic impacts on work content. The term "industrial management" became increasingly irrelevant as the nature and content of work shifted to computerization and other spheres of the economy.

Modern technological devices, particularly in the areas of computers, electronics, thermodynamics and mechanics, have made automatic and semi-automatic machines a reality. The development of such automation is bringing about a second industrial revolution and is causing vast changes in commerce as well as the way work is organized. Such technological changes and the need to improve productivity and quality of products in traditional factory systems also changed industrial management practices.

Today, the segment of management that seeks improvements in efficiency and productivity is known as *production and operations management*. Its most recent developments include integrated methods of management that contain elements of programmable technology, quality improvement, just-in-time delivery, lean production, and supply chain management.

In India, many colleges and universities provide degree in Industrial Engineering. All big organisations like TISCO, TELCO, RIL, etc., employ industrial engineers. The reporting of such engineers is directly to the top-management.

SELF-STUDY

Assignment I : What are the ancient civilization examples that required Industrial Management applications?

Assignment II : Which was the largest industrial plant of the medieval world? List its industrial management applications.

1.4 INDUSTRIAL MANAGEMENT VERSUS PRODUCTION MANAGEMENT

- Industrial management deals with the analysis, design and control of productive systems. A productive system is any system that produces either a product or a service. On the other hand, production management attempts to familiarize a person with concepts and techniques specific to the analysis and management of a production activity.
- Production management is mostly associated with managing a production environment. The design and analysis of productive system are outside its purview. On the other hand, industrial management is concerned with designing system and providing expert information without actually operating the systems. Production or operations management is a sub-speciality of industrial management.

1.5 INDUSTRIAL ORGANISATION

When we talk about management of an industry, we should be clear about what is to be managed. There are various departments in a big organisation engaged in various activities which play their own role in helping the production department meet its objectives. Even in service organisations like banks, software companies, hospitals, etc. there are various departments which have to managed through industrial management. Here we will be discussing the general organisation of a big manufacturing factory which can be modified for any service-industry also according to its needs.

(1) *Head of Production Department* : Production head is the supreme officer of production organisation. He is called *works manager* or *general manager*. He is the person who is responsible for all the function of production department and all the other sub-divisions of production organisation is controlled and directed by him.

(2) *Manufacturing Department* : Manufacturing department is that portion of production organization where the actual activities or operations are performed for the transformation of raw material into finished goods. The head of this department is called *production manager*. The prime responsibility of production manager is to ensure the production according to the predetermined plan and directions received.

If the organisation is diversified, meaning producing different types of product then in such a case the manufacturing department can be further divided in various sub-manufacturing department like manufacturing unit, repairing unit, assembling unit, etc.

(3) *Technical Department* : The primary task of technical department is to enhance the quality of finished goods by performing research and development on modern techniques of production. *Technical director* is the head of this department. Generally following sub-sections are included in this department :

(i) Development section

(ii) Design section

(iii) Research section

(iv) Testing section

(4) *Production, Planning and Control Department* : The main function of this department is preparation of production plan and execution of that plan in order to achieve predetermined goals in a given period of time. This department also controls all the other department related to production. The head of this department is known as *Production Controller*.

(5) *Quality Control Department* : Generally the function of quality control is performed by production planning and control department but some firms establish a separate quality control department to ensure the quality of their finished product. *Chief Inspector* is the head of this department. He has a group of inspectors under him. This department controls the quality at various level of production.

(6) *Engineering Department* : This department is headed by *chief engineer*. Maintenance of machinery of firm as well as continuous improvement in machines and tools used in production are included in the function of this department. Department also prepares various dies used in production.

(7) *Purchase Department* : Generally the purchase department works under the chief works manager. The main function of this department includes the purchase of raw material, machine tools and other necessary items used in production. This department evaluates the price and quality of purchased material at the point of purchase.

Various department send their requirement to purchase department which purchases the items at favourable price.

(8) *Store Department* : Each firm establishes a store department headed by *chief store keeper* to balance the demand and supply of raw material and finished goods. Availability of required type of material of required quality in adequate quantity, adequate and safe handling, disposal of scrape, measurement of material and record of entries related to store in related books are the various functions performed by the store department. Inventory management is also performed by them.

(9) *Maintenance Department* : Maintenance department is a main and necessary department of a manufacturing firm. Maintenance department looks after the various assets of the firm like machinery, building, vehicles, etc. Department is headed by *Maintenance Manger.*

(10) *Security Department* : This department is responsible for security in the industry. Department is headed by *Security Director*. Department formulates the security related rules and execute the rules at all the level in the concern. In case of any accident, investigation and analysis is done by this department and department also prepares necessary documents.

Along with all above departments, some other departments are also established such as legal department, export-import department, Safety-Health and Environment department, etc. in a big manufacturing concern.

1.6 OBJECTIVES OF INDUSTRIAL MANAGEMENT

The ultimate objective of industrial management is to produce the right quantity of right quality goods at the right time. These are attained through :

(1) *Manufacturing Costs* : The unit cost of the product should be estimated carefully and every effort should be made to stick to the cost standards. For this purpose, the efforts should be made to segregate the costs into two—direct costs and variable costs. Efforts should be made for the following :

(i) Reduction in the variable costs.
(ii) Reduction in the fixed costs.
(iii) Increase in the volume of production, so that the fixed costs may be spread over more production resulting in the reduction in the per unit absorption.

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(iv) The allocation of the fixed overheads should be made on scientific basis.

(2) *Machinery and Equipment* : The objectives in the area of machinery and equipment are divided into :

(i) Selection and acquisition of machinery and equipment according to production process.

(ii) Utilization of machinery and equipment.

The adequacy of the existing machinery should be considered and proper additions and replacements should be made according to the requirements. Efforts should also be made to increase the utilization rate of machinery through repair, maintenance and maximum occupancy of the machines.

(3) *Materials* : The materials objectives must be prescribed in terms of units, rupee value and space requirements. The per unit materials costs should be specified and efforts should be made to increase the inventory turnover of all types of inventories–raw materials, work-in-progress and finished goods.

(4) *Manpower* : Manpower is an important as well as typical input in manufacturing activities. So the objectives of the production activities are as regards manpower must be closely allied with the objectives of selection, placement, training, rewarding and utilization of manpower. Usually, these objectives are considered in terms of employee turnover rates, safety measurements, industrial relations, absenteeism, etc.

(5) *Manufacturing Services* : The provision of proper and adequate services directly affects the utilization of other inputs such as men, machines and materials. Proper objectives should be set for the installation of important facilities such as power, water supply, material handling, etc. In a condensed form, it can be stated that the objectives of the manufacturing activities are–to manufacture a quality product on schedule, at the lowest possible costs, with maximum asset turnover, to achieve consumer satisfaction. This statement is closely related to the ultimate and intermediate objectives of the production function.

(6) *Product Quality* : Generally, the product quality standards are often established by the product specifications or by the consumers. The manufacturing organization should try to translate such quality prescriptions into some measurable objectives. It should be noted that the product quality comes in conflict with the manufacturing cost objective and the manufacturing time-schedule. The maintenance of the quality should not result in increase in manufacturing costs or delay in the production. A proper balance must be maintained between quality and cost as well as quality and time-schedule.

(7) *Manufacturing Schedule* : There are many forces which compel side-tracking in the manufacturing activity. The time schedule should not be set for the shipment alone; it should be broken up into all the sub-systems like operating cycle time, inventory turnover rate, machine utilization rate, direct and indirect man-hours per unit, capacity utilization, machine and labour idle time, set-up, repair and maintenance time, etc. Time schedule objective directly affects the cost, quality and the goodwill of the business in terms of regularity of shipment.

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1.7 APPLICATIONS OF INDUSTRIAL MANAGEMENT

Earlier, Industrial Management was mainly applied to manufacturing industries for improving methods of productions, to develop work standards or to formulate production control and wage policies. Later on, it's use started in non-manufacturing activities such as construction and transportation, farm and air-line operation and maintenance, public utilities, government and military operations. Today also, Industrial Management find major applications in manufacturing plants and industries. In the present era of cut-throat competition at various stages of operations, an enterprise should produce goods and services keeping into consideration the requirements and satisfaction of the potential customer. The objective should be to produce goods at least costs and to the maximum satisfaction of the buyer. To meet this objective, application of Industrial Management is in following areas :

(1) ***Design and Development*** : Product design and development depends heavily on inputs from the marketing function and several branches of engineering, *e.g.*, plant engineering, manufacturing engineering, including production engineering. If the design of the production is not good from the production stand point, it may require costly adjustments to the production process in terms of equipment, material and man power. If the design is good, production costs may be low enough to substantially enhance a firm's profit making position. The key role of good and effective product design is rapidly becoming evident and firms prominent in competitive market tends to exploit details of design that reduce production costs or develop product features that allow it to appeal to a wider market.

(2) ***Plant Layout and Material Handling*** : The physical arrangement of manufacturing components and the equipment for handling the material during production process has considerable effect on cost of production. The material handling system and the plant layout should be most efficient for the given situation.

(3) ***Method Study and Work Measurement*** : Method study and measurement techniques are applied to find out the relationship between output of goods and services and input of human and material resources. If material including scrap and waste, can be accurately measured and controlled, it is possible to do so for labour component too. The problem associated with measuring labour efficiency are more difficult than with material, but they are not unmeasurable. The measurement should try to find the most appropriate method of performing various operation involved in a production system so as to obtain optimum use of resources and man-machine relationship in increasing productivity.

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(4) ***Production Forecasting*** : Forecasting is necessary if the business firm is to anticipate the demand for its products and services. Sufficient time must be allowed to get inputs and transform them into output at right time and ritht place. Forecasts can be used as an analysis of past data, consideration of current events and future developments. These forecasts becomes the basis for the plants and schedules for buying, manufacturing, selling and other activities of the firm.

(5) ***Production Planning and Scheduling*** : In order to co-ordinate different activities and operations of an organisation, a master plan of activities and a schedule of their performance is needed. Careful planning anticipates the need for people, materials and equipment so that sufficient time between order and delivery of goods and services is available to make necessary changes, if required. The planning and scheduling of a firm perform a co-ordinated effort with resources and available time in attempting to utilise the full capacity to the firm to produce.

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(6) ***Proper Inventory Control*** : Inventory implies all the materials, parts, supplies, tools and in-process or finished products kept in stocks for some time. The procurement policy of these items requires careful consideration and analysis. The purchases should be planned in economic lot sizes and the time of purchase should be so scheduled that the investment in the inventory is at lowest possible level. This implies determination of economic lot sizes and re-order level. It also involves exploring reliable sources for obtaining materials and supplies.

(7) ***Quality Control*** : While planning, scheduling and inventory control are responsible for providing quantity and timing of production, quality control is responsible for providing quality. Quality must be designed and manufactured into the product. Although customers may desire higher quality, they may not be willing to pay the resulting price. In such a way quality standard should be set up that will be acceptable to the customers and yet economically feasible to the product. It is a matter of finding a balance between too much and too little quality.

(8) ***Production Control*** : It is very necessary in today's highly competitive world that organisation should invest its resources intelligently and carefully. A major part of these resources are utilised in production activities. Through it is the prime responsibility of production manager to control the quantity of the produced goods, proper Industrial Management avoids the situation of over-production and under-production. In case of over-production the resources which are scare in nature will be wasted and in the situation of under production organisation will be unable to meet the demand in the market. So both the situations will adversely effect the profitability of the company.

(9) ***Method Analysis*** : There can be a number of ways in which some operation can be executed. Through Industrial Management we select the most efficient and economical method to perform the operation. Method analysis improves the productivity of the concern and minimizes the cost of production.

(10) ***Motivate Workers*** : We have to motivate workers to generate their interest in work and increase their efforts. This can be done by providing them wage incentives. This will result in an increase of labour productivity.

(11) ***Other Functions*** : Alongwith the above functions and responsibilities, other important functions can be included in this list of functions. Activities such as arrangement of efficient labour, attract funds, devise systems for coordinated efforts, to be in touch with modern production techniques, interaction with marketing, research and development departments, meeting environmental and other legislations etc.

1.8 IMPORTANCE OF INDUSTRIAL MANAGEMENT

Earlier when the scope of business was limited and total production, total market and total demand was comparatively less, there was no accute need of industrial management. But now the world has been changed a lot. Now the enterprises are broader and more diversified. Today the world is of high production and competition. So the concept of industrial management is continuously developing and spreading. In the world of cut throat competition only those product can survive which can be proved to be the best. Now organisations are focussing on quality control, standardisation and use of modern techniques in their production systems. The production function is based upon the effective plans that serves organisation for achieving the organisational objectives. So we can say that the industrial management is the key function that plays a vital role in the success of organisation. The results of industrial management are reflected in the serving of many interested parties of an organisation such as :

(1) *The Consumers :* The consumers benefits from higher productivity, better and reliable quality, reasonable price, satisfactory service and timely delivery of goods.

(2) *The Investors :* The investors get higher return on investment and their investments obtain capital appreciation also. Market value of securities is governed by the earning power and asset value of the business.

(3) *The Community :* When all business which are operating in the community are prosperous, due to industrial management, we have economic and social stability and the citizens of that community have pride and satisfaction.

(4) *The Suppliers :* Small or large companies depend upon other companies as sources of raw materials, components and services. We have effective co-operation, best inter communication and mutual confidence between the business buyers and their suppliers. The company and its suppliers can have enduring partnership for the satisfaction of both.

(5) *The Employees :* The employees including the management get higher remuneration, stable employment, security of jobs, better working conditions and above all enhanced personal satisfaction through joy of achievement. High employee morale due to job satisfaction gives higher output.

(6) *The Nation :* When all industries in the national economic system demonstrate industrial management, the entire national economy will accomplish all round security and prosperity.

1.9 PROBLEMS OF INDUSTRIAL MANAGEMENT

The job of industrial management is difficult because of changes in market, technology, attitude of people, government regulations, etc. The regular problems faced in industrial management are :

(1) *Problem of Location* : Main problem of industrial management is associated with the selection of plant location. While deciding for the location,

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industrial management has to keep in mind various aspects such as availability of efficient labour, nearness of the potential market, climate and weather conditions, etc. All the conditions can not be favourable at all the times.

(2) *Problem of Selection of Production Method* : After selection of the location next main problem arises which is related to the selection of production method. There are various alternative method of production available to produce a particular product. Industrial management has to select the best method as per the requirement, sources available and quality of the method.

(3) *Problem of Plant Layout* : Problem of plant layout is one of the important problem in front of the industrial management. The layout should be such that it is most suitable for the production of that product and eliminate/ minimises the breakdown in production process.

(4) *Problem of Designing of Product* : After selection of labour, the next problem arises related to the designing of the product. Designing of product should be done carefully because frequent changes are not possible in the designed product. While designing the product, factors such as specific, identity, market demand, simplicity in production have to be considered.

(5) *Problem of Production and Inventory Control* : Problem related to production and inventory control is also a major problem. Sufficient raw material for the production function and regular supply of finished product according to market demand are two major responsibilities of industrial management. The stock of raw material and finished goods should not be more than the requirement. To ensure this the industrial management is facilitated by various methods such as Economic Order Quantity (EOQ), Re-order Point (ROP), ABC technique of Inventory Control, etc.

(6) *Problem of Quality Control* : Maintaining the quality of a product can be seen as another important problem of industrial management. To ensure the quality of finished product, industrial management ensures inspection activities at various level of production. Standardisation is also done while keeping this problem in mind.

(7) *Labour Problem* : For effective and quality production, the need of efficient and skilled labour arises. The aquision of efficient labour is also one of the problem of industrial management. After acquiring the labour, their training is also arranged by the industrial management. Industrial management should keep eyes on the production capacity of the labour and try to improve their overall performance. Various methods such as work measurement, work analysis, work supervision and motivational method of wage payment, etc. can be aplied by industrial management for this purpose.

(8) *Problem of Cost Control* : Any product can survive in the market for long time when it is available at lower price than its competitors. That can be possible only by cost control. Cost can be controlled by reducing or eliminating the wastage at all level and by maintaining economy in production. Cost control is also one of the main problem of industrial management.

Apart from all these above problems, sometimes industrial management has to deal with various problems such as pollution control, limited financial resources of the organisation, government policies and regulations, etc.

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1.10 SCOPE OF INDUSTRIAL MANAGEMENT

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The scope of industrial management can be discussed in two broad areas :

(1) Designing of the industrial system and product

(2) Analyzing and controlling the industrial system

(1) *Activities Relating to Industrial System Designing* : The industrial management work starts as soon as the idea of production of a certain commodity comes in the mind of an entrepreneur. Primary task includes preparation of product profile with the help of experts of technological department and market serveys. Plant location and plant layout have to be decided. Decision relating to the industrial system design is the second activity of the industrial management. This activity concerns the production engineering and includes problems regarding design of tools and jigs, the design-development -installation of equipment and the selection of the optimum size of the firm. All these areas require the technical expertise. The selection of an optimum plant location very much depends upon the decision taken regarding production engineering. The next decision regarding production system design concerns the use of those techniques which are concerned with work environment and work measurement and includes problems like motion study, process analysis, layout the plant, materials handling and time study.

Apart from these problems, the system designer should pay full attention to two other important problems, viz. :

(i) Human factor, *i.e.*, the impact of production system on the workers operating it and

(ii) Research and development activities.

These two problems have a vital impact on industrial system designing.

(2) *Activities Relating to Analysis and Control of Activities* : The next problem after the designing of the industrial system is the analysis and control of the production system. It includes all decisions regarding production administration and therefore all functions of the management so for as they are applicable to the production system. These form the subject matter of the industrial management. These activities are :

(i) *Production Planning* : The first decision in this regard is production planning. It includes preparation of short-term production schedules, plan for maintaining the records of raw materials and finished and semi-finished stock, specifying how the production resources of the concern are to be employed over some future time in response to the predicted demand for products and services.

(ii) *Production Control* : After planning, the next managerial function is to control the production according to the production plans because production plans cannot be activated unless they are properly guided and controlled. For this purpose, production manager has to regulate work assignment, review work progress and remove discrepancies, if any, in the actual and planned performances. The production manager has to look after the production control activities at three levels :

(a) Control of static inventory such as raw materials, purchased parts, finished goods and supplies through the inventory control technique;

(b) Control of flow of materials into the plants through the technique of judicious purchasing;

(c) Control of work-in-progress through production control.

(iii) *Quality Control* : The other important decision concerns quality control. Product quality refers to the composite product characteristics of engineering and manufacturing that determines the degree to which the product in use will meet the expectations of the customers. Quality control can be ensured through the techniques of inspection and statistical quality control.

(iv) *Co-ordination with Other Departments* : No plan can be successful until and unless it gets an active support from rest of the departments of organisation. For instance, marketing department provides the data related to estimated demand without which the production plan can not be prepared. So co-ordination with other departments is also included under the scope of industrial management.

(v) *Dependent Services and Departments* : Various services and departments on which produciton plan is totally dependent is also included in the scope of industrial management such as standardisation, simplification, inspection, specialisation and quality control, inventory control, research and development, diversification, employee amenities, pollution control, etc.

REVIEW QUestions

1. Define Industrial Management and explain its concept.
2. Trace the evolution and historical development of Industrial Management.
3. How is Industrial Management different from Production Management?
4. How is an industry organised? How is this set-up different for service organisation?
5. What are the principles of industrial management in an organisation?
6. What are the various objectives of industrial management?
7. Why is industrial management necessary?
8. What is industrial management human relation?
9. What are the application areas of industrial management?
10. Describe clearly the various functions of industrial management in a modern organisation.
11. What are the responsibilities of a person associated with industrial management?
12. What is the importance of industrial management?
13. What are the problems associated with industrial management?
14. What is the scope of industrial management?

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2 PRODUCTIVITY, PRODUCTION SYSTEMS AND INDUSTRIAL OWNERSHIP

Learning Objectives

After reading this chapter, you will understand :

- Meaning and concept of productivity
- Difference of productivity from production and profitability
- Various measurements of productivity
- Purpose and benefits of increasing productivity
- Importance of productivity
- Various techniques and procedure for increasing productivity
- Various types of production systems—their characteristics, advantages, disadvantages and suitability
- Various types of industrial ownership—their salient features, merits, demerits and applications

2.1 PRODUCTIVITY

To understand productivity, we start with discussing the production process. Fig. (1) shows a simple production process representation.

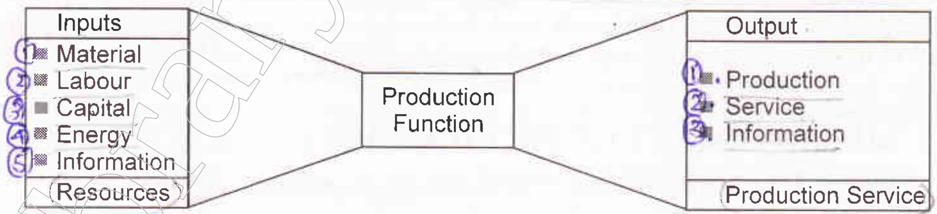

Fig. (1) Production process

From the figure we observe that there are various inputs or resources which are converted to output through the production function. The production function converts the inputs into output. Inputs may be in the form of materials, labour, capital (money), energy, information, etc. Output can be in the form of a product, service or information.

Having understood this, we will now define productivity.

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Definition

Productivity is defined as the ratio of output to input of a production system, *i.e.*,

$$\text{Productivity} = \frac{\text{Output}}{\text{Inputs}}$$

Meaning

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Productivity of a production system is analogous to the efficiency of a machine. Therefore, productivity is an efficiency of the production system. Just as it is desired to increase the efficiency of a machine, it is also aimed to raise the productivity within the available resources.

Hence, to increase productivity we want to make this ratio of output to inputs as large as possible which can be practical. This can be achieved by :

(i) *Either* producing more output with the same inputs.

(ii) *Or* using fewer inputs for the same outputs.

Productivity is a common measure of how well a country, industry or business unit is doing using its resources or factors of production.

Productivity and Production

The concept of productivity and production are totally different. Production refers to absolute measure of output whereas productivity is a relative term. Here output is expressed in terms of input.

Production may show a rise without a corresponding rise in the productivity and vice versa. Note that rising productivity does not necessarily mean an increase in production.

Imp: **Productivity and Profitability**

Profitability is the ratio of difference of revenue and cost to investment, *i.e.*, Profitability = (Revenue − Cost)/investment. Profitability can be increased by reducing costs which in turn also increases productivity. However, productivity is a necessary but not a sufficient condition. For example, profitability can be increased by increasing selling price. This may not increase productivity since, revenue is not related to productivity. A decrease in the price of the product may lead to decreasing profitability even though productivity may be rising.

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2.2 MEASUREMENT OF PRODUCTIVITY

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There are three major types of productivity measures :

(1) Partial Productivity

Partial productivity is the ratio of output to one class of input among many factors of production. For example, labour productivity measures the productivity of labour. Similarly, material, machine, land and capital productivities can be defined. Thus,

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$$\text{Labour Productivity} = \frac{\text{Output}}{\text{Labour Input}}$$

$$\text{Capital productivity} = \frac{\text{Output}}{\text{Capital employed}}$$

$$\text{Material productivity} = \frac{\text{Output}}{\text{Materials input}} \quad \text{and so on.}$$

(2) Total Factor Productivity

Total factor productivity is the ratio of net output to the sum of associated labour and capital (factor) inputs. Net output means output minus material, capital, energy and other input expenses. Thus,

$$\boxed{\text{Total Factor Productivity} = \frac{\text{Net Output}}{\text{Labour inputs} + \text{Capital inputs}}}$$

Net output = output – material, capital, energy & other input expenses

(3) Total Productivity

Total productivity is the ratio of total output to the sum of all input factors. Thus, it represents the joint impact of all the input factors in producing the output.

$$\text{Total Productivity} = \frac{\text{Total Tangible (measurable) Output}}{\text{Total Tangible Input}}$$

tangible - अतिरिक्त

Total tangible output = Value of finished goods + value of partially finished units + dividends from securities + interest + other income.

Total tangible input = Value of human, material, capital, energy and other inputs used.

The outputs and inputs of the company must be expressed in a common unit preferably in monetary value, say rupee value. To compare productivity, indices are to be adjusted to the base year and must be stated in terms of base year rupee value. This is referred to as deflating the input and output factors. Deflators are used to nullify the effect of changing price from one year to another.

$$\boxed{\text{Deflator} = \frac{\text{Current Year Price}}{\text{Base Year Price}}}$$

2.2-1 *PRODUCTIVITY INDEX*

Productivity index is used to compare the productivity during the current year with the productivity during the base year. Base year is any year which the company uses for comparative study.

$$\text{Productivity Index} = \frac{\text{Productivity during the current year}}{\text{Productivity during the base period}}$$

The three major sources of information for constructing various types of productivity index are :

(1) Product Identification Information

(2) Accounting Information

(3) Work Measurement Information

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(1) *Product Identification Information*

The product catalogs and drawings serve to provide a framework for identifying the different kinds of products prior to weighting each kind of output in the mix. Only after proper weighting the outputs can be aggregated.

(2) *Accounting Information*

Depending on the sophistication of the accounting system in use, the weighting of each kind of output may or may not be feasible from accounting records alone. With a detailed cost accounting system (having data of allocating labour, material and overhead costs to each kind of product) all the requisite information may be available.

In the case of *service* or *indirect activities* for which *output identification* is seldom available, even sophisticated cost accounting systems tend to lump together functional costs regardless of the product mix or its change from period to period. Hence, subsequent to the use of some technique for identifying the different kinds of service outputs, some type of *work measurement* is usually necessary to assist in allocating the different costs (weightings) to the different kinds of products prior to aggregation.

(3) *Work Measurement Information*

Work measurement is used here to refer to the use of any technique to determine the amount of *labour* required to produce each kind of output in a base period. Such information is needed to complete almost all productivity computations other than those for raw materials.

Example 1 *Find the partial productivity and total productivity for a company for which the following data is available :*

Output = *Rs.* 15000, *Labour input* = *Rs.* 4500, *Material input Rs.* 3000, *Capital input* = 4500, *Energy input* = *Rs.* 1500, *Other input expenses* = *Rs.* 750. *Assume the above values are in constant rupees with respect to a base period.*

Solution

$$\text{Labour productivity} = \frac{\text{Output}}{\text{Labour input}} = \frac{15000}{4500} = 3.3$$

$$\text{Material productivity} = \frac{\text{Output}}{\text{Material input}} = \frac{15000}{3000} = 5.0$$

$$\text{Capital productivity} = \frac{\text{Output}}{\text{Capital input}} = \frac{15000}{4500} = 3.3$$

$$\text{Energy productivity} = \frac{\text{Output}}{\text{Energy input}} = \frac{15000}{1500} = 10.0$$

$$\text{Other expenses productivity} = \frac{\text{Output}}{\text{Other expenses input}} = \frac{15000}{750} = 20.0$$

$$\text{Total factor productivity} = \frac{\text{Net output}}{\text{(Labor + capital) input}}$$

$$\text{Net output} = \text{Output} - (\text{Material input} + \text{Capital input} + \text{Energy input} + \text{Other expenses input})$$

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$$= 15000 - (3000 + 4500 + 1500 + 750)$$
$$= 15000 - 9750 = \text{Rs. } 5250$$

$$\text{Labour + Capital input} = (4500 + 4500) = \text{Rs. } 9000$$

Therefore, $\text{Total factor productivity} = \frac{5250}{9000} = 0.583$

$$\text{Total productivity} = \frac{15000}{4500 + 3000 + 4500 + 1500 + 750} = \frac{15000}{14250} = 1.05$$

Example 2 *Products X and Y are being manufactured by a company using materials A and B. Both materials are equally suitable. Product X is expected to sell at Rs. 75 per unit and product B at Rs. 35 per unit. The operating data is given below :*

	Material A	Material B
Output X	200 units	400 units
Output Y	300 units	200 units
Quantity of raw material usage	1000 kg	1000 kg
Labour usage	300 man-hours	250 man-hours
Electric energy consumption	1000 kWh	1500 kWh
Cost of raw material/kg	Rs. 22	Rs. 33
Labour cost per man hour	Rs. 10	Rs. 10
Electric Energy/kwhr	Rs. 2.0	Rs. 2.0

Compare the productivity of material, labour and electrical energy in using materials A and B. Comment on the relative advantage of using either of the materials.

Solution $\text{Productivity} = \frac{\text{Value of Output}}{\text{Value of Input}}$

Sales value of output with material A

= Output of product X in unit's × rate/unit of X

+ output of product Y in unit's × rate/unit of Y

$= 200 \times 75 + 300 \times 35 = 15000 + 10{,}500 = 25{,}500$

Sales value of output with material B

$= 400 \times 75 + 200 \times 35 = 30{,}000 + 7{,}000 = 37000$

The partial productivity of different factors of production is as follows :

S. No.	Productivity (type)	Material A	Material B
(1)	Productivity of raw materials $= \frac{\text{Sales value of output}}{\text{Value of raw material used}}$	$\frac{25{,}500}{1000 \times 22} = 1.16$	$\frac{37{,}000}{1000 \times 33} = 1.12$

(2)	Labour productivity $= \dfrac{\text{Sales value of output}}{\text{Value of labour used}}$	$\dfrac{25{,}500}{300 \times 10} = 8.5$	$\dfrac{37{,}000}{250 \times 10} = 14.80$
(3)	Productivity of energy $= \dfrac{\text{Sales value of output}}{\text{Value of electrical energy used}}$	$\dfrac{25{,}500}{1000 \times 2} = 12.75$	$\dfrac{37{,}000}{1500 \times 2} = 12.33$

Hence, we see that the productivities at (1) and (3) by using either material A or B are nearly the same. If labour is the key factor, use of material B is better as it yields higher productivity 14.8 > 8.5.

2.3 PURPOSE AND BENEFITS OF INCREASING PRODUCTIVITY

(1) For Management

(i) To earn good profit because of reduction in costs.

(ii) To sell more, to earn profit.

(iii) To have better utilization of resources.

(iv) To stand better in the market.

(v) Provide overall prosperity and reputation of the company.

(2) For Workers

(i) Higher wages.

(ii) Better working conditions, improved morale.

(iii) Higher standard of living.

(iv) Job security and satisfaction.

(3) For Consumers

(i) Better quality goods at reduced prices which helps to raise their standard of living.

(ii) More satisfaction.

(4) To Government

(i) Higher profits earned by factories will bring more revenue to the government by taxation.

(ii) Export trades may develop bringing more foreign exchange to the nation.

(iii) It helps to increase the welfare of the nation and development of national economy.

(iv) It helps better utilization of resources of the nation.

(v) It increases per capita income.

(vi) Development of the nation.

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2.4 FACTORS AFFECTING PRODUCTIVITY

Productivity is defined as the ratio between output and input. Thus, all factors which affect output and inputs will also affect the measure of productivity. Following factors affect the productivity :

(1) *Technological Development :* Technical factors including the degree of mechanization, technical know-how, raw materials, layout and the methods and techniques of work determine the level of technological development in any industry. The principal factors in technological development affecting productivity are :

(i) *Size of the Plant :* The size of the plant and the capacity-utilization has direct bearing on productivity. Production below or above the optimum level will be uneconomical and will tend towards lower level of productivity.

(ii) *Research and Development :* Investment in research and development may yield better method of work and better design and quality of products.

(iii) *Plant and Job Layout :* The arrangement of machines and positions in the plant and the set-up of the work-bench of an individual worker will determine how economically and efficiently production will be carried out.

(iv) *Machine and Equipment Design :* Whether the design of machinery and equipment is modern and in keeping with the limitations and capacities of the workers will also determine the production efficiency and level of productivity.

(v) *Production Processes :* Advanced production processes involving the use of modern integrated and automatic machinery and semi-processed materials have been known to help in raising levels of productivity.

(vi) *Power, Raw Materials, etc. :* Improved quality of raw materials and efficient use of power have a favourable effect on productivity.

(vii) *Scientific Management Techniques :* Scientific management techniques such as better planning of work, simplification of methods, time and motion study, emphasis for reduced wastage and spoilage have positive effects on productivity.

(2) *Individual Factors :* Individual factors such as knowledge, skill and attitude also affect the productivity of industry. Knowledge is acquired through training, education and interest on the part of learner. Skill is affected by aptitude (one's capacity to learn a particular kind of work), personality (emotional maturity, balance of mind, etc.) as also by education, experience, training, etc. Increased knowledge, skill and aptitude certainly increase the productivity and a person deficient in these personal attributes is less productive than an average man.

(3) *Organization Factors :* Organization factors include various steps taken by the organization towards maintaining better industrial relations such as delegation and decentralization of authority, participative management, workers' participation in management, organizational efficiency, proper personnel policies relating to selection, placement, promotion, wage salary levels, incentives, merit rating, job evaluation, training and provision for two-way communication, supervision, etc. These factors also influence motivation.

(4) *Work Environment :* The importance of proper work environment and physical conditions on the job has been emphasized by industrial psychologists and human engineers. Better work environment ensures the greatest ease at work through better ventilation and light arrangement, improved safety devices, reduction in noise, introducing suitable rest-pause, etc.

(5) *Other Factors :* There are several other factors that affect productivity. These are :

(i) *Natural Factors :* Physical, geographical and climatic conditions influence the productivity at large. Abundance of natural resources affects the productivity and similarly climate affects the efficiency of workers to a great extent.

(ii) *Managerial Factors :* The industrial productivity is influenced very much through managerial ability and leadership. The managerial ability of utilizing the available resources to the maximum, organizing capacity, foresightedness, decision-making ability and entrepreneurship are certain factors that contribute to productivity.

(iii) *Government Policy :* Government policies towards industry also contribute to industrial productivity. Taxation policy, financial and administrative policy, tariff policy and protection policy affect the productivity to a large extent.

2.5 INCREASING PRODUCTIVITY OF RESOURCES

Increasing productivity of resources implies, getting more number of goods (output) from the same amount of resources (input). Increasing productivity is possible through :

(1) *Material :* Industries in which the cost of raw material is a big percentage of the cost of finished goods, higher productivity can be achieved through proper use of materials, *i.e.,* by reducing scrap. Sometimes a little change in the design of the component or component layout may save a lot of material. Productivity of materials can also be increased by using correct process, properly trained workers, suitable material handling and storage facilities and proper packaging. All these factors reduce scrap rate.

(2) *Labour :* A little change in the design of component parts, so as to facilitate final assembly, can increase the number of products assembled per day with the same amount of labour.

Work methods, if improved through workstudy techniques, can substantially increase the rate of production.

(3) *Plant Equipment and Machinery :* Productivity can be increased through the use of improved tools (*e.g.,* cutting tools in a machine shop), simple

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attachments and other devices. Total production times can be cut short considerably by improving machine setting up methods, thereby reducing set-up times. Proper maintenance will avoid sudden breakdown and add to the productivity.

(4) *Land and Buildings :* A suitable plant layout can accommodate more machinery in the same space and thus raise productivity. Proper orientation, construction and inside conditions of a building definitely affect productivity.

2.6 IMPORTANCE OF PRODUCTIVITY

The importance of the concept of productivity can be viewed from the following points :

(1) *To Beat the Competition :* It is an age of cut-throat competition. There may be other commodities which can serve as the substitutes of the company's 'product' and can attract the consumers' purchasing power. The firm whose productivity is higher can only beat the competition and can exist in the market for long.

(2) *Guide to Management :* The productivity indices are very useful for the management and can be used for different purposes. These indices can serve as a valuable guide to the management for improving the performance of its enterprise. The productivity measures can be used for the following purposes :

(i) *Strategic :* With the help of productivity indices, the efficiency of different firms can be measured, analyzed and compared. The necessary steps can be taken to improve the productivity of the firm taking in view the productivity of the other competitive firms.

(ii) *Tactical :* Different units or the sectors of the firm can also be compared as regards to their productivity. The productivity of the less productive units or sectors can be improved.

(iii) *Planning :* A firm uses different inputs in producing the goods. A comparison of relative benefits accruing from the use of different inputs can be had and the most beneficial input can be used in production. It helps the management to plan for the future.

(iv) *Administration :* Productivity indices indicate the progress of the firm over a period of years. The productivity of different inputs, including labour, can be measured individually. The individual productivity indices help the management in bargaining with the labour leaders, trade unions and the Government in case of labour disputes regarding welfare activities.

(3) *Indicator of Progress :* In economically backward countries, productivity movement is basic aspect of progress. It implies the development of an attitude of mind and a constant urge to better, cheaper, quicker and safer ways of doing a job, manufacturing a product and providing a service. In an urge to improve the productivity, new inventions take place. Thus, productivity is an aspect of basic progress.

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(4) *Maximum Utilization of Scarce Resources :* In order to provide the articles or commodities to the consumers at the lowest possible cost, the productivity concept urges to utilize the available resources to the maximum for the satisfaction of customers. The productivity processes and techniques are designed to facilitate more efficient work involving less fatigue to workers by improvements in the layout of the plant and work, better working environment and simplification of works.

(5) *Key to National Prosperity :* The productivity, in fact, has become the synonymous to progress. Higher productivity is an index of more production with the same inputs at lower cost. It enables industry to offer goods to the general public at cheaper rates and results in expansion of markets. The working conditions and wages of workers will improve and industrialists too will get larger profits. Thus, higher productivity is the key to national prosperity. The secrets of Japan and Western countries' prosperity lie in increased productivity.

(6) *Prosperity to Labour :* The higher productivity is a boon to labour also. It brings improved working conditions, better wages and salaries to workers, better labour welfare activities etc. Thus, their standard of living is improved.

(7) *Other Uses :*

(i) Higher productivity increases the profits and reserve funds of the industry that can be used for expansion and modernization.

(ii) It increases the goodwill of the firm due to cheaper goods to the public, well-off staff and more profits and better financial position.

(iii) It improves the competitive strength of the company in export markets through reduction in cost of production and quality products.

In this way, increasing productivity is the only way to make the overall progress of the country.

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2.7 TECHNIQUES OF INCREASING PRODUCTIVITY

The various techniques or ways by which productivity can be increased are :

(1) *Product Development :* Product development reduces work content due to design defects and excess material removal. It also reduces ineffective time.

(2) *Specialization and Standardization :* Specialization reduces idle time through variety reduction. Standardization reduces idle time due to short runs and due to increased batch sizes.

(3) *Market, Consumer and Product Research :* Market research is done to find out the problems relating to sale of goods. Consumer research is the process of analyzing information obtained from consumers of the products for making those products more suitable for them. Product research is a research to find out whether it fulfills its functional requirements.

Market, consumer and product research ensure correct quality standards. Hence, more rejects, rework and waste of material can be avoided.

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(4) ***Value Analysis :*** This is systematic investigation of the product to reduce cost and improve value. Value analysis reduces excess work content due to design defects and excess material.

(5) ***Process Planning and Research :*** Process planning ensures selection of correct machines. Thus it reduces work content due to use of wrong machines. Process research ensures correct operation and hence excess work content due to inefficient process is reduced.

(6) ***Method Study :*** Method study is a technique to simplify the job and develop more economical methods of doing it. By method study, layout may be improved. The wasted movements caused due to bad layout can be eliminated.

(7) ***Work Measurement :*** Proper production planning can be worked out only by knowing accurately the time required for completion of job. The standard time for completion of a job is set by the use of work measurement.

(8) ***Operator Training :*** Through training or re-training of workers, sound and uniform working methods can be ensured. Operator training reduces work content due to bad working methods.

(9) ***Production Planning and Control :*** Proper planning and control reduces idle time of men and machines. In other words, effective production planning and control will reduce the ineffective time.

(10) ***Material Control :*** Irregular supply of materials may cause idle time of men and machines. Material control ensures right type of material, at right time, in right quantities and at competitive prices. It avoids locking up capital and reduces manufacturing cost.

(11) ***Plant Maintenance :*** Lack of proper maintenance results in breakdown of machines and plant. This in turn causes idleness of men and machines, reduces productivity and increases cost of manufacturing. Proper maintenance reduces idle time of men and machines due to breakdowns. Plant in good condition reduces ineffective time.

(12) ***Improved Working Conditions :*** Bad working conditions force the workers to take more rest. Heating, ventilation, lighting, colour, noise level, personal comfort, etc., will have their own effect on productivity. Good working conditions enable the workers to work efficiently to raise productivity.

(13) ***Safety :*** Unsafe conditions and unsafe acts cause accidents. Accidents results in loss of time. Safety measures will reduce ineffective time due to accidents.

(14) ***Personnel Policy :*** This refers to the complete policy of the management towards employees, in matters like method of remuneration, welfare services, relations with trade unions, social security, etc. A sound personnel policy will create a good relationship between management and employees and reduce ineffective time due to absence, idleness, lateness, carelessness, etc.

(15) ***Incentives :*** Workmen, in general, will not produce on their own upto their capacity. The workers' interest in increased production can be stimulated only by rewards that satisfy them. Incentive wage system (the amount earned is dependent on the production) arouses interest in an employee to produce more.

2.8 PROCEDURE FOR INCREASING PRODUCTIVITY

(1) *Improving the Existing Method of Plant Operation :* The use of systematic procedure is recommended to improve the productivity. Method study and work measurement may be used to improve the existing method to select a process, machines, tools, etc.

The first step is to gather all information about the process and present it in a form suitable for study. Information gathered may include all operations, facilities, transportation facilities used, distances moved, all inspections, inspection time, storage facilities and time spent in storage, all drawing and design specifications etc. This information may be presented in the form of flow process chart.

The usual technique is the critical examination which consists of asking questions on every activity shown on the flow process chart and then finding out the best possible answer. The answers to these questions may result in the elimination or combination of some of the elements of operation; improvement in the plant layout; rearranging the operations in an efficient way, proper selection of machines and tools; reduction of scrap and improvement in quality of the products manufactured.

(2) *Purpose of Operation :* Before accepting any operation as absolutely necessary, the analyst should determine the purpose of the operation. Possibly, it may be found that some operations are unnecessary.

(3) *Design of Part :* The product designs are not permanent. They can be changed, and improvement is possible. To improve the design, the production engineer should keep in mind the following points that may be helpful in reducing the cost of design under study :

(i) Reduce number of parts, thus simplifying the design.

(ii) Reduce the number of operations and length of travel in the manufacturing by joining parts better and making the machining and assembly easier.

(iii) Utilize a better and economical material.

(iv) Rely on accuracy for key operations.

(v) Install efficient system of quality control.

(vi) Standardize the materials, processes, tools used and the sequence of operations, etc.

(4) *Tolerance and Specifications :* Functional designers have a tendency to specify closer tolerance than necessary while developing the products. Enforcing tolerances that are too tight or rigid tends to increase cost of production. On the other hand, if the tolerances are too liberal, the value of the product decreases. It is difficult to achieve interchangeability of manufacture. Therefore, instead of having tight tolerances which are loosely enforced, it is necessary to design realistic tolerances and create controls needed to enforce them strictly. The designers may consult the production engineers and cost analysis group for setting realistic tolerances. The design should be optimum based on type of customers in the market.

(5) *Effective Utilization of Materials :* There are many industries in which the cost of material is a big percentage of the cost of the finished product. Many industries have to import a very large proportion of their basic raw materials and pay for them in scarce foreign currencies. Under either of these conditions higher productivity can be achieved through proper use of materials and reduction of scrap.

The material to be used is actually specified by the designer but the production engineer should try to find out alternative economical materials which will not affect the proper functioning of the product.

(6) *Process of Manufacture :* There are many manufacturing processes. Moreover, a part or component can be manufactured by two or more processes. The process selected must be an economical balance of material, manpower, product design, tooling and equipment, plant space and other factors influencing cost and practicability. The break even analysis may be used for selection of the economical process for a given volume of production. In order to reduce the cost considerably, proper speeds and feeds should be used. The grinding of cutting tool should be proper to enhance the rate of production and reduce the number of regrindings. Cutting tools should be properly mounted and right lubricant should be used. Proper maintenance will ensure that plant and machinery is operating properly and will prolong its life, so reducing capital expenditure.

(7) *Set-up and tools :* The economic advantage of lower labour costs is the controlling factor in the determination of the tooling. Other considerations such as improved interchangeability, increased accuracy, reduction of labour trouble, increased rate of production are dominant reasons for use of jigs and fixtures.

Set-up times depends on tooling considerations since, it determines the set-up time and tear-down time. When the ratio of set-up time to production run-time is high, then the methods engineer should develop possibilities for set-up and tool improvements.

(8) *Working Conditions :* Working conditions means the condition of the plant where the actual work is carried out. Working conditions should be good, safe and comfortable. Experiments have proved that plants providing good working conditions have more productivity. Ideal, working conditions will improve the safety record, reduce absenteeism and tiredness, raise employee morale, help to motivate the workers to improve their efficiency and hence, enhance the productivity. Some common conditions for improving working conditions are :

(i) Proper lighting in the working areas.

(ii) Control of temperature so that it is neither too cold nor too hot.

(iii) Provision of adequate ventilation.

(iv) Controlling excessive noise levels.

(v) Proper cleanliness and good house keeping.

(vi) Arrangement of disposal of dusts, fumes and gases produced during operations.

(vii) Provision of necessary protective equipment.

(9) *Material Handling :* Material handling increases the cost of the product. So it should be minimized as far as possible. The production engineer should adopt the following objectives related to the material handling :

(i) As far as possible reduce material handling by using mechanical equipment and a good plant layout.

(ii) Reduce time spent in picking up and handling the materials by installing efficient material handling systems.

(iii) Make better use of existing handling facilities by proper planning and scheduling.

(iv) Handle material with great care to prevent its damage and reduce chances of accidents.

(v) Maintain the material handling equipment by routine check ups and periodic maintenance.

(10) *Plant Layout :* Plant layout should be designed to introduce maximum economy during machining operation. The plant layout should be such that the material flows smoothly from one operation to the next without any delay. The machines and various departments should be located such that there is no back tracking, long moves and work stoppages because of delay in transporting the material from one operation to another. Storage areas should be properly arranged to minimize searching and handling. For better work efficiency service centres should be located close to production centres. There should be enough space for the worker to move and operate. Passageways between working places, roads, tracks, etc., must never be obstructed. Material handling equipment must be properly installed.

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2.9 PRODUCTION SYSTEMS

Production process is an act of making something with the object of satisfying demands. In the context of production system, 'It is an intentional act of producing something.' Production system involves in producing goods with the help of an efficient management, utilizing land, labour, machines, capital and materials. A production system constitutes an efficient process with an organized procedure for accomplishing the transformation of input elements to useful output products. Production management takes decisions to evaluate efficient production process to produce goods at lower cost and at the right time.

In any production process, there is an organized procedure to produce a unit of output from the several types of inputs as such materials, labour, machines, facilities, energies, information and technology. Besides input there are so many factors which affects the conversion process as :

(1) Types of production,

(2) Plant location and layout,

(3) Management skills,

(4) Safety and maintenance requirements,

(5) Available capacity,

(6) Government restrictions, etc.

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Fig. (2) shows a general model of the production system.

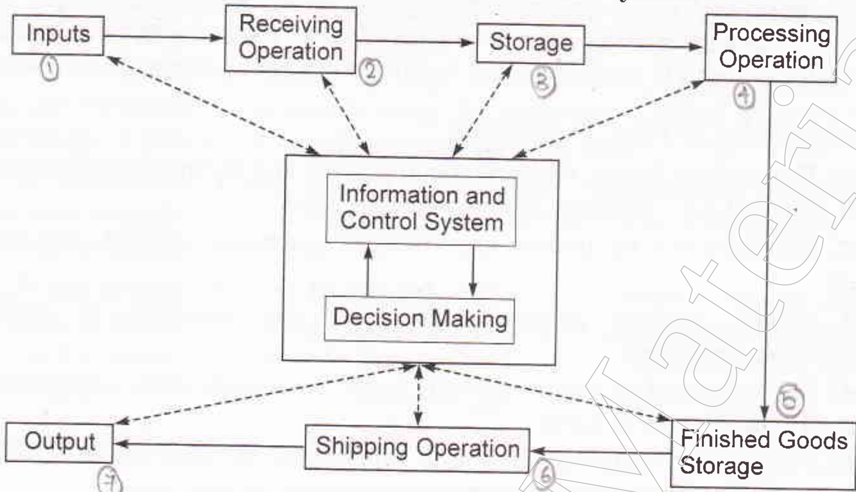

Fig. (2) A General Model of Production System

2.10 TYPES OF PRODUCTION SYSTEMS

There are various types of production systems and subsystems as shown in fig. (3).

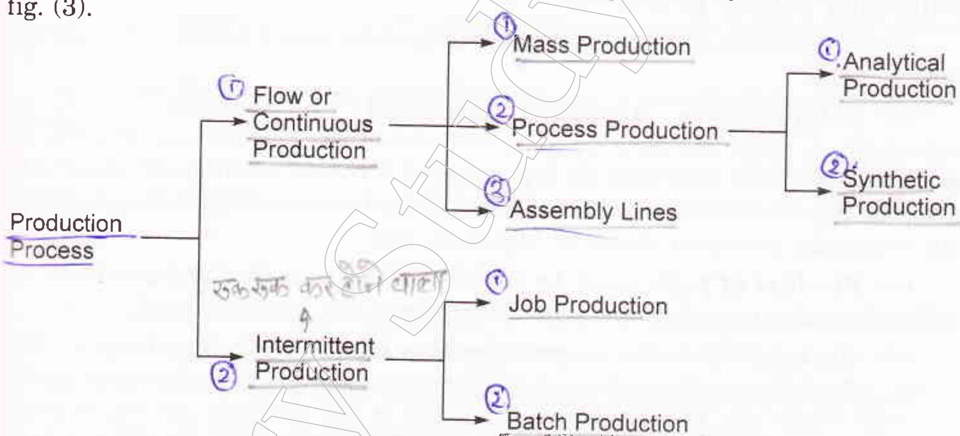

Fig. (3) Types of production system

We will now discuss these in detail.

2.10-1 FLOW PRODUCTION

It is most useful for product of repetitive nature. Each work is passed to the next stage immediately after the previous operation is completed without waiting for the finishing of work as a total batch. In order for the flow to be smooth, the times that the task requires to be spent on each stage must be of equal length, and there should be no movement off the flow line. For example, inspection should be physically located within the flow line, and be subject to the same time constraints as the other processs. Furthermore, since, the whole system is balanced, any fault or error at a particular stage affects not only that stage but also all other stages in the flow line. Thus, a fault or error occurring at one stage on a line, which cannot be resolved within the cycle time of the line, will result in that stage being held up. This in turn causes all previous stages to be held up and all subsequent stages to run out of work. Thus, the flow line must be considered as a single entity and not be allowed to break down at any point.

Characteristics of Flow Production

(1) The product design, the conversion process and the operations sequence are all identical, *i.e.*, identical products are produced.

(2) Machines and equipment are arranged according to functional layout pattern.

(3) Special purpose automatic machines are required to perform standardised operations.

(4) The volume of output is generally large (mass production) and goods are produced according to demand.

(5) Fixed path materials handling equipment is used because of the predetermined sequence of operations.

(6) Machines capacities are balanced so that materials are fed at one end of the process and the finished product is received at the other end.

Suitability of Flow Production

Flow production is suitable for those industtries which satisfy the following requirements :

(1) ***Substantially Constant Demand :*** If demand is below expectations, there will be a build-up of finished work which can give rise to storage difficulties. Alternatively, if production is caused to fluctuate along with demand, then the setting-up and balancing of the flow line will need to be carried out frequenty, giving an excessive high total cost.

(2) ***Product of task must be standardized :*** A flow line is inherently inflexible and cannot accommodate variations in the work required.

(3) ***Materials must be to specification and delivered in time :*** Due to the inflexibility mentioned above, the flow line cannot accept the variations in material which can be incorporated if batch or job methods are being used. Furthermore, if material is not available when it is required, the effect is very serious. The whole line will be stopped.

(4) ***Task must be defined :*** In order that the line will maintain its balance, all operations must remain constant. This can only be done if the operations are recorded in detail.

(5) ***Work must conform to quality standards :*** Using job or batch methods, variations in quality/errors at one stage can be compensated for by extra work else where. With flow methods this cannot happen, since, each stage has a defined operation, with a pre-set allowed time.

(6) ***Correct plant and equipment must be provided at each stage :*** Lack of correct apparatus will unbalance a line, causing weakness throughout the whole sequence. This can result in a severe under-utilization of equipment; should a work-station/stage require a piece of equipment for only a part of the operation time, this equipment must be provided and *its under-utilization accepted.*

(7) *Maintenance must be by Anticipation, not Default :* If equipment breaks down at any one stage, the whole line is halted. To avoid this, a programme of preventive maintenance must be in force.

(8) *Inspection must be 'In Line' with Operations :* Unless the inspection stage is balanced with the rest of the operations, a dislocation of the flow will inevitable take place.

(9) *All stages must be Balanced :* If the requirement that the tasks do not queue is to be fulfilled, then the time taken at each stage must be the same, *i.e.*, the line must be 'balanced'. Due to an inability to balance stages leads to inefficiency.

Merits of Flow Production

(1) The direct labour content will be reduced, since the comprehensive pre-planning which is necessary will often produce economies in time.

(2) Assuming the product/task is initially 'designed' correctly, the reproducibility and hence the accuracy and precision, are high.

(3) Since, inspection is 'in line', deviations from standard are rapidly picked up.

(4) Since, there is no rest period between operations, work-in-progress is at a minimum.

(5) Again, since there is no waiting period, the provision of work-in-progress stores is unnecessary, and the total storage space required is significantly reduced.

(6) Handling is reduced.

(7) Control (including operations, budgetary, quality and supervisory control) is simplified, the flow line being virtually self-controlling.

(8) Any weakness in materials or methods is immediately highlighted.

(9) Material requirements can be planned more accurately.

(10) Investment in materials and resources used for a task can be more rapidly translated into income from sales.

Demerits of Flow Production

(1) Set up costs are high as expensive plant and equipment are required.

(2) It is not possible to offer a wide product range as parts are standardized.

(3) Poor workforce motivation may affect quality as jobs tend to be boring being repetitive.

(4) Any breakdowns or stoppages cause whole system to stop.

(5) Production lines tend to be dedicated to producing one product only.

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2.10-2 TYPES OF FLOW PRODUCTION

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Flow production can be of following types :

(1) Mass Production

It refers to the manufacture of standardized parts or components on a large scale. Standardization of materials, machines, products and processes is the basic characteristics of mass production. The greater will be volume of mass production, the more would be the reduction in direct labour cost per unit. In mass production, items are produced in huge quantity and much emphasis is not given to consumer's order. In this system one type of products are produced at a time and planning and scheduling of the production are done in advance. Fig. (4) shows the principle of mass production.

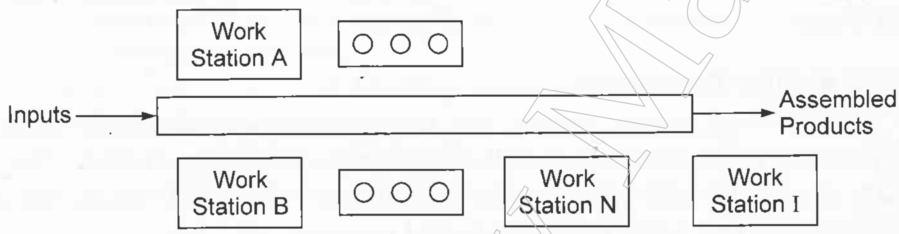

Fig. (4) Mass Production

Mass production system is employed when production is carried out without interruption. For example : automobiles plant, electronics industry type industry, electricals, etc. Quality of products tend to be uniform and high due to standardization and mechanisation.

Merits of Mass Production

workstation

(1) There is a smooth flow of materials (from one WS to another WS) which is either straight line, or L-type or U-type or circular or S-type.

(2) There are small WIP (work in process) inventories because output of one becomes input of the other process.

(3) Production time/unit as a whole is less.

(4) Closely spaced WS's reduce material handling.

(5) PPC (production planning and control) is very simple.

(6) Less storage space for temporary storage and WIP.

Demerits of Mass Production

(1) One machine failure results in a stoppage of the whole operation following it.

(2) Production speed is determined by the slowest machine.

(3) Mass production requires general rather than specific supervision.

(4) Capital intensive owing to installation of special type machines and their possible duplication along the line.

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(2) Process Production

In this, various processes are inter linked and production is carried on continuously through a uniform and standardized sequence of operations. This type of production is used in bulk processing of crude oil into petroleum, kerosene, diesel oil, etc. More stress is given on automation and volume of production is very high. This method is used for those products whose demand is continuous like petroleum, chemical, medicines, etc. Single raw material can be transformed into different kinds of product at different stages of production process. Planning and scheduling is done in advance.

(a) Analytical Process : Here a raw material is broken down into different products. For example, crude oil is analyzed into gas, petrol, kerosene and diesel oil as shown in fig. (5).

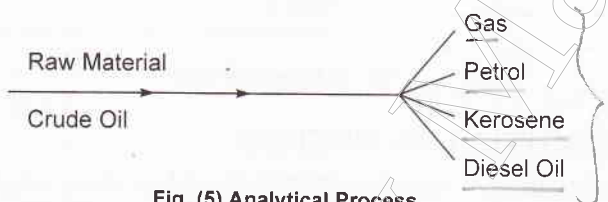

Fig. (5) Analytical Process

(b) Synthetic Process : It involves the mixing of two or more materials to manufacture a product. For example, lauric acid, myristic acid, plasmitic acid, stearic acid, linoleic acid are synthesized to manufacture soap as shown in fig. (6).

Fig. (6) Synthetic Process

Merits of Analytical Process

(1) Manufacturing cost per unit is less.

(2) Size of plant is also small.

(3) Semi-skilled labour with more managerial skill is needed.

(4) Organisational structure is centralised.

(5) Purpose of production is to produce rather than wait for order since demand of the product is continuous.

(6) Scale of production is very large.

Demerits of Analytical Process

(1) Heavy capital investment is required in plant.

(2) Less flexibility lies in process production.

(3) Only specific type of product can be produced.

(4) It is difficult to change the location of plant.

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(3) Assembly Lines

It was developed in the automobiles industry in USA. Here two or more components are combined to manufacture a finished product as shown in fig. (7). Assembly line is particularly useful when a limited variety of similar products is to be produced on a mass scale or in fairly large batches on a continuous basis. The design of assembly line involves the proper balancing of technology and other manufacturing facilities so as to develop a rational approach of optimization of results.

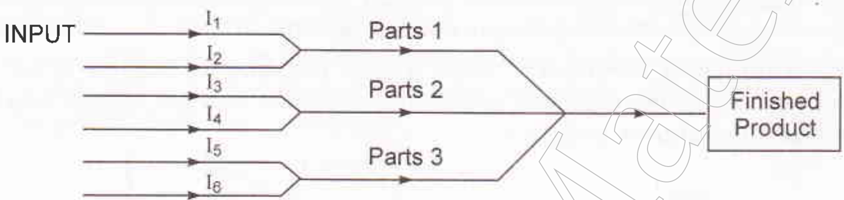

Fig. (7) Assembly Line

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2.10-3 INTERMITTENT PRODUCTION

Here the production is not continuous and is designed only when it is required. There is not a single procedure and the production usually is not uniform and the basic product design changes from time to time. The facilities are flexible to adjust production according to the order or time.

Characteristics of Intermittent Production

(1) General purpose machines and equipment are used so as to adopt to a wide variety of operations.

(2) A wide variety of products are produced.

(3) The flow of production is intermittent not continuous.

(4) No single sequence of operations is used and adjustments are made after a certain interval to suit different jobs or batches.

(5) Functional or process layout is adopted.

(6) The components are produced for inventory but they are assembled as per customer orders.

(7) The volume of production is generally small.

2.10-4 TYPES OF INTERMITTENT PRODUCTION

(1) Job Production

Job or 'make complete' production is the system of manufacturing a single complete unit by an operator or a group of operator, *i.e.*, bridge building, dam construction, ship building, etc. Here whole production is considered as one operation and work is completed on each product before passing on to the next. Each product is a class itself and requires a distinct and separate job for production purpose. System requires highly skilled labour and high capital investments. Control of operations is relatively simple. Goods are produced to definite customer's orders. Continuous demand and manufacturing depends on the receipt of orders.

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Characteristics of job production are :

(1) A wide range of general purpose machines like grinder, drill press, sharpner, etc. are used.

(2) Variable path material handling machinery are used.

(3) Whole project is taken as a single operation.

(4) The product manufactured is customized.

(5) Volume of output is generally less.

(6) Machines and equipments are arranged or assembled at a particular place, *i.e.,* fixed position layout is used.

(7) Work is to be completed on each product before processing the next one.

(8) Versatile and skilled labour is needed.

(9) High capital investment is required.

(10) Control is relatively simple.

Advantages of Job Production are :

(i) Firms' can offer the 'personal touch' which some customers prefer.

(ii) Unique or 'one-off' orders according to customer needs can be produced.

(iii) It is possible to change the product specification even if work has begun.

(iv) Quality tends to be very high as workers are skilled and well motivated.

(v) Organization is fairly simple as only one job is done at a time. So communication, supervision and inspection can be regularly carried out.

(vi) It is easier to identify and deal with problems.

Disadvantages of Job Production are :

(i) It is expensive method of production as workforce is skilled.

(ii) A wide range of tools, machines and equipment is needed which is expensive.

(iii) Selling costs may be very high if the product is highly complex and technical.

(iv) Once a reputation has been made and demand rises, costs can also rise as the company struggles to meet demands.

(2) Batch Production

Production schedule can be made according to specific order or on the basis of demand forecast. The items are produced in lots or batches. New batch is undertaken for production only when the work on all items of a batch is completed.

Any product is divided into parts or operations and each operation is to be completed through out the whole batch before the next operation is undertaken. After the production of one batch the plant and machines become available to other batch of similar type of production. More specialised labour and low investment is needed. Organisation Planning is more complicated. No schedule is prepared in advance and items are produced for definite customers and not for

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inventories. This system is adopted by some of the industries like chemical industry, electronics instrument, machine tools, printing press, etc.

Characteristics of Batch Production are :

(i) Organizationally difficult.

(ii) Use of specialized skills.

(iii) Possibility of high equipment utilization.

(iv) Probability of poor work flow.

(v) Value added slowly/work completed slowly.

Advantages of Batch Production are :

(i) Fewer machines are required, since machine utilisation is better.

(ii) Specialised supervision is possible.

(iii) Not-so-capital-intensive as low investment is required in machines.

(iv) Flexibility with respect to personnel, equipment, etc.

(v) Job satisfaction for the operatives.

Disadvantages of Batch Production are :

(i) Material handling is more costly since the flow is longer and irregular.

(ii) Production planning and control is elaborate.

(iii) Generally, the production time is longer .

(iv) Work-in-progress ties up large capital and requires space.

(v) Skills of a higher order are necessary considering the variety.

2.11 COMPARISON BETWEEN VARIOUS PRODUCTION SYSTEMS

There are four major production systems—Job production, Batch production, Mass production and Process production. Although the objective of each production system is to convert the raw material into finished goods but each system has its specific characteristics and limitations which makes one system different from other systems. Following are the different features of various production systems :

(1) *Level of Production :* From the view point of capital investment, production capacity, size of organisation and number of labour—production is done at lower level in Job production, moderate in Batch production, large level in Mass production and at very large level in Process production.

(2) *Pattern of Organisation :* On the basis of pattern of organisation the production system are divided into two categories, in first category—Job and Batch production are included. Mass and process production are included in second category.

Pattern of organisation in Batch and Job production systems is functional in which co-ordination is established in activities on top level. The nature of these activities is centralised. In contrast to it mass and process systems are based on policy of decentralisation in which rights of planning and policy formulation is

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given to various departments. Pattern of organisation in these systems is departmental.

(3) *Production Cost per Unit :* It is a fact that as the scale of production increases per unit cost of production decreases. So, per unit cost of production is minimum in process system and it is maximum in Job production system. From the view point of per unit cost—the production systems can be arranged in increasing order as—Process, Mass, Batch and Job.

(4) *Production Flexibility :* Since emphasis is given on automation, heavy investment and standardisation is needed in process and mass production. So flexibility is less in these production systems. In contrast, production is possible by keeping short term demand of market in mind in Job and Batch production. So sufficient flexibility is found in these systems.

(5) *Decision Making :* Since heavy investment and automation is needed in Process and Mass production, so they cannot be changed frequently because management have to take long term decisions. On the other hand, decisions are short term and changeable according to the demand of market in Job and Batch production.

(6) *Required Skills and Abilities :* Due to need of specialisation, high skilled labour is needed in Job production. Specialised work on machine is required in Batch production while in case of Process and Mass production semi–skilled labour can do the job. Therefore, more managerial skill is also required in them.

(7) *Employment :* In Job and Batch production, the number of labour employed are more but less job security is there due to fluctuations in market demand. In Process and Mass production, the number of labour are less due to mechanisation and automation but job security is high.

(8) *Suitability :* Job production is used in building roads, bridges and dam constructions. Batch production is suitable in machine tools, textile, engineering, etc., where a wide range of products are produced. While mass production system is useful in automobile, sugar, paper, TV, refrigerator, etc., which have more demand. On the other hand, in case of such products where complex nature of machinery is used like petroleum, dairy, chemicals, iron and steel and power industries, process production system is suitable.

2.12 INDUSTRIAL OWNERSHIP

To start an industry or business, money (capital) is required. Who-so-ever provides the money becomes the owner of that particular enterprise. Ownership when applied to an industrial enterprise means *title to* and *possession* of the assets of the enterprise, the *power to* determine the policies of operation, and the *right to* receive and dispose of the proceeds. Broadly, money can be arranged for an industry in three different ways :

(1) If the capital is provided by single individual, it is known as *Individual ownership, Individual entrepreneur organisation, Single ownership or Individual proprietorship* company.

(2) If the capital is supplied by two or more persons, it refers to *partnership* organisation.

(3) If the capital is provided by many persons in the form of shares to an institute with a legal entity, it is called a *Joint Stock Company.*

Note that there are other forms of ownership also, but they are merely outgrowths of the three types mentioned above.

Types of Ownership

The different types of ownership are shown in fig. (8).

TYPES OF OWNERSHIP

Private Sector Enterprises

(1) Individual ownership
(2) Partnership
(3) Joint Hindu Family Business (HUF)
(4) Joint Stock Company
(a) Private Limited Co.
(b) Public Limited Co.

Co-operative Sector Enterprises (OR Societies)

(1) Producers Co-operative Society
(2) Consumers Co-operative Society
(3) Housing Co-operative Society
(4) Credit Co-operative Society, etc.

Public Sector Enterprises

(1) State Enterprises
(2) Public Corporations

Fig. (8) Types of Industrial Ownership Organisation

Now, we will discuss these one by one.

2.13 PRIVATE SECTOR ENTERPRISES

Salient Features

- Private sector serves personal interests and is a non-government sector.
- The main objective is to earn profit (rather than service).
- Private sector mainly constitutes consumer's goods industries where profit possibilities are high.
- Private sector does not undertake risky ventures or those having low-profit margin.
- Private enterprises are run by businessmen, capital is collected from the private partners.

Examples of big and famous private sector enterprises are TISCO, TELCO, RIL, etc.

Merits

(i) The magnitude of profits earned is usually high.

(ii) The efficiency of the private enterprise is high.

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(iii) Wastage of material and labour is minimum.

(iv) Decision-making is very prompt.

(v) There is no interference in its internal affairs by politicians or Government.

(vi) Competent persons occupy high levels.

Demerits

(i) Private enterprises leads to concentration of wealth in few hands.

(ii) They lead to unbalanced growth of industries and sometimes monopolistic market situation arises.

(iii) Profit is the main motive which may lead to exploitation of workers and unfair deal to consumers.

2.13-1 SINGLE PROPRIETORSHIP (INDIVIDUAL OWNERSHIP)

This is the simplest and oldest form of business organisation. A business owned by one person is called single ownership or sole/individual proprietorship enterprise. Here an individual exercises and enjoys ownership rights in his own interest.

In this type of enterprise the individual entrepreneur supplies the entire capital (even if he has to borrow). He organises and manages the business himself, and takes the entire risk. The entire authority and responsibility in the matter of decision making, policy making and working belongs to him. All profits and losses are his own. If necessary, he can employ some persons to assist him. This type of business can be started by any person having initiative, tact, selling aptitude and little capital to enter into business. It is owned, managed and controlled by only one man hence, it is also called as *one man business.*

Examples of enterprises run by single owner are printing press, auto repair shop, wood working plant, a small fabrication shop, etc., *i.e.,* retail traders, service industries and small engineering firms.

Summarizing, the ***salient features*** of single ownership enterprise are :

- *Individual ownership* and one-man effort.
- *Enterprise and owner entity is same.*
- *All risks* related to business are *covered by one owner.*
- *All profits* after deduction of taxes *go to the proprietor.*
- *Minimal legal formality* to start.
- *Unlimited Liability :* In case of loss, the entire debt or loan is recovered from the assets of owner.
- *Ownership and management have no separate entity.*

Merits

(i) *Easy formation and closure* as no legal formalities are required.

(ii) *Flexibility in Management :* Easy to change the product/services, policies and control.

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(iii) *Extremely easy decision-making.*

(iv) *High Motivation :* Due to single ownership, all profits and growth of business are shared by one owner. He is, therefore, highly motivated to work for improvement and profit.

(v) *Full control* of business activities.

(vi) *Secrecy :* Trade secrets are easy to maintain. There is no compulsion to publish the account.

(vii) *Personal touch for excellence.*

(viii) *Simple and less complicated operation.*

Limitations

(i) *Limitations on resources :* Due to financial capacity of sole owner.

(ii) *Limitation of managerial skill :* Due to human limitation of excellence in all spheres such as production, marketing, finance, liaison, etc.

(iii) *Unlimited liability :* In case of failure or loss in business, the trader loss is not covered by anybody else.

(iv) *Lack of continuity :* In case the trader is ill or busy in his family affairs, the business has to close down. Further, the firm has limited life and usually ends with the death of the proprietor.

(v) *Absence of specialized knowledge* in more than one or two areas of business operation.

(vi) Unduly *stressed owner* due to variety of jobs.

(vii) Generally, due to work pressure and limited capital, sole traders are exploited by big industries.

(viii) Not suitable for large-size operations due to limited resources.

(ix) *Comparatively less stable :* Due to non-availability of another person to share the responsibility.

(x) *Limited scope for economies of scale :* When the production volume is less (as the case of sole ownership), the over-head costs are not widely distributed on the price of the product. This may be a cause of high cost of product.

Applications

Single ownership is suitable for :

(1) For retail trades, service concerns and small engineering firms which require relatively small capital to start with and to run.

(2) For those businesses which do not involve high risks of failure.

(3) The business which can be taken care of by one person.

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2.13-2 PARTNERSHIP FIRMS

Partnership is an association of two or more (upto 20) persons to carry on business as co-owners for sharing profit. They put their money, ability, skill,

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knowledge, etc. for the purpose of running an enterprise and earn profits. Partnerships are based upon a partnership agreement (usually in writing). It defines the authority, rights and duties of each partner including percentage of profit (or loss) sharing. It comes handy in case of disagreement among the partners.

Partnership becomes necessary when the size of business enterprise grows beyond a certain limit. The two major differences from sole proprietorship firms are :

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1. Number of owners are more than one but less than 20.
2. More capital, asset and diversified expertise are available due to more than one owner.

Salient Features

- More than one but less than twenty partners are needed.
- There must be an agreement among partners which could be written, oral or implied.
- Joint liability of all partners in case of liquidation (which may be proportional to their share in deed).
- Success of the partnership firm is possible when there is full trust and honesty. Sharing of information, transaction and client dealing is must.
- Registration of the partnership firm is not necessary. However, if registered with the registrar of firms, legal complications are minimized परेशानी in case of disputes. विवाद
- Time span of partnership firm depends upon the 'will' of all partners. It can be dissolved on death or any time when all partners agree.

Types of Partnership

[I] *Based on extent of participation*

(1) *Active (or working) partner :* Takes active part in business.

(2) *Sleeping (or dormant) partner :* Simply invests in the business and collects profit but does no interfere in day-to-day management.

[II] *Based on liabilities*

(1) *General partner :* He covers unlimited liability irrespective of contributed capital. He participates in the day-to-day management of the firm.

The two main disadvantages of general partnership are :

(i) Each partner has unlimited liability for the debts of the firm.

(ii) Investors and lenders hesitate to provide money because of the doubts about stability of a partnership.

These disadvantages are overcome in limited partnership.

(2) *Limited partner :* He covers liabilities limited to the contributed capital.

A disadvantage associated with limited partnership is that the limited partner has no voice in the management though he has invested in the business.

Merits of Partnership Firms

(i) *Ease of formation :* By an agreement or partnership deed.

(ii) *Larger pooling of financial resources :* Due to more number of capital sharing members.

(iii) Sharing of managerial skill by partners.

(iv) Collective business decisions by partners.

(v) Flexibility in change-over due to lesser number of mutually interactive members.

(vi) Secrecy due to lesser members.

(vii) Active interest by members due to major share in capital and direct risk in business dealings.

(viii) Check and control due to watchfulness of all partners.

(ix) The interest of partners is fully protected. In case of dissatisfaction, any partner can press for dissolution of deed.

Limitations of Partnership Firms

(i) Limited capital as compared to joint stock company.

(ii) Unlimited liability in case of dissolution of firm.

(iii) Uncertainty of existence due to death, bankrupty or demand of a partner.

(iv) Risk of sharing loss due to other partner's misdeeds.

(v) Risk of disharmony due to difference of opinion among partners.

(vi) *Lack of public and institutional confidence :* This is due to no disclosure of accounts and progress report of the firm.

(vii) *Difficulties in expansion and modernisation :* This is because not more than 20 partners can be accommodated in the firm. Therefore, future fund generation is difficult.

(viii) *Difficult to withdraw from firm :* This is because consent of all other partners may not be readily forthcoming.

Applicability of Partnership Firms

Partnership is an ideal form of organisation for small scale and medium size business where there is a limited market, limited risk of loss and limited capital and limited specialisation in management is needed. Examples are : wholesale trade, retail trade, commercial forming, small scale industries, local enterprises, warehousing, transport services, professional services, marketing services, etc.

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2.13-3 DISTINCTION BETWEEN INDIVIDUAL OWNERSHIP AND PARTNERSHIP

	Parameter	Individual Ownership	Partnership
1.	Membership	Individual Owner (One Man Business)	Minimum 2 Maximum 20
2.	Formation	No agreement is required for its formation.	An agreement (Partnership Deed) is required for its formation.
3.	Capital	Limited capital contributed only by the owner.	Comparatively large capital contributed by number of partners.
4.	Registration	Not necessary	Registration is necessary under the Partnership Act 1932.
5.	Risk/Profit	Individual owner has to bear the risk and enjoys the entire profit.	Risk spread out amongst the partners. Profit is shared according to the agreement reached between themselves.
6.	Management	Individual owner has to manage the entire business.	The management of the business is shared by the partners.
7.	Secrecy	The individual entrepreneur can easily maintain the secrets of the business.	A partner may withdraw from the firm and establish his own enterprise with the knowledge and secrets of business.
8.	Soundness of decisions	An individual owner may not be an expert in all aspects of business. Hence sometimes his decisions may go wrong.	The problem is examined from more than one point of view. Hence decisions arrived are likely to be sounder.
9.	Suitability	Suitable for small scale business only.	Suitable for small as well as medium scale business.
10.	Divison of Labour	Not possible	The partners divide the work among themselves. Division of labour is thus possible to some extent.

2.13-4 JOINT HINDU FAMILY BUSINESS (HUF)

It is a form of family business governed by the Hindu law. Two systems of inheritance are common :

(a) *Dayabhaga :* Both male and female members of the family can become co-partners in the family business or property. It is only found in West Bengal in India.

(b) *Mitakashara :* This system is found in India at places other than West Bengal. Only the male members of the family can become the co-partner in the family business.

Property of a Hindu is inherited after the death by his son, grand sons and great grand sons, *i.e.,* by next three generations. Each member of the three generations are co-partner in the ancestoral property.

Salient Features

The Hindu Undivided Family business (HUF) (or property) is handled and controlled by the head of the family, who is called as *Karta*. Other ***salient features*** are as follows :

- Membership is granted by birth of a child. In case of *mitakashara system,* only male child gets automatic membership after the birth.
- Minors can become full-fledged members.
- There is no limit on number of members. However, the lower limit is two members.
- There is no need for the registration of the family business.
- The management of business is handled by *Karta* of the family.
- Any member can ask for his share of account from the *Karta*.
- The system is continuous or perpetual. It runs generation-after-generation.
- The liability of *Karta* is unlimited, while the liability of other members is limited to the share of their property.
- Except in West Bengal, only male member can become member of the business.

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2.13-5 JOINT STOCK COMPANY

The most important feature of a joint stock company is that it is an association of individuals called *shareholders* who join together. They agree to supply capital divided into shares and want to share profit. It is that form of business activity, which is most suited for large-scale business. It does not suffer from limitations of capital and management as in case of partnership firms. Sufficient number of skilled persons and experts may be employed to run the business professionally. The company is managed by a *Board of Directors* elected by the shareholders who make policies, take decisions and run the company.

Types of Joint Stock Company

There are two types of joint stock companies :

(A) Private Limited Company

(B) Public Limited Company

[A] *Private Limited Company*

It is established by an Article of Association, which has the following main features :

- Restriction on the right of the members in transferring the shares.
- Decides the number of its members which can be between 2 to 50.
- Restricts involvement of public, other than its member, to subscribe its shares or debentures.

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- A private company must get its accounts audited.
- A private company has to send a certificate along the *annual return* to the Registrar of Joint Stock Companies stating that it does not have shareholders more than fifty excluding the employee and ex-employee shareholders.

Actually, a private joint stock company resembles much with partnership firm and has the advantage that big capital can be collected than could be done in partnership firm.

[B] *Public Limited Company*

It is also established by an Article of Association, which has the following main features :

- No restriction on the right of the members in transferring the shares.
- Puts no upper limit on the number of members. Minimum number of shareholders is seven.
- Keeps the company free to invite public to subscribe its shares or debentures usually having small face value (Rs. 10, 100, etc. per share).
- It has to hold a general meeting of its shareholders every year.
- The company must gets its account audited every year by registered auditors.
- A public limited company has to file with the Registrar of Joint Stock Companies, documents such as consent of the directors, list of directors, director's contract, etc., along with the memorandum of association and articles of association.

Advantages of Joint Stock Companies

(i) A huge sum of money can be raised.
(ii) It associates limited liability with it.
(iii) Shares are transferable.
(iv) Company's life is not affected by the life (death) of shareholders.
(v) Services of specialists can be obtained.
(vi) Risk of loss is divided among many shareholders.
(vii) The company associates with it stability, efficiency and flexibility of management.

Disadvantages of Joint Stock Companies

(i) A good deal of legal formalities is required for the formation of a joint stock company.
(ii) Company is managed by big shareholders only.
(iii) Highly paid officials manage the whole show; they cannot have as high interests in the company as the proprietors can have.
(iv) People can commit frauds with the company.
(v) Board of directors and managers who remain familiar with the financial position of the company may sell or purchase shares for their personal profits.

(vi) It is difficult to maintain secrecy as in partnership.
(vii) The team spirit with which partnership works, is lacking in a joint stock company.
(viii) Dividend responsibility.

Applications of Joint Stock Companies

(i) Steel mills,
(ii) Fertiliser factories, and
(iii) Big engineering concerns, etc.

2.13-6 DISTINCTION BETWEEN PARTNERSHIP AND JOINT STOCK COMPANY

S. No.	Partnership	Joint Stock Company
1.	In a partnership firm, the liability of the members is unlimited.	Liability is limited to the value of their share.
2.	Minimum number of partners is 2, and maximum number is 20.	In private limited company minimum number of shareholders is 2 and maximum number is 50. In public limited company minimum number of members is 7 and there is no maximum limit.
3.	A partnership firm has no separate legal entity.	A joint stock Co. has a legal existence.
4.	Limited capital.	Large amount of capital can be collected.
5.	It is managed by the partners.	It is managed by the elected board of directors.
6.	The partner cannot transfer his share without the consent of all other partners.	In public limited company the shares are transferable; but not in private limited company.
7.	It has short life. The partnership may come to an end due to death or retirement of any partner.	It has permanent/perpetual existence.
8.	It can be started very easily. Procedure for registration is simple and moreover registration is not compulsory.	Its formation, functioning involves very large legal procedures.
9.	Selfish attitude among partners may create difficulties in business.	Smooth and efficient management is possible as it works on the democratic principles.
10.	There are no restrictions of keeping detailed accounts and they are not required to be submitted to Govt.	It has obligation to keep detailed accounts of business and present the balance sheet and audit report (by some authorized Chartered Accountant) to the Government.
11.	It is governed by the Partnership Act, 1932.	It is governed by the Indian Companies Act of 1956.

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S-1

2.13-7 Comparison between Private and Public Limited Joint Stock Companies

S. No.	Particulars	Private Limited Joint Stock Company	Public Limited Joint Stock Company
1.	Membership	The membership is confined to close friends and relatives of the promoters; they contribute their capital. They cannot invite public to share the capital.	The membership is open to the general public. Any person interested can contribute and become shareholder.
2.	Limits to membership	The minimum number of members required is two, while the maximum number is limited to 50.	A minimum of 7 members are required to form the company. There is no limit to the maximum number of members.
3.	Election of Directors	There is no need of holding a statutory meeting to elect the director.	The statutory meeting has to be held and the shareholders elect the directors.
4.	Resale of shares	The shares cannot be resold or transferred without the consent of the company.	The shares can be resold or transferred without the consent of the company.
5.	Audit of Accounts	There is no legal provision of the audit of company's account	The accounts have to be audited legally and circulated among the members of the company.
6.	Minimum Capital	Can be started with any amount without any legal binding.	Minimum lay-down capital is legally required before starting the business.
7.	Name	It has to use words "Private Limited" at the end of its name.	It has to use only the word 'Limited' at the end of its name.
8.	Number of Directors	It has to have minimum 2 directors.	It has to have minimum 3 directors.
9.	Legal Control	There are less legal controls.	Regulations are more strict.
10.	Remuneration of Directors	Restrictions are less for Directors' Remuneration.	Remuneration of Directors is restricted to 11% of the net profits.

2.14 COOPERATIVE ENTERPRISES (SOCIETIES)

Co-operative or societies is a form of organisation, wherein persons voluntarily associate together on the basis of equality for the fulfilment of their common economic interests. The basic aim of cooperative organisation is self-help through mutual cooperation.

Salient features of cooperative societies

- Voluntary organization.

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- Suited for relatively economical weaker sections.
- Objective is mutual help and service.
- Common interest of members.
- Open membership.
- *Democratic set-up :* One person-one vote principle.
- Separate legislative entity : Registration is required.
- Disposal of surplus, interest or profits, among members in accordance with their share capital.
- Special laws deal with the formation and taxation of cooperatives.

Advantages

(i) Daily necessities of life can be made available at lower rates.

(ii) It is the democratic form of ownership.

(iii) Overheads are reduced as members of the cooperative may render honorary services.

(iv) It promotes cooperation, mutual assistance and the idea of self-help.

(v) The chances of large stock-holding (hoarding) and black marketing are eliminated.

(vi) No one person can make huge profits.

(vii) Common man is benefited by cooperatives.

(viii) Monetary help can be secured from government.

(ix) Goods required can be purchased directly from the manufacturers and therefore can be sold at less rates.

Disadvantages

(i) Since, the members of the cooperative manage the whole show, they may not be competent enough to make it a good success.

(ii) Finance being limited, specialist's services cannot be taken.

(iii) Conflict may arise among the members on the issue of sharing responsibility and enjoying authorities.

(iv) Members who are in position may try to take personal advantages leading to corruption.

(v) Members, being in services elsewhere, may not be able to devote necessary attention and adequate time for supervising the works of the cooperative enterprise.

Types of Co-operative Societies

There are basically four types of societies :

(1) *Producer cooperatives* which work for group buying and selling such items as grains, fruit, dairy products, etc.

(2) *Consumer's cooperatives* which work in retail trade and services.

(3) *Housing cooperatives* which work for contructing and providing houses to the members.

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(4) *Credit cooperatives* which provide loans to its needy members.

2.14-1 Distinction between Co-operative and Joint Stock Company

S. No.	Parameters	Co-operative Society	Joint Stock Co.
1.	Formation	(i) Under Co-op. Society Act (ii) Minimum members is 10	Under Companies Act. Minimum members are 2 for Private Ltd. and 7 for Public Ltd.
2.	Fundamental Principles	(i) Spirit of co-operation. (ii) Promote self help and mutual assistance among members (iii) Unity of purpose. (iv) Community interest. (v) Socialist bias	Spirit of competition. No need for unity of purpose. Capitalistic bias. Larger number of shareholders.
3.	Membership	Generally local or regional territory (from limited area)	Wide spread membership.
4.	Capital	Limited	Large capital
5.	Transfer of shares	A member can withdraw his share capital, shares are not transferable.	Shares are transferable
6.	Liability	Limited	Limited
7.	Distribution of Profit	(i) Maximum dividends on shares 12 percent (ii) Its main purpose is to serve members. Profit is not important.	No limit on dividend. Profit motive.
8.	Privileges	Govt. gives special privileges to encourage co-operative movement.	No such special privileges. On the other hand, Govt. exercises strict legal control.
9.	Management	Democratic with equal voting rights ("One Man One Vote")	Democratic unequal voting right ("One Share One Vote")
10.	Contact	Members are generally known to each other. They come together to fulfil their common needs.	Shareholders have no contact with each other. They invest money to earn profit.
11.	Life	Short. It may be dissolved if the common need is fulfilled, members lose their interest.	Perpetual or permanent existence.

2.15 PUBLIC SECTOR ENTERPRISES

A public sector enterprise is owned and managed by the State (government). The aim of such enterprises is not to earn profit but to prevent unbalanced growth of industries and ultimately attain self reliancy. Such enterprises are accountable for their results to Parliament and State Legislature. Public enterprises are mostly operated in case of public utility services like water supply, electricity, transportation, etc.

Objectives of Public Sector

The objectives of public sector enterprises are :

(1) Equitable distribution of wealth and income by preventing concentration of economic power in few hands.

(2) Balanced economic development through dispersal of industrial location.

(3) Adequate employment opportunities.

(4) Speedy agricultural and industrial development without the growth of monopolies.

(5) Self-sufficiency of the nation in modern technology and mangerial skills so that in due course, the country need not depend on foreign collaboration in capital technology, skill, etc.

(6) To act as role-model for private sector by avoiding exploitation of workers and consumers.

Public sector includes (i) State Enterprises and (ii) Public Corporations.

Merits of Public Sector

(1) Public sector helps in the growth of those industries which require huge amount of capital and which cannot flourish under the private sector.

(2) Public sector helps in the implementation of the economic plans and enables them to reach the target of achievement within a prescribed period by taking initiative in the establishment of industries of its own accord.

(3) Due to the absence of project motive in the public sector, the consumers are benefitted by greater, better and cheaper products.

(4) Public enterprise prevents the concentration of wealth in the hands of a few and paves the way for equitable distribution of wealth among different sections of community.

(5) Public enterprise encourages industrial growth of under-developed regions in the country.

(6) Profits earned by public sector may be used for the general welfare of the community.

(7) Public sector offers equitable employment opportunities to all; there is no discrimination, as may be in a private sector.

(8) Capital, raw material, fuel, power and transport are easily made available to them.

Demerits of Public Sector

(1) Public sector can rarely attain the efficiency of a private enterprise; wastage and inefficiency can seldom be reduced to a minimum.

(2) Due to heavy administrative expenses, state enterprises are mostly run at a loss leading to additional burden of taxation on the people.

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(3) There is too much interference by the Government and Politicians in the internal affairs of the public enterprises. As a result, inefficiency increases.

(4) Delay in decisions is a very common phenomena in public enterprises.

(5) Incompetent persons may occupy high levels.

(6) Workers (unlike in private concerns) shirk work.

2.15-1 DISTINCTION BETWEEN PRIVATE SECTOR AND PUBLIC SECTOR S-1

S. No.	Private Sector	Public Sector
1.	The main objective of private sector is to earn more and more profit. It benefits only the owners.	Social benefit is of primary importance while profit motive is given secondary importance.
2.	The enterprise is owned and managed by individual or a group of individuals.	It is owned and managed by the Central or State Government.
3.	There is a limit to the capital which can be raised by private sector.	Govt. has ample funds and can borrow more if needed, in the money market at lower rate. Hence, large amount of capital can be collected.
4.	It causes concentration of wealth in the hands of few capitalists.	It leads to equitable distribution of wealth and income. Profit is utilized for the welfare of the nation.
5.	Private sector has to face competition in the market.	There is absence of competition. Generally the projects undertaken needs huge capital and private sector is not attracted to them.
6.	Private Sector dominates in the production of consumer goods.	It generally dominates in the production of producer goods.
7.	There are chances of exploitation of general public (workers and consumers).	Public sector enterprises are subjected to greater control and it helps to protect the workers and consumers from exploitation.
8.	Private sector does not undertake risky ventures or those having low profit margin.	It helps in the growth of industries which require huge capital but useful for the welfare of the nation even though profit margin is less.
9.	Private Sector leads to unbalanced growth of industries.	Public sector encourages industrial growth of under-developed regions in the country.
10.	Wastage of material and labour is minimum.	Public sector can rarely attain the efficiency of private sector; wastage and inefficiency can seldom be reduced to minimum.

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2.6 COMPARISON OF DIFFERENT FORMS OF INDUSTRIAL OWNERSHIP

S. No.	Factor	Forms of Ownership					
		Sole Ownership	Joint Hindu Family	Partnership	Private Limited Company	Public Limited Company	Cooperative Society
1.	Ownership	Single	Family	2 ≤ members ≤ 20	2 ≤ members	Members ≤ 7; No upper limit	Member ≥ 10; No upper limit
2.	Formation	Easy; No legal formality	Easy; No major legal formality	Moderately easy; Only an agreement required	Different; legal entity	Major legal formalities	Moderate legal formality
3.	Separate Legal Status	None	None	None	Yes	Yes	Yes
4.	Capital Required	Small or Limited	Limited	Limited	Large	Very large	Not substantial
5.	Management	By owner – Quick decisions	By owner	By owner(s) and shared	By hired experts or owner	Separate from owner	Few elected members
6.	Secrecy	Complete	Complete	Shared among partners	Shared among members	No	Limited to members
7.	Govt. Regulation	No	No	Fairly low	Fairly high	Highly regulative	Moderate
8.	Expertise needed	Limited	Limited	Limited	Fairly high	Quite high	Moderate
9.	Owner's Liability	Unlimited, full risk	Unlimited	Unlimited	Limited	Limited	Governed by-laws
10.	Profit Sharing	Completely by owner		Shared among partners	Proportionate to share being held		Based on volume of business by members
11.	Governed by law	No	No	Indian Parliament Act, 1932	Companies Act, 1956		Cooperative Society Act 1912
12.	Transfer of Ownership	Any time at will	After death of father to son	Relatively difficult, with mutual consent only	Difficult and restricted by article of association	Very easy by transfer of share	Restricted
13.	Tax Structure	**Very less**			**Heavy**		Exemption
14.	Audit	No	No	No	Must	Must	Must
15.	Closure	**Any time**		**As per Act**			

16.	Documentation	Not much written papers	Governed by will of owner	By consent of all partners	Not much	Very systematic; Governed by Memorandum of Association	
17.	Suitability	Small business, Dependent on the expertise of owner		Medium business; depends on capital, expertise and market forces	Medium to large business; depends upon market forces	Medium to large business; depends upon Govt. priorities	Medium business; depends upon mutual benefits of members
18.	Stability	Life of owner	After the death of owner passed to son	Depends upon all partners' will	Continuous	Continuous	Comparatively short life

REVIEW QUestions

1. Define productivity and explain its meaning with suitable examples. How is it different from production and profitability?
2. What are the different methods to measure productivity?
3. Describe the various kinds of partial productivity measurement.
4. State the benefits of increasing productivity to :

   (a) Management (b) Workers (c) Society
5. Explain the importance of productivity.
6. Describe the various techniques of improving productivity.
7. What measures would you suggest to improve productivity of a firm?
8. Discuss the necessity of close interaction between product design and process design on improving productivity.
9. Discuss the effects of the following on productivity :

   (a) Plant layout (b) Working conditions (c) Design of part (d) Manufacturing process (e) Combined operations (f) Tolerance and specifications
10. Describe the procedure for increasing productivity.
11. Justify the statement :

    "Productivity is a means for increasing the welfare and wealth of the nation."
12. There are two industries manufacturing two types of plugs. The standard time per piece is 1.5 minutes. The output of the two industries is 300 and 200 respectively per shift of 8 hours.

    (a) What is the productivity of each per shift of 8 hours?

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(b) What is the production of each per week (6 days) on the basis of double shift?

[**Ans.** (a) Industry I—15/16 = 0.937; Industry II—5/8 = 0.625
(b) Industry I—3600; Industry II—2400]

13. Distinguish among the characteristic features of job, batch and flow production. Mention the reason for you to recommend the type of production process for :

(a) An industrial unit manufacturing drugs and medicines

(b) A commercial bank providing variety of services to its customers

(c) An industrial unit manufacturing refrigerator

(d) An industrial unit manufacturing paints

14. Differentiate between "job-order production" and "batch production system". Which amongst these will be suitable for a small-car manufacturing plant?

15. What are the various forms of industrial ownership? What factors should be considered for deciding the ownership of an industry before starting it?

16. What are private sector enterprises? Discuss their relative merits and demerits.

17. What do you understand by single proprietorship firm? What are the merits and limitations associated with such firms?

18. What are the salient features of partnership firms? Discuss the types of partnership alongwith their merits and limitations.

19. Compare individual ownership with partnership firms.

20. What do you understand by Joint Hindu Family business? Discuss its salient features.

21. What is a Joint Stock Company? How is it different from partnership firms?

22. Compare private limited and public limited joint stock companies.

23. Define co-operative organisation. State the characteristics of co-operative organisation.

24. What is the distinction between co-operative and joint stock company?

25. What are the various objectives for forming public sector enterprises? Discuss their merits and demerits.

26. How is private sector different from public sector?

27. Make a comparison of different forms of industrial ownership.

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3 MANAGEMENT FUNCTIONS

Learning Objectives

After reading this chapter, you will understand :

- Meaning of management—its principles and functions
- Different management tools
- Time study (Meaning, objectives, uses, benefits and procedure)
- Motion study (Meaning, objectives and procedure)
- Work study (Meaning, objectives, procedure and benefits)
- Process charts (Meaning, symbols and classification with different charts)
- Flow diagram (Meaning and drawing with example)
- String diagram (Meaning and drawing with example)

3.1 INTRODUCTION

Let us first understand 'what is ***management***'. The management may be called an ***art*** as well as a ***science.*** It is an art in the sense that management means coordinating and getting work done through others. On the other hand, it is a science in the sense that management techniques are susceptible to measurement and factual determination.

Management is an ***executive function*** and does not frame policies. It only implements/executes the policies laid down by the administration. Therefore, the main functions of management are executive and largely governing. The various functions of management includes ***planning, organising, motivation, directing, coordination*** and ***control all functions.*** The management provides new ***ideas and vision*** to the organisation. It provides ***stability*** to the enterprise by changing and modifying the resources in accordance with the changing environment of the society. So management only meet the ***challenge of change.***

Let us now consider ***administration.*** Administration is supreme master of the industry and is needed for controlling any enterprise. Administration makes policies and decides the goals/targets to be achieved. It coordinates ***finance, production*** and ***distribution.*** An ***administrator*** organises his own work and

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that of his subordinates. He delegates responsibility and authority and measures, evaluates and control position activities.

Finally let us define an ***organisation.*** Organisation is a framework of management. This is a ***group of persons*** or a ***system.*** The organisation is concerned witth the ***building, developing*** and ***maintaining*** of a structure of ***working relationship*** in order to acomplish the objectives of the enterprise.

So we can say that, "*Management carries out the policies of administration through the framework of the organisation.*" The aim of this chapter is to discuss the functions and principles of management and also discuss various management tools.

3.2 IMPORTANCE OF MANAGEMENT

No enterprise can be run without management. The importance of management can be understood as under :

(1) Management *guides* and *controls* the activities of man-power for the optimum utilisation of company resources, such as men, materials, money, machines, methods etc.

(2) Management creates a vital, dynamic and life giving *force* to the enterprise.

(3) Management *coordinates* activities of different departments in an enterprise and establishes team-spirit among the different persons.

(4) Management provides new *ideas and vision* to the organisation to do better.

(5) Management *tackles business problems* and provides a tool for the best way of doing things.

(6) It is by management only that we can meet the *challenge of change.*

(7) Management provides *stability* to the enterprise by changing and modifying the resources in accordance with the changing environment of the society.

(8) Management helps *personality development.* Thereby it raises efficiency and productivity.

3.3 CHARACTERISTICS OF MANAGEMENT

(1) Management is *goal oriented.* It achieves the organizational goals through coordination of the efforts of the personnel.

(2) Management works as a *catalyst* to produce goods using labour, materials and capital.

(3) Management is a distinct *process* comprising of functions such as planning, organising, staffing, directing and controlling.

(4) Management represents a system of *authority*—a hierarchy of command and control. Managers at different levels possess varying degrees of authority.

(5) Management is a *unifying force*. It integrates human and other resources to achieve the desired objectives.

(6) Management *harmonises* the individual's goals with the organisational goals to minimize conflicts in the organisation.

(7) Management is a *multi-disciplinary subject*. It grew taking the help of subjects such as Engineering, Psychology, Sociology, Anthropology, Operations Research, etc.

(8) Management is *universal* in character. The principles and techniques of management are equally applicable in the fields of business, industry, education, government, army, hospitals, etc.

(9) It is *scientific* in nature as its techniques can be measured and factualy determined.

(10) Management is an *art* because it requires actual work to be done through other people.

3.4 OBJECTIVES OF MANAGEMENT

Managerial objectives are the intended goals which prescribe definite scope and suggest direction to the efforts of a manager. They should be clearly defined, properly communicated and reasonably attainable. Further, these objectives should not be conflicting with the overall organisational goals.

Managerial objectives may be classified as

(1) General objectives

(2) Specific objectives

(1) General objectives

(i) Nature of business

(ii) Continuous supply of capital

(iii) Growth of firm

(iv) Increasing production and productivity

(v) *Economic objectives* (*e.g.*, profit).

(vi) *Social objectives* (*e.g.*, to offer goods of superior quality and services to the society at reasonable rates, to provide workers with fair wages and incentives and to pay taxes honestly, etc.).

(vii) *Human objectives* (*e.g.*, to understand the needs of subordinates, to motivate them and to boost their morale).

(2) Specific objectives

(i) Nature of goods to be produced or services to be rendered.

(ii) Type of Customers (*e.g.*, rich, poor, individuals, business houses, Government, etc.

(iii) Market standing (*e.g.*, local, national or international).

(iv) Product diversification, if required.

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3.5 MANAGEMENT SKILLS

All managers must have five critical skills : technical skill, interpersonal skill, conceptual skill, diagnostic skill and political skill.

[I] Technical Skill

Technical skill involves understanding and demonstrating proficiency in a particular workplace activity. It is essential for a manager to know which technical skill should be employed in a particular work situation. Technical skills are things such as using a computer word processing program, creating a budget, operating a piece of machinery, or preparing a presentation. The technical skills used will differ in each level of management. First-level managers may engage in the actual operations of the organization; they need to have an understanding of how production and service occur in the organization in order to direct and evaluate line employees. Additionally, first-line managers need skill in scheduling workers and preparing budgets. Middle managers use more technical skills related to planning and organizing, and top managers need to have skill to understand the complex financial workings of the organization.

[II] Interpersonal Skill

Interpersonal skill involves human relations, or the manager's ability to interact effectively with organizational members. Communication is a critical part of interpersonal skil. *Communicating skill* is the ability to pass on information to others. Improper, insufficient and poorly expressed information/instruction can create confusion and annoyance. A manager with excellent technical skill but poor interpersonal skill is unlikely to succeed in their job. This skill is critical at all levels of management.

Motivation is also a part of interpersonal skill. *Motivating skill* inspirses people to do what the manager wants them to do.

Another interpersonal skill is the *leadership skill.* It enables a manager to lead people working under him. It is the ability to inspire confidence and trust in the subordinates in order to have maximum cooperation from them for getting the work done.

[III] Conceptual Skill

Conceptual skill is a manager's ability to see the organization as a whole, *i.e.,* as a complete entity. It involves understanding how organizational units work together and how the organization fits into its competitive environment. Conceptual skill is crucial for top managers, whose ability to see "the big picture" can have major repercussions on the success of the business. However, conceptual skill is still necessary for middle and supervisory managers, who must use this skill to envision. For example, how work units and teams are best organized.

Decision making skill is a part of conceptual skill. It is the ability of a person to take timely and accurate decisions. This requires mental abilty and presence of mind.

Organisational skill help to select and assign different people to different works. There is always a right person for the right job.

[IV] Diagnostic Skill

Diagnostic skill is used to investigate problems, decide on a remedy and implement a solution. Diagnostic skill involves other skills—technical, interpersonal, conceptual and political. For instance, to determine the root of a problem, a manager may need to speak with many organizational members or understand a variety of informational documents. The difference in the use of diagnostic skill across the three levels of management is primarily due to the types of problems that must be addressed at each level. For example, first-level managers may deal primarily with issues of motivation and discipline, such as determining why a particular employee's performance is flagging and how to improve it. Middle managers are likely to deal with issues related to larger work units, such as a plant or sales office. For instance, a middle-level manager may have to diagnose why sales in a retail location have dipped. Top managers diagnose organization-wide problems, and may address issues such as strategic position, the possibility of outsourcing tasks, or opportunities for overseas expansion of a business.

[V] Political Skill

Political skill involves obtaining power and preventing other employees from taking away one's power. Managers must use power to achieve organizational objectives. This skill can often reach goals with less effort than others who lack political skill. Much like the other skills described, political skill cannot stand alone as a manager's skill. In particular, using political skill without appropriate levels of other skills can lead to promoting a manager's own interest rather than reaching organizational goals. Managers at all levels require political skill. Managers must avoid others taking control that they should have in their work positions. Top managers may find that they need higher levels of political skill in order to successfully operate in their environments. Interacting with competitors, suppliers, customers, shareholders, government and the public may require political skill at all levels of management.

3.6 LEVELS OF MANAGEMENT

The term *'Levels of Management'* refers to a line of demarcation between various managerial positions in an organization. The number of levels in management increases when the size of the business and work force increases and vice versa. The level of management determines a chain of command, the amount of authority and status enjoyed by any managerial position. The levels of management can be classified in three broad categories :

1. Top level/Administrative level
2. Middle level/Executory
3. Lower level/Supervisory/Operative/First line managers

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Managers at all these levels perform different functions. The role of managers at all the three levels is summarized in fig. (1).

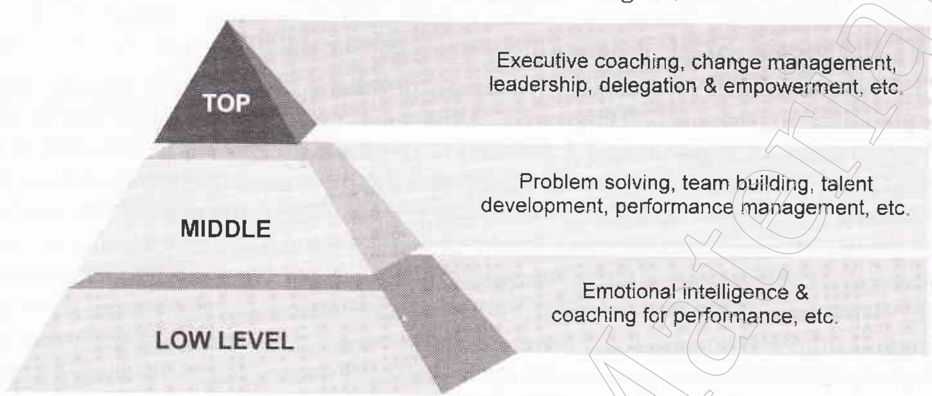

Fig. (1) Levels of Management

[I] *Top Level of management*

It consists of board of directors, chief executive or managing director. The top management is the ultimate source of authority and it manages goals and policies for an enterprise. It devotes more time on planning and coordinating functions.

The role of the top management can be summarized as follows :

(1) Top management lays down the objectives and broad policies of the enterprise.

(2) It issues necessary instructions for preparation of department budgets, procedures, schedules, etc.

(3) It prepares strategic plans and policies for the enterprise.

(4) It appoints the executive for middle level, *i.e.,* departmental managers.

(5) It controls and coordinates the activities of all the departments.

(6) It is also responsible for maintaining a contact with the outside world.

(7) It provides guidance and direction.

(8) The top management is also responsible towards the shareholders for the performance of the enterprise.

[II] *Middle Level of Management*

The branch managers and departmental managers constitute middle level. They are responsible to the top management for the functioning of their department. They devote more time to organizational and directional functions. In small organization, there is only one layer of middle level of management but in big enterprises, there may be senior and junior middle level management. Their role can be emphasized as :

(1) They execute the plans of the organization in accordance with the policies and directives of the top management.

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(2) They make plans for the sub-units of the organization.

(3) They participate in employment and training of lower level management.

(4) They interpret and explain policies from top level management to lower level.

(5) They are responsible for coordinating the activities within the division or department.

(6) They also send important reports and other important data to top level management.

(7) They evaluate performance of junior managers.

(8) They are also responsible for inspiring lower level managers towards better performance.

[III] Lower Level of Management

Lower level is also known as supervisory/operative level of management. It consists of supervisors, foreman, section officers, superintendent, etc. Supervisory management refers to those executives whose work has to be largely with personal oversight and direction of operative employees. In other words, they are concerned with direction and controlling function of management. Their activities include :

(1) Assigning of jobs and tasks to various workers.

(2) They guide and instruct workers for day to day activities.

(3) They are responsible for the quality as well as quantity of production.

(4) They are also entrusted with the responsibility of maintaining good industrial relations in the organization.

(5) They communicate workers problems, suggestions and recommendatory appeals, etc. to the higher level and higher level goals and objectives to the workers.

(6) They help to solve the grievances of the workers.

(7) They supervise and guide the sub-ordinates.

(8) They are responsible for providing training to the workers.

(9) They arrange necessary materials, machines, tools, etc. for getting the things done.

(10) They prepare periodical reports about the performance of the workers.

(11) They ensure discipline in the enterprise.

(12) They motivate workers.

(13) They are the image builders of the enterprise because they are in direct contact with the workers.

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3.7 FUNCTIONS OF MANAGEMENT

Following are the basic elements in various functions of management :

1. Forecasting

- Forecasting is a necessary preliminary to planning.
- Forecasting estimates the future work or what should be done in future; for example, with regards to sales or production or any other aspect of business activities.
- Forecasting begins with the sales forecast and is followed by production forecast and forecasts for costs, finance, purchase, profit or loss, etc.

2. Planning

- Planning all aspects of production, selling, etc., are essential in order to minimise intangibles.
- Planning is a process by which a manager anticipates the future and discovers alternative courses of action open to him.
- Planning is a rational, economic, systematic way of making decisions today which will affect the future, *e.g.*, what will be done in future, who will do it and where it will be done.
- In fact, every managerial act is some type of planning.
- Without proper planning, the activities of an enterprise may become confused, haphazard and ineffective. For example, if a refrigerator making concern does not plan in advance—how many refrigerators and of what capacities are to be made before the summer starts and thus it does not procure necessary materials, tools, supplies and personnel in time, it cannot reach the production targets and hence may not run profitably.
- Prior planning is very essential for utilizing the available facilities (men, materials, machines, etc.) to the best of advantage.

3. Organising

- Organising is the process by which the structure and allocation of jobs is determined.
- Organising involves determining activities required to achieve the established company objectives, grouping these activities in a logical basis for handling by subordinate (persons), managers and finally, assigning persons to the job designed. In carrying out the above, the manager will delegate necessary authority to his subordinates (persons). They, in turn, will take the necessary responsibility.
- Organising means, organising people, materials, jobs, time, etc., and establishing a framework in which responsibilities are defined and authorities are laid down.

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4. Staffing

- Staffing is the process by which managers select, train, promote and retire their subordinates.
- Staffing involves the developing and placing of qualified people in the various jobs in the organisation.
- Staffing is a continuous process. The aim is to have appropriate persons to move into vacated positions or positions newly created in the enterprise.

5. Directing

- Directing is the process by which actual performance of subordinates is guided towards common goals of the enterprise.
- Directing involves motivating, guiding and supervising subordinates towards company objectives.
- Directing thus includes :

(i) Giving instructions to subordinates.

(ii) Guiding the subordinates to do the work.

(iii) Supervising the subordinates to make certain that the work done by them is as per the plans established.

- Directing involves functions such as

(a) Leadership, (b) Communication,

(c) Motivation, and (d) Supervision

a) Leadership

- Leadership is the quality of the behaviour of the persons (Managers) whereby they inspire confidence and trust in their subordinates, get maximum cooperation from them and guide their activities in organized effort.
- Leadership is more than personal ability and skill.

b) Communication

- Communicating is the process by which ideas are transmitted, received and understood by others for the purpose of effecting desired results.
- Communication may be verbal or written orders, reports, instruction, etc.
- A manager communicates to his subordinates as what they should do.
- An ineffective communication leads to confusion, misunderstanding, dissatisfaction and sometimes even strikes.

c) Motivation

- Motivating means inspiring the subordinates to do a work or to achieve company objectives effectively and efficiently.

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(d) Supervision

- Supervision is necessary in order to ensure,

(i) that the work is going on as per the plan established, and

(ii) that the workers are doing as they were directed to do.

6. Coordinating

- Coordinating means achieving harmony of individual effort towards the accomplishment of company objectives.
- Ineffective coordination between different functions of a business enterprise (such as production, sales, administration, etc.) can ruin the enterprise.
- Coordination involves making plans that coordinate the activities of subordinates, regulate their activities on the job and regulate their communications.
- Besides other factors, informal relationships within an organization also tend to facilitate co-ordination, because workers who like each other outside the factory, prefer to work together on the job also.

7. Controlling

- Controlling is the process that measures current performance and guides it towards some predetermined goal.
- Controlling involves :

  (i) the monitoring of programme activities to make sure that end objectives are being met.

  (ii) the initiation of corrective action as required to over-come problems, if any, hindering the accomplishment of objectives.
- Checks and examinations are required on a periodic basis to ensure that the things are proceeding as per plans established.
- Controlling is necessary to ensure that orders are not misunderstood, rules are not violated and objectives have not been unknowingly shifted. Control means control of persons and other things.
- Controlling is a continuous process which measures the progress of operations, compares, verifies their conformity with the predetermined plan and takes corrective action, if required.
- Hence, we can say that controlling process

  (i) Sets standards,

  (ii) Measures job performance, and

  (iii) Takes corrective action, if required.

8. Decision Making

- Decision making is the process by which a course of action is chosen from available alternatives for the purpose of achieving desired results.

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- An outstanding quality of a successful manager is his ability to make sound and logical decisions.
- Management decisions range from establishing consumer operational development needs to the selection of a preferred system design configuration to many other aspects of business enterprise.

3.8 SCIENTIFIC MANAGEMENT

Scientific management is an attempt to determine and apply the facts and laws that are essential for efficient running of an enterprise. Scientific management was first of all introduced by F.W. Taylor in America (1856-1915) who is regarded as father of scientific management. Before Taylor business was managed by the rule of thumb and common sense. He found inefficiency all around the business and introduced scientific management as their solution. Taylor introduced this only in manufacturing shops but now-a-days it is applied in a wider sense in all the sections of the factory or enterprise, *i.e.*, shops, processes and operations, planning, scheduling, budgetary control, stock control, market research and wage control, etc. It is also applicable to the building, equipping, operating and buying of raw materials and selling of finished goods.

Scientific management may be defined as *"Art of knowing exactly what is to be done and the best way of doing it."* This is simply as systematic approach in solving operation problems. In short *"Scientific management is the application of scientific principles and methods to management."*

In scientific management, the best method of doing a job is scientifically thought out, the employees are scientifically selected and trained to perform the job and an efficient speed is scientifically determined by considering the following facts :

- Recognise the problem, analyse and define objectives.
- Collect and analyse the required data.
- Select alternatives, if possible.
- Evaluate and review each alternative.
- Test conclusions and if required, correct actions.
- Take selected actions, and
- Formulate and test principles based on experimental results of all the cases.

Summarising, we can say that scientific management involves :

(i) scientific study and analysis of work;

(ii) scientific selection and training of employees; and

(iii) standardisation of raw materials, working conditions and equipment.

Aims of Scientific Management

The aims of scientific management are :

(a) *Increased production :* Increase in the rate of production by use of standardised tools, equipment and methods.

(b) *Quality control :* Improvement in the quality of the output by research, quality control and inspection devices.

(c) *Cost reduction :* Reduction in the costs of production by rational planning and regulation and cost control techniques. This also leads to increased purchasing power of customer due to lower unit cost.

(d) *Elimination of avoidable wastes :* Elimination of avoidable wastes in the use of resources and methods of production.

(e) *Right men for right work :* Through scientific selection and training, placement of right person on the right job.

(f) *Incentive wages :* Payment of uniform wages to workers and giving incentives according to their efficiency.

3.8-1 PRINCIPLES OF SCIENTIFIC MANAGEMENT

The scientific management approach proposed by Taylor is based on following five principles :

(1) *Use of scientific method :* According to traditional method of management, decisions were based on opinion, intuition or rule of thumb. Scientific management advocates the use of scientific studies to take managerial decisions. This is the key difference between traditional and scientific approach.

(2) *Scientific selection and training of workers :* Every organisation should follow a scientific system for selection so that only the best worker is selected for a particular job. The selected workers are to be trained so that they do not follow wrong methods at work. Management is responsible for their education and training. In addition, management should provide opportunities for development of workers having better capabilities.

(3) *Co-operation between labour and management :* Management should cooperate with the workers. This requires a change of mental attitude in both—the management and the workers. Taylor described it as *"mental revolution"*.

(4) *Maximum output :* The management and the workers should try to achieve maximum output in place of restricted output. This will be beneficial to both the parties. Maximum output will also be in the interest of the society.

(5) *Equal division of responsibility :* There must be equal division of responsibility between the managers and the workers. The management should take responsibility for the work for which it is better suited. For instance, management should decide the method of work, working conditions, time of completion of work, etc. instead of leaving these at the discretion of workers. The management should be responsible for planning and organising the work, whereas the workers should be responsible for the execution of work as per instructions of management.

3.8-2 MENTAL REVOLUTION

The basic idea behind the principles of scientific management is to change the mental attitudes of the workers and the management towards each other. Taylor called it *'Mental Revolution'*. The mental revolution has three aspects :

(i) all out efforts for increase in production;

(ii) creation of the spirit of mutual trust and confidence; and

(iii) inculcating and developing the scientific attitude towards problems.

Taylor suggested that management should try to find the best methods of doing various jobs. They should introduce standardised materials, tools and equipment so that wastages are reduced. The management should select right types of people and give them adequate training so as to increase the quantity and quality of production. It must create good working conditions for optimum efficiency of the workers. It should perform the decision-making function and should always give maximum cooperation to the workers to ensure that work is done according to the scientific techniques.

The workers should also change their attitude towards the management. They should be disciplined, loyal and sincere in fulfilling the tasks assigned to them. They should not waste resources. Both the management and the workers should trust each other and cooperate in achieving maximum production.

Thus, Taylor stood for creating a mental revolution on the part of management and workers. It is to be noted that Taylor's thinking was confined to management at the shop level. However, he demonstrated the possibility and significance of the scientific analysis for the various aspects of management.

Summarising, we can say that Taylor laid emphasis on :

(1) Science and not rule of thumb.

(2) Harmony in group action, rather than discord.

(3) Maximum output in place of restricted output.

(4) Scientific selection, training and placement of the workers.

(5) Development of all workers to the fullest extent possible for their own and organisation's highest prosperity.

3.8-3 TECHNIQUES OF SCIENTIFIC MANAGEMENT

Taylor and his associates suggested the following techniques to implement the philosophy of scientific management :

(1) *Scientific task setting :* Management should set a standard task which a worker must do during a day. Taylor termed it *"a fair day's work"*. It is the task set up by the management which an average worker, under average standardised conditions will do during a working day. This will prevent the worker from doing work below his capacity.

(2) *Work study :* Work study implies an organised, objective, analytical and critical assessment of the efficieny of various operations in an enterprise.

Work study can be conducted by following methods :

(i) *Method study :* It is conducted to know the best method of doing a job. It helps in reducing the distance travelled by material, and brings improvements in handling, transportation, inspection and storage of raw materials and finished goods.

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(ii) *Motion study :* It is conducted to know the movement of an operator of a machine. There may be some useless motions while the operator is doing a job. Those motions are to be identified and eliminated. By conducting this study, we come to know whether some elements of a job can be eliminated, combined or their sequence changed to get the best method of doing a job.

(iii) *Time study :* Time study is the technique of observing and recording the time required to do each detailed element of an industrial operation. Through time study the precise time required for each element of a man's work is determined. It heps in fixing the standard time required to do a particular job.

(iv) *Fatigue study :* Fatigue (physical or mental) has an adverse effect on worker's health and his efficiency. Fatigue study helps in reducing fatigue among the workers. Fatigue is generally caused by long working hours without rest pauses, repetitive operations, excessive specialisation and poor working conditions. The purpose of fatigue study is to maintain the operational efficiency of the workers.

(3) *Planning the task :* Taylor advocated that the planning function should be separated from the executive function. Workers should not be asked to choose their own methods and decide what they have to do. The detailed planning should be done by the planning department. The planning department should prepare detailed instructions for the workers as to the type, quality and quantity of the products which are to be produced.

(4) *Standardisation :* Taylor advocated the standardisation of tools and equipment, cost system and several other items. Efforts should be made to provide standardised working environment and methods of production to the workers.

(5) *Scientific selection and training :* The management should design scientific selection procedure so that right men are selected for the right jobs. Workers should be specifically trained for the jobs they are appointed so that they can perform their jobs effectively.

(6) *Differential piece-wage plan :* This plan was suggested by Taylor to attract highly efficient workers. Under this plan, there are two piece-work rates, one is lower and another is higher. The standard of efficiency is determined either in the terms of time or output based on time and motion study. If a worker finishes work within standard time or produces more than standard output within the standard time, he should be given higher piece rate. On the other hand, if a worker is below the standard, he shall be given lower piece rate.

(7) *Specialisation :* Taylor advocated *'functional foremanship'* to introduce specialisation. He recommended eight foreman in all to control the various aspects of production. He suggested four foreman in the planning department, namely, route clerk, instruction card clerk, time and cost clerk and shop disciplinarian. The four foreman recommended for getting the required performance from the workers include gang boss, speed boss, repair boss and inspector.

3.8-4 CONTRIBUTIONS OF SCIENTIFIC MANAGEMENT

The chief contributions of scientific management are :

(1) Emphasis on rational thinking on the part of management replacing the traditional thumb rules method.

(2) Focus on the need for better methods of industrial work through systematic study and research. It leads to standardisation of tools, equipment, materials and work methods. Proper selection and training of workers is also promoted.

(3) Emphasis on planning and control of production leading to division of responsibility between the workers and management.

(4) Development of cost accounting, elimination of avoidable wastes and better utilisation of various resources.

(5) Development of incentive plans of wage payment based on systematic study of work.

(6) Focus on the problem of fatigue and rest in industrial work.

(7) Improving worker-management relationship.

(8) Focus on the need for separate department to control various aspects of production.

3.8-5 ADVANTAGES OF SCIENTIFIC MANAGEMENT

Scientific management is an approach which serves the common interests of employees, workmen and society.

Advantages to the employees are :

(1) A better workforce can be created by proper selection and training of the workers.

(2) Coordial relations are developed between the workers and the management.

(3) The responsibilities of the workers and the management are clearly defined.

(4) Efficiency of the industry is increased due to standardisation of tools, equipment, materials and work methods.

(5) Various resources are better utilised and avoidable wastes are identified and minimized.

(6) Determination of work to be done by a worker during a working day.

Advantages to the workers are :

(1) There are opportunities for training and development for workers which increases their work knowledge and skills.

(2) Detailed instructions and guidance is provided to the workers which reduces the chances of accidents.

(3) Production linked incentives in pay-package.

(4) Reduction in fatigue due to application of scientific methods at job.

(5) Better working conditions and tools. This leads to better health of workers.

Advantages to the society are :

(1) Better quality products at lower costs to the people.

(2) Higher standard of living of people through better products.

(3) Increased productivity in the country.

(4) Industrial peace in the country.

(5) Technological development due to scientific investigation.

3.8-6 CRITICISM OF SCIENTIFIC MANAGEMENT

Sientific management ignores human factors such as personality, motivation and job satisfaction. Worker is regarded as another machine within the industry. Worker is looked upon as a more instrument of production and reduces him to a semi-automatic attachment to the machine or tool. So, scientific management was criticized not only by the workers and managers but also by the psychologists and the general public. Their viewpoints are now discussed.

Worker's Viewpoint

The workers criticized scientific management on the following grounds :

(1) *Speeding up of workers :* Workers feels that scientific management treats them like machine demanding maximum output. It does not bother about the adverse effect of speeding up of work on the physical and mental well being of the workers.

The counter viewpoint as advocated by followers of scientific management is that speeding up of work is the result of improved methods of work, tools and working conditions.

(2) *Boredom :* Workers are given a particular job to do in which they are expected to specialise. This leads to monotony in job, *i.e.*, same job being repeated again and again. After some time workers may feel boredom.

(3) *No scope for initiative :* Workers are given a particular job with instructions on how to do it and in what time. There is no scope for initiative or find new methods of work.

(4) *Unemployment :* There is a general feeling among workers that as the output per worker increases, job opportunities will reduce. This leads to increase in unemployment.

(5) *Weakening of trade union :* Scientific management rests on the fundamental economic principle that harmony of interests exist between employers and workers. It discourages disputes over the distribution of gains from increased productivity. In this way it weakens the trade union movement.

(6) *Exploitation of workers :* There is a general feeling among workers that scientific management is a clever device for the exploitation of the workers. They feel that the wages of the workers were not increased in direct proportion to productivity increases.

Employer's Viewpoint

The employers criticized scientific management on the following grounds :

(1) *Expensive process :* The introduction of scientific management requires a lot of money. Standardisation of methods of work, tools and improvement in working conditions—all require huge amount of money. The employers have to bear extra cost of planning department in the industry.

(2) *Re-organisation :* The process of introduction of methods of scientific management in an existing industry means stoppage of work. Further, full-capacity production takes some time. The management has to suffer losses.

(3) *Lack of financial control :* Scientific management is silent on the issue of financial control. This can lead to inefficiency in the enterprise.

(4) *Impractical functional foremanship :* The eight foremans recommended by Taylor are not practical. It is not possible for a worker to receive commands from eight bosses at a time and satisfy them all.

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3.9 PRINCIPLES OF MANAGEMENT

V Imp.

A principle is a basic statement that provides understanding and guide to thinking and action. 'Principles of management' implies a list of current management practices. Though F. W. Taylor developed principles of management, the credit goes to Henri Fayol for advocating and publicizing these principles.

Henri Fayol listed 14 principles of management on the basis of his experience. They are :

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DAD UUSRC SCOE SIE

1. ***Division of work***
2. ***Authority and Responsibility***
3. ***Discipline***
4. ***Unity of command***
5. ***Unity of direction***
6. ***Subordination of individual to general interest***
7. ***Remuneration***
8. ***Centralisation of authority***
9. ***Scalar chain***
10. ***Order***
11. ***Equity of treatment***
12. ***Stability***
13. ***Initiative***
14. ***Esprit de Corps***

① Division of work ② Authority and Responsibility ③ Discipline ④ Unity of command ⑤ Unity of direction ⑥. Subordination of individual to general interest ⑦ Remuneration ⑧ Centralisation of authority ⑨ Scalar chain ⑩ Order ⑪ Equity of treatment ⑫ Stability ⑬ Initiative ⑭ Espirit de corps.

1. Division of Work

The division of works means dividing the workers on the principle that different workers are best fitted for different jobs depending upon their personal aptitude and skills. Division of work leads to specialisation. The main advantage of division of work is that the quality of the product is improved.

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2. Authority and Responsibility

An executive can justice with his responsibility only when he has proper authority. Responsibility without authority or *vice versa* is meaningless.

3. Discipline

Discipline is necessary for efficient functioning of all enterprises. This is a respect for agreements that are directed at achieving obedience and the outward marks of respect.

4. Unity of Command

Unity of command means that employees should receive orders and instructions from only one boss or supervisor. This means that an employee should work under only one boss or supervisor.

5. Unity of direction

Unity of direction implies that there should be one plan and one head for each group of activities having the same object.

6. Subordination of individual to general interest

The interests of an individual person should not be permitted to supersede upon the general interests of the enterprise. This is necessary to maintain unity and to avoid friction among the employees.

7. Remuneration

Remuneration is the price paid to employee for the services rendered by him to the enterprise. It should be fair and should bring maximum satisfaction to both (employee and employer).

8. Centralisation of authority

In an organisation, the authority should be centralised for the best overall performance. The authority should not be dispersed among different sections.

9. Scalar chain

Scalar chain means that there should be an unbroken line of authority and command through all levels from the highest (general manager) to lowest ranks (employee). The managers should be regarded as a chain of superiors.

10. Order

This means that everything (*e.g.*, materials) and everyone (human being) has his place in the organisation.

11. Equity of treatment

Equity of treatment means that the manager of the organisation should deal with the subordinates with kindness and justice. This will make employee more loyal and devoted towards his duties and management.

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12) Stability

Instability is the result of bad management. The stable and secure work force is an assest to the enterprise. For example, an average employee who stays with the organisation for a longer time is much better than outstanding employees who merely come and go.

13) Initiative

Initiative is one of the keenest satisfactions for an intelligent employee.

14) Esprit de corps

This principle of management emphasizes the need for team work among the employees.

3.10 MANAGEMENT TOOLS

There may be management situations in which all the needed data for solving a problem is not readily available. In such cases, it is necessary to go beyond the analytical approach and use the ***design approach*** for solving problems. ***The tools that are used effectively for solving management problems are known as management tools.***

Following are the seven management tools

1. ***Affinity diagrams***
2. ***Interrelationship diagrams***
3. ***Tree diagrams***
4. ***Matrix diagrams***
5. ***Matrix data analysis***
6. ***Process decision program charts*** (PDPC)
7. ***Arrow diagrams.***

The following table list the seven tools and their utilisation.

Table 1. List of seven tools in Nutshell

S.No.	Tool name	Utilisation
1.	Affinity diagrams	Used to organise abstract thinking about the problem To analyse the problem in relation to the customers
2.	Inter-relation diagrams	To analyse the problem in relation to different relationship Used for determining casualities among parts of a problem
3.	Tree diagrams	Functional analysis system technique (FAST) in value engineering To get the root cause to solve the problem
4.	Matrix diagrams	Used to organise knowledge in matrix format To establish relationships between various elements and arrange them in a matrix

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5.	Matrix data analysis	Principal components technique is performed on matrix data To take clue from the structured form at and analyse the problem
6.	Process decision program charts (PDPC)	Determining which processes to be used by evaluating events and prospective outcomes using operations research method
7.	Arrow diagrams	To arrange activities in correct sequence Used to do 'what fifing' on flow of process

3.10-1 AFFINITY DIAGRAMS

The affinity diagrams is a very simple technique which is based on group work. Every participant writes down his/her ideas, options and facts relating to a broad problem. The data is gathered and organised for problem understanding. Once the problem is identified, generation of solution will be easy.

The major stages in planning for problem solving are :

Stage I : Problem definition

Stage II : Development of strategies

Stage III : Formulation of action plan

The following steps are used in this technique :

1. Decide the topic on which confusion exists, for example lack or productivity or how to improve the English language speaking skills of students, etc.

2. Select a team of right people. The team must have common goals and interest. The purpose is to find the solution of the problem.

3. Allow each member to write down as many contributing factors as possible to the problem on a data card. The contributing factors may be facts, opinions and ideas and should be written on separate cards.

4. Spread the card randomly on a table with written matter facing up side. Now ask the team to logically group and cards.

5. Pick out the pairs of cards which have natural affinity and arrange them side by side.

6. Combine the statements of these two cards and form a single sentence. Write down this statement in a card. This is known as ***affinity card.*** This is done for all pairs of cards having natural affinity.

7. Continue the same steps for affinity cards. Pair the similar affinity card together.

8. Form a new affinity card with a sentence, which reflects both the cards.

9. The above procedure is repeated till all the cards are joined and a single or a couple of statements emerge.

10. Discuss the changes and generate the solution of problems.

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Fig. (2) shows the affinity diagram.

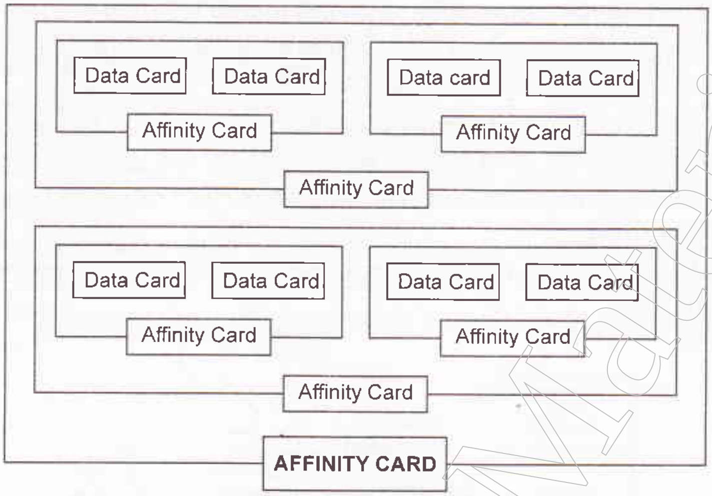

Fig. (2) Affinity Diagram

Exercise. *Draw an affinity diagram to improve the English language speaking skills of students.*

Solution. The affinity diagram is shown in fig. (3).

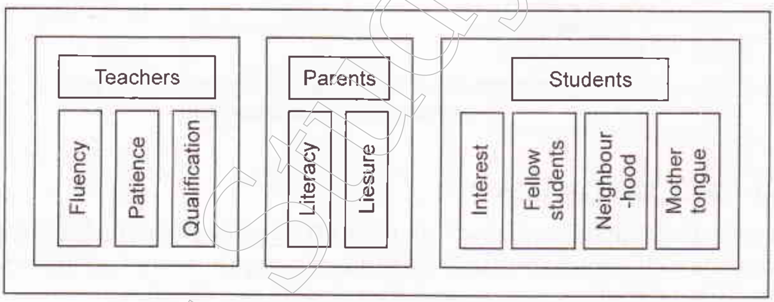

Fig. (3) Affinity diagram to improve the english language speaking

3.10-2 INTERRELATION DIAGRAMS

The interrelation diagrams are also known as relations diagram. Interrelation diagram (ID) is used to find appropriate solutions of the problem ***by studying the relationship between various causes and effects.*** Therefore, this tool helps in identifying the relationship between different factors which cause a problem or issue. This technique is often used after the affinity diagram had clarified issues and problems.

Steps

1. Appoint a team which agree on the issue or problem statement.
2. State clearly the issue or problem. Write it on a card and place it at the centre of a board.
3. Ask the team members to think about the problem and provide five different causes cards for the problem.

4. Place these cards around the central problem. Now arrange the cards in such a manner that similar ones are placed together.
5. Determine if *cause-effect* relationship exist between any of the cards. If so, draw an arrow from the '*cause*' card to the 'effect' card.
6. Cards that have most arrows going from them tend to be the '*root causes*'. Cards that have most arrows going to them are the '*root effects*'.
7. From the above discussion, the most important cause and root cause can be identified.

Fig. (4) shows the relationship diagram drawn to improve customer satisfaction.

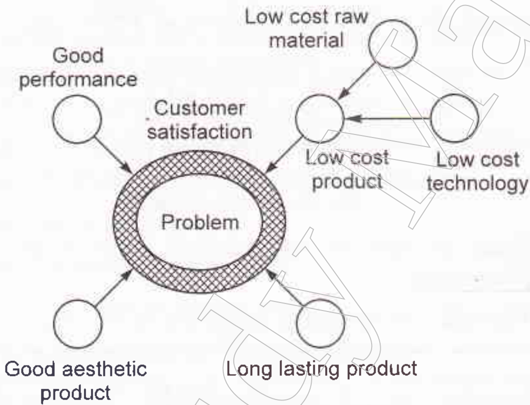

Fig. (4) Example of a relationship diagram drawn to improve customer satisfaction

3.10-3 TREE DIAGRAMS

A tree diagram is used to obtain ***best strategies for an objective.*** This is a technique which serves the purpose of developing the essential means to achieve an objective or goal.

A tree diagram is a tool which brings the issues and problem revealed by the affinity diagram and inter-relationship diagram down to ***operational planning stage.***

The final chart shows steps from the initial problem to the sequential development till the final conclusion. The chart look like a tree and hence called a tree diagram.

Therefore, ***a tree diagram systematically shows the means and procedures necessary to successfully implement a given plan.***

Steps

1. Identify the problem. Write it on a card. This card is known as *objective card.*
2. Identify constraints to be taken care of and how the objective can be achieved. Note them on a separate card.

3. Allow the team to discuss the means of achieving the objectives. The members of the team will suggest the different methods. Select three or four methods. Write them on separate cards. These are known as *primary cards*. Place the primary cards on the right of objective card.
4. Considering different primary cards, discuss and identify various methods for achieving it. Write them on different cards. These are known as *secondary cards*. Arrange the secondary cards corresponding to a primary card.
5. Discuss secondary cards which will give many root causes of the problem. When appropriate one is selected and tackled, the problem will be solved.

Fig. (5) shows a tree diagram constructed to analyse the monthly outgoings in a company.

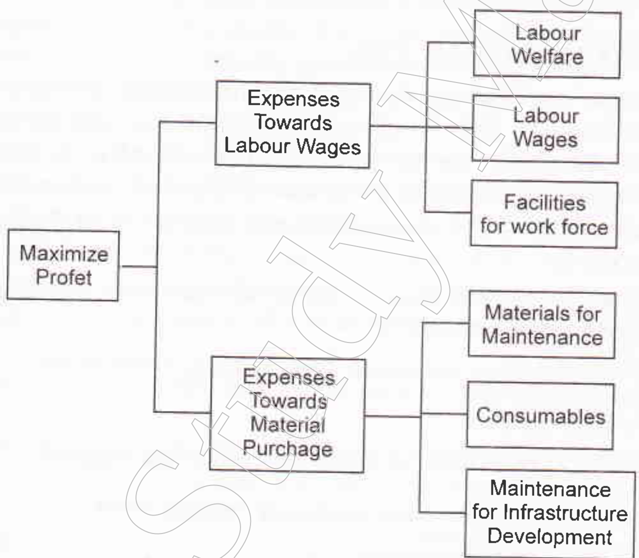

Fig. (5) Tree diagram for maximize profit

3.10-4 MATRIX DIAGRAMS

The matrix diagram consists of a set of columns and rows. The interconnections of these rows and column are checked for determining the nature and strength of the problem. Therefore, interrelationship between two data are considered for analysis. The ideas in this diagram are conceived on two dimensional relationship.

Steps

1. Identify the set of variables to be considered for the analysis. For example, consider two variables (goals and action) for a company.
2. Take the goals as rows of a matrix and actions as columns of the matrix.
3. Discuss among the team and find out the relation between different elements. Specify clearly them as strongly related (•), medium related (O) and weak related (Δ).

4. Indicate them in appropriate boxes as shown in fig. (6).

5. Analyse the matrix diagram to get a solution of the problem.

Fig. (6) shows the matrix diagram.

Matrix diagram

Goals \ Actions	Improve work environment	Improve manufacturing technology	Develop new products
Cost effectiveness	•	O	
High quality	•	•	
Shareholder value		Δ	•

Fig. (6) • strongly related, O medium related and Δ weak related showing matrix diagram

3.10-5 MATRIX DATA ANALYSIS

This chart is used when the matrix chart does not provide detailed information sufficiently. This is only method within the new seven tools that is based on ***data analysis*** and gives ***numerical results.*** It is important to mention that other management tools essentially deal with verbal data. The matrix analysis is also called as multivariate analysis or principal component analysis.

Let us consider matrix data analysis of customer requirement for an electronic component of a company.

Following informations are taken from market researchers :

1. ***Consumer requirements***

   They are : Price, reliability, delivery and technical support

2. ***Importance weighting for each customer requirement***

   0.2, 0.4, 0.1 and 0.3 respectively

3. ***Determination of other best competitors***

   7, 5, 8 and 6 respectively

4. ***Company's evaluation***

   8, 10, 6 and 4 respectively

   The above data are placed in matrix form.

Matrix data analysis of customer requirement of electronic component

Requirement	Importance weight (out of one)	Best competitors	Company's evaluation
Price	20% or 0.2	7	8
Reliability	40% or 0.4	5	10
Delivery	10% or 0.1	8	6
Technical support	30% or 0.3	6	4

The problem of the company is to which action the company should take to better meet key customer requirement. The problem can be solved by matrix data analysis as follow :

From the table, the reliability is the highest in importance (0.4). The company has a lead over its competitor. So, the company should not proceed in this direction. Next to reliability, technical support has high importance. The company is inferior to its best competitor in this category. Therefore, improving the quality of ***technical support*** should be a ***major objective of the company.***

3.10-6 PROCESS DECISION PROGRAM CHARTS (P.D.P.C.)

The process decision program chart (P.D.P.C.) is a very useful and powerful method to overcome an unfamiliar problem or a goal. PDPC avoids surprises and identifies possible counter-measures. This tool encourages team members to think what can happen to a process and how counter measures can be taken. Therefore, it provides the mechanism to effectively minimize uncertainty in the implementation plan.

Let us consider the process decision program chart (P.D.P.C.) to plan a successful conference. This is illustrated in fig. (7). The following steps are used :

1. First of all the ***activities*** are decided. Let the activities be registration, presentation and facilities. Here we shall consider only presentation activity.

2. Secondly, the team of experts of the conference will decide about the ***factors which may go wrong with the conference.*** This is denoted by what if in fig. (7).

3. Thirdly, the expert team will decide about the ***counter measures*** of the above factors.

4. The last step is to evaluate the counter measures and to select the optimal ones by placing O underneath and X under those are ***rejected.***

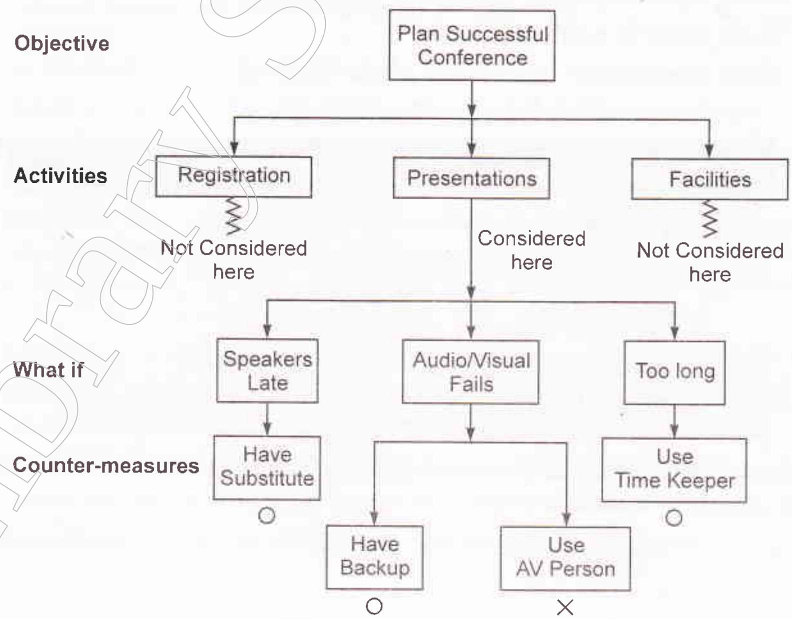

Fig. (7) PDPC for conference presentation

Fig. (8) shows PDPC for selection a proper route.

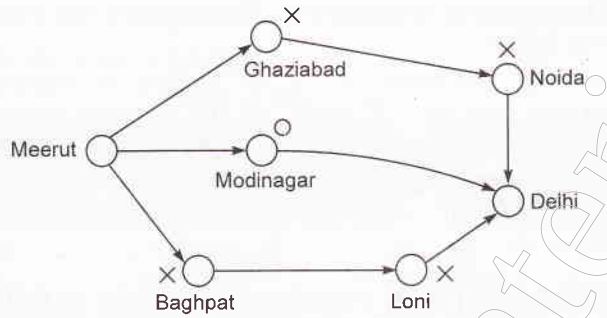

Fig. (8) Example of PDPC for Commuting between Meerut and Delhi

3.10-7 ARROW DIAGRAMS

Arrow diagrams are used for working out optimal schedules for any process. Controlling can be made effective using arrow diagrams.

This analysis is used to identify the factors that may influence the problem or goal. The positive factors are reinforced while the negative factors are eliminated.

The following steps are used :

1. Objective of the problem. Consider the example of ***stop smoking.***
2. Selection of promoting factors. Following are the promoting forces of the above problem :

   poor health, smelly clothing, poor example, cost and impact on others
3. Selection of inhibiting factors. Following are the inhibiting factors :

   habit, addition, taste, stress and advertisement
4. Place them in a tabular form.
5. Make appropriate table using arrow diagram.

Object : Stop smoking

Promoting factors	Inhibiting factors
Poor health →	← Habit
Smelly clothing →	← Addiction
Poor example →	← Taste
Cost →	← Stress
Impact on others →	← Advertisement

Take action to strengthen the promoting factors and weaken the inhibiting factors.

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3.11 WORK STUDY

[A] Meaning and Definition of work study

Work study is the most effective tool in the hands of management. It is the study of work of workers in all aspects in order to increase productivity. It is a systematic and analytical study of work process and work methods with the objective of increasing efficiency and reducing costs. The work study may be defined as follow :

- ***Work study is systematic, objective and critical examination of all the factors governing the operational efficiency of any specified activity in order to effect improvement.***
- ***Work study is a term used to embrace the techniques of method study and work measurement (discussed in next article), which are employed to ensure the best possible use of human and material resources in carrying out a specified activity.***

[B] Objectives of work study

Work study is designed to achieve the following objectives :

1. The maximum use of plant and equipment.
2. The most effective use of human work.
3. Provide more and improved physical means to motivate the workers.
4. Improve the basic process by research and development.
5. Improve the methods of operation.
6. Establishment of standards for measuring performance.
7. Improve organisation product, planning and control.
8. Improve manpower efficiency at all levels.

[C] Basic procedure for work study

The basic procedure of work study consists of the following steps :

1. ***Define the problem.*** The first step is to select the job or process or the operation to be studied.

2. ***Record.*** The purpose is to obtain all relevant facts. The relevant facts include job or process or operation using suitable charting techniques such as *operation process chart, flow process chart, flow diagrams* and other relevant charts.

3. ***Examine.*** Critically examine all recorded facts associated the problem.

4. ***Develop.*** Consider the alternative methods and decide which one is the best.

5. ***Measure.*** Establish the standard time using an appropriate work measurement technique. Install the new method as standard practice.

6. ***Maintain.*** The new method for the job/process/operation.

[D] Benefits of work study

1. Increased productivity and operational efficiency
2. Reduced cost of production
3. Improve plant layout
4. Better man power planning and capacity planning
5. Fair wages to workers
6. Better working conditions to employees.
7. Reduced material handling costs
8. Provides a standard of performance to measure labour efficiency.
9. Better industrial relations and employee morale
10. Basis for suitable incentive schemes and provides better job satisfaction to employee.

[E] Techniques of work study

There is a fixed and ordered sequence of analysis used in all work study exercise. It consists of two categories of activities, namely (a) method study and (b) work measurement. The work study is shown below in tabular form.

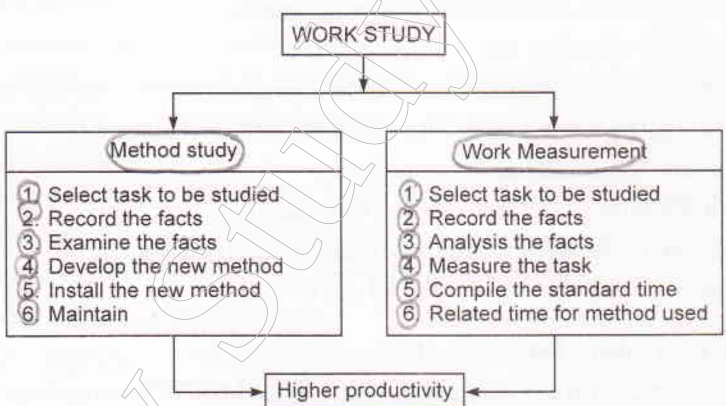

Table for work study components

3.11-1 METHOD STUDY OR WORK SIMPLIFICATION

Method analysis or methods study is the scientific technique of observing, recording and critically identifying the operations performed and the movements involved in doing a job with the aim of making improvements therein. It is an organised and systematic study of work organised and work processes and working conditions. It is a very wide term embracing all of the physical aspect of operations, methods, conditions equipment, etc.

According to the ***British Standards Institute***, **"methods study is the systematic recording and critical examination of existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs".**

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Method study is done to evolve the most economical method of doing the job. It is also termed as *work simplification*.

Method study is useful under following situations :

(1) High operating cost.
(2) High wastage and residual.
(3) Excessive movement of materials and workmen.
(4) More production bottlenecks.
(5) More rejections and rework.
(6) Complaints about quality.
(7) Complaints regarding poor working conditions.
(8) More number of accidents.
(9) Excessive use of overtime.

Objectives of Method Study

(1) To eliminate unnecessary and inefficient motions.
(2) To remove repeating of effort.
(3) To eliminate unnecessary fatigue and thereby effect economy in human effort.
(4) To improve product design and plant layout.
(5) To standardise work processes, working conditions and tools or equipments, and
(6) To maximise the utilization manpower, materials, machinery and other facilities.

Advantages of Method Study

(1) Work simplification.
(2) Better working method (cheaper method).
(3) Better product quality.
(4) Improved plant layout.
(5) Improved equipment design.
(6) Better working conditions or environment.
(7) Better materials handling system and lesser materials handling cost.
(8) Improved work flow.
(9) Less fatigue to workers.
(10) Optimum utilization of all resources.
(11) Higher safety to workers.
(12) Shorter production cycle time.
(13) Higher level of job satisfaction for workmen.
(14) Reduced material consumption and wastages.
(15) Reduced cost of production and higher productivity.

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Procedure of Method Study

The procedure of method study involves the following steps :

(1) Selection of the job to be studied and simplified.

(2) Collection and recording of data about the existing method.

(3) Critical examination or analysis of the data collected.

(4) Development of most practical and economical method.

(5) Installation of new method and evaluation of its efficiency.

(6) Maintenance of new method.

Techniques of Method Study

(1) Process charts

(2) Flow diagrams

(3) String diagram

(4) Travel charts

3.11-2 WORK MEASUREMENT

Work measurement is defined as the application of techniques designed to establish the work content of a specified task by determining the time required for carrying out the task at a defined standard of performance by a qualified worker.

Objectives of Work Measurement

Objectives of work measurement can be to achieve :

(1) Improved planning and control of activities or operations.

(2) Reliable ideas for workers performance.

(3) Reliable basis for workers cost control.

(4) Basis for suitable incentive schemes.

Advantages of Work Measurement

Work measurement helps :

(1) To develop a basis for comparing alternate methods developed in method study by establishing the work content in each method of doing the job.

(2) To prepare logical work schedules by accurate assessment of human work.

(3) To set standards of performances for labour utilization by establishing the labour standards for a part of work, operation or product under ordinary working condition.

(4) To compare actual time taken by the worker with the allowed time (standard time) for effective control of labour.

(5) To assist in labour cost estimation.

(6) To provide information related to estimation of tenders, fixation of selling price and assessment of delivery schedule.

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Techniques of Work Measurement

The main techniques used to measure work are :

(1) Direct Time Study.

(2) Synthesis Method.

(3) Analytical Estimating.

(4) Pre-determined Motion Time System (P.M.T.S.).

(5) Work Sampling or Activity Sampling or Ratio Delay Method.

3.12 TIME STUDY

[A] Meaning and definition of time study

Time study is concerned with the determination of total time required to perform a unit of work. It consists of the process of observing and recording. The purpose is to estimate reasonable time required to perform each element of an operation so that work should be finished.

The time study is defined as follows :

- ***Time study consists in finding the time required to perform each elementary details of an operation.***
- ***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 analysing the data so as to obtain the time necessary for carrying out the job at a defined level of performance.***

[B] Objectives of time study

The main objective of time study is to determine through direct observation, the quantity of human work in a specified task and hence to calculate the standard time, within which an average worker working at a normal speed should complete the task using a specified method.

The other objectives are :

(i) To set labour standard for satisfactory performance.

(ii) To compare alternative methods in method study in order to select the best method.

(iii) To determine standard costs related to the work.

(iv) To determine equipment and labour requirements.

(v) To determine the normal times.

(vi) To set the completion schedules for individual operation of job.

(vii) To determine the cycle time for completion of a job.

(viii) To determine the number of equipments an operator can handle.

(ix) To balance the work of operators in production or assembly lines.

(x) To provide a basis for setting incentive wages.

(xi) To provide a basis of comparison for determining operating effectiveness.

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[C] Uses of time study

(i) Manpower planning

(ii) Arriving at cost standards per unit of output for the various jobs used for cost control and budgeting for deciding on sales price.

(iii) Determining the work content and thereby setting wages and incentives.

(iv) Arriving at job schedules for production planning purposes.

(v) Comparing the work efficiency or different operators operating a machine.

(vi) Helping in the method study

- (a) To appropriately sequence the work of an operator and the machines or that a group of workers
- (b) To compare costs of various other methods
- (c) To highlight time more consuming elements

(vii) Product design by supplying basic data on costs of alternative materials and methods required to manufacture the product.

[D] Benefits/Advantages of time study

(i) Time studies may be taken for checking operator complaints about time rates.

(ii) During a time study, the observer may note inconsistencies, in methods or motion sequences used by individual operators, leading to various recommendation.

(iii) Observations during a time study may enable the engineer to recommend further improvements in work methods and work place layout.

(iv) Output standards are easily convertible into standard labour costs per unit of output.

(v) Output standards also facilitate evaluation of machine capacities, which aids plant engineers in selecting alternate machine for purchase and use.

(vi) Output standards facilitate scheduling and controlling the line of production, through the determination of numbers of equipment, tool and operators required to meet production schedules and through balancing time production for the several time operations.

3.13 TIME STUDY PROCEDURE

[A] Equipments

The equipments used in carrying out time study consists of following equipments

1. *Stop watch.* This is a watch which is used to calculate the time taken in doing a particular part of a job.

2. *Study board.* This is a flat board which is used to record time.

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3. *Time study forms.* Printed forms of a fixed size are used to make the time studies recorded in a standard manner. Several types of forms are used depending upon the method used.

[B] Time study procedure

The steps involved in carrying out time study are as follows :

(1) *Selecting the job to be studied*

The primary step in time study is the selection of the job to be studied. The reasons for selecting a job for time study are :

(i) New job taken for production.

(ii) Change in manufacturing method.

(iii) Design change.

(iv) Change in raw material or components used for a job.

(v) Workers have complained that time standard is not logical.

(vi) When labour cost is high.

(vii) To find out plant utilisation where the output is considered low.

(viii) To compare the efficiency of two alternative methods.

(ix) To establish standard time as a basis for incentive scheme.

(2) *Select the worker to be studied/timed*

An ideal worker is termed as *qualified worker*. A qualified worker may not be available in the organisation. Therefore, a best available worker is chosen and his rating is determined as compared with qualified worker.

(3) *Breaking the job into elements*

The job to be studied is divided into basic elements. An element is a separate part of the specified job selected for convenience of observation, measurement and analysis.

(4) *Timing of each element*

The time taken in each element is measured with the help of stop watch.

(5) *Averaging*

A number of readings are taken for each element depending upon the level of accuracy desired and length of work cycle. The number of times for which an element is to be studied can be fixed with the following formula :

$$N = \left[\frac{40\sqrt{N\,\Sigma X^2 - (\Sigma X)^2}}{\Sigma X}\right]^2$$

where N is the size of sample workers and X stands for individual time values for various elements.

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(6) *Rating*

For each element, a standard time is fixed before hand. *Rating factor* is determined by comparing the actual speed of working (of the worker studied) with the standard speed of working of the qualified worker.

(7) *Determination of normal or basic time*

Once, the rating of the worker under observation is assessed then it is compared with the standard rating of qualified worker.

$$\text{Normal or basic time} = \text{Observed time} \times \text{Rating factor}$$

$$= \text{Observed time} \times \frac{\text{Observed rating}}{\text{Standard rating}}$$

(8) *Determination of relevant allowances*

Once, the basic time per cycle required by the qualified worker to perform each element at standard rate of working is determined, the next step is to determine the time allowance to be given to the operator for relaxation, fatigue, contingency, etc.

The following allowances are

(i) Relaxation allowance

(ii) Process allowance

(iii) Special allowance

(i) *Relaxation allowance.* The relaxation allowance is granted to allow the worker to recover from physiological and psychological effects of carrying a particular work under specified conditions. It also attends personal need. This relaxation allowance is an addition to basic time.

(ii) *Process allowance.* A process allowance is an allowance of time given to compensate for enforced idleness on the part of an operator due to the character of the process or operation on which he is employed.

(iii) *Special allowance.* Special allowances are given for activities not normally forming part of the operation, cycle but essential to satisfactory performance of the work.

3.14 MOTION STUDY

[A] Meaning and Definition of motion study

Motion study or movement study is a *formal engineering analysis of motions* performed to accomplish work. The motions or movements of a worker play an important part in the fabrication or manufacture of the products. By carefully observing a worker his unnecessary and unproductive motions or movements can be identified and can be eliminated.

There are various definitions of motion study. Few of them are as follows :

- Motion study is defined as ***analysis of an operation when carried out in terms of individual motions of a worker.***

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- ***Motion study is the science of eliminating wastefullness resulting from unnecessary, ill treated and inefficient motion.***
- ***Motion study is formal engineering analysis of motion performed to accomplish work with the intent to eliminate waste motions and ill-treated inefficient motions.***
- ***Motion study is a systematic and scientific method of the motions unnecessary, wasteful and unwanted motions.***

The purpose of motion study is to design an improved method which eliminates unnecessary motions and employs human efforts more productivity.

[B] Objectives of motion study

1. Eliminating unwanted motions.
2. Simplifying complex motions.
3. Increase the efficiency of activities.
4. Improving the order of necessary motions.
5. Change the sequence of activities.
6. Improve the materials handling process.
7. Make the activity more safe.
8. Standardize the optimum procedures and working conditions so that the employees uniformly use the best possible way of performing activity.

[C] Basic procedure of motion study

The following steps are used for basic procedure of motion study :

1. Select the job or process to be studied keeping in view *human, technical* and *other factors*. The job selected should be capable of yielding results so that the cost may be reduced. The following points are to be considered :

(i) High rate of rejected work due to ineffective use of materials and machine capacity.

(ii) Workers complaints high fatigue from the job.

(iii) Extra operating costs due to bad plant layout and unnecessary movement of men and materials.

2. Collection of all related facts regarding present and proposed work methods using correct recording techniques.

3. To examine the recorded facts carefully. It is then decided whether some elements can be removed, combined or simplified. This steps ensures the defects in existing methods.

4. Develop the latest and improved method. Improvement may be brought in any of the following ways :

(i) Improved product design and material specifications

(ii) Effective tools and equipment

(iii) Improved sequence of operations

(iv) *Improved layout*

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5. Select the new method and its requirements.
6. Install the new method with coordination of supervisor and operator.
7. A proper training should be given to operators for the new method.

[D] Techniques of Motion Study

(1) *THERBLIG Analysis :* Therblig was suggested by Gilbreth (Gilbreth spelt backwards with one transposition). Therblig are used to describe the basic elements of movements or fundamental hand motions of the work cycle. Each type of motion is called a therblig and represented by a definite colour and with a word or two to record the same. A single operation can consist of many therblig. Various Therblig alongwith their symbol are shown in table I.

Table I : Therblig along with their symbol

Assemble	#	Rest	
Disassemble	#	Position	
Avoidable delay		Inspect	0
Unavoidable delay		Preposition	8
Transport loaded		Grasp	∩
Transport empty		Use	U
Search		Hold	
Find		Select	→
Plan		Release load	

(2) *Micromotion study :* Micromotion study is defined as the study of fundamental elements of an operation. It is carried out with the help of a high speed movie camera in order to eliminate the unnecessary motions involved in the operation and balancing the necessary motion. The elements or motions are finite subdivisions of the work cycle. These elements are expressed in the units of TMU where 1 TMU = 0.0006 minute. These motion elements were classified into basic elements known as fundamental motions or therbligs.

3.15 PROCESS CHARTS

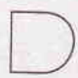
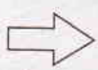
In general, a chart may be a diagram, a picture or a graph that gives an overall view of a situation say a process. ***A chart representing a process may be called as a process chart.***

A process chart records graphically or diagrammatically in sequence, the operations connected with the process. Therefore, ***a process chart is a representation of events and information related to the process during a series or operations.***

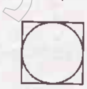
In an organisation, producing any product, process chart is a diagrammatic representation of all the activities of operation passing from beginning with the first operation to the last operation, *i.e.,* completion of product. It is important to mention here that process charts represent a picture of a given process so clearly that every step of the process can be understood by those who will study the charts.

Charts are generally represented by symbols. The following five basic symbols are used to record different types of events.

Symbols used in Process chart

S. No.	Event	Symbol	Description
1.	Operation	 (Circle)	It indicates the main steps in process, method or procedure. The operation may involve modification of a material, change in location or condition of product. Example : Cutting a bar on a power hacksaw.
2.	Storage	 (Inverted triangle)	This represents a stage when a raw material awaits an action or an item has been retained for some time for reference purposes. Example : refrigerators in a stock room.
3.	Delay or temporary storage	 (Letter D)	It indicates work waiting between consecutive operations or object laid aside before next operation is performed on it. Example : power failure, waiting for the lift or a traffic jam.
4.	Transportation	 (Arrow)	It indicates the movement of workers materials or equipment from one place to other place. It indicates a change in location of the object. Example : steel rods being sent from stores to machine, aeroplane flying from one city to another.
5.	Inspection	 (Square)	This shows an examination or check on quality or quantity of the product. Example : checking the hardness of a metal piece.

In addition of above basic symbols, there are two more symbols for combined activities. The important event has the outer symbol. These symbols are :

6.	Operation cum transportation	 Arrow within sphere	Example : Articles are being pained as they are transported by chain conveyor.
7.	Inspection cum operation	 Circle within sphere	Example : Power milk tin is being weighted (inspection) as it is filled. Both the events occur simultaneously.

3.16 CLASSIFICATION OF PROCESS CHARTS

Process charts are of the following three types :

1. ***Flow process chart***
2. ***Outline process chart***
3. ***Two handed process chart***

1. Flow process chart

Flow process chart is defined as a graphical representation of all operations, transportations, inspections, delays and storage during a process. This includes information considered necessary for analysis such as time required, distance moved, quantity, etc.

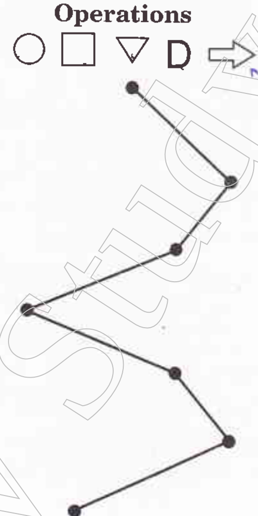
There are three types of flow process charts, namely

(i) ***Main type or operator type.*** It records what the worker does, *i.e.*, it represents the process in terms of activities of the man or the operator.

(ii) ***Material type*** or ***product type.*** It records what happens to the material, *i.e.*, process in terms of the events which occur to the material or product.

(iii) ***Equipment type*** or ***machine type.*** It records how the equipment is used, *i.e.*, the process in terms of machine or equipment.

Fig. (9) shows the flow process (material/product type) chart for flow of product.



Activity	Distance Moved (m)	Time (minutes)
Castings lying in foundary store	—	—
Moved to gas cutting machine	10	3
Wait, cutting machine being set	—	5
Rises cut	—	20
Wait for trolly	—	10
Moved to machine shop	20	6
Inspected before machining	—	15

Fig. (9) (Material/product) type flow process chart

2. Outline process chart

The outline process chart gives the overall picture of the process. It considers only (main) operations and inspections. It is a graphical representation of the points at which materials are introduced into the process and sequence of all operations and inspections associated with the process.

Fig. (10) shows an outline process chart of changing refill of a ball point pen.

Let the chart begins with the process of unscrew cap and the chart ends at screw the cap.

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Outline (opration) process chart of changing refill of a ball point pen

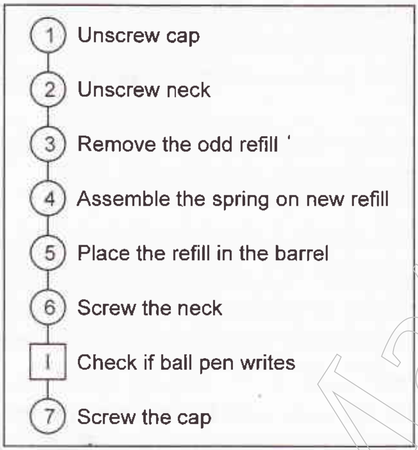

Fig. (10) Outline process chart

Example *Let, there are two main units in a production process known as X and Y.*

The unit X has three operations A, B and C, then an inspection and after that operations D, E and F.

The unit Y has four operations G, H, J and K and then inspection and after that one operation L. When all operations are completed, the final operation M is applied to get the product and it is again finally inspected.

In this process, there are 12 operations and three inspections. Draw the outline process chart.

Solution Outline process chart is shown in fig. (11).

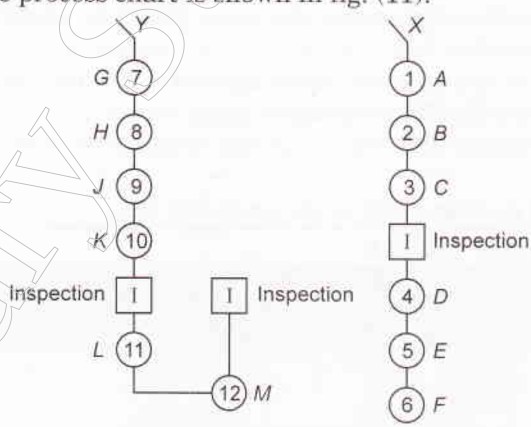

Fig. (11) Operation flow chart.

In this chart, the general flow of the process is indicated by vertical line while horizontal line is used to indicate the material being introduced.

Objectives of operation process chart

1. It helps to decide whether a further and more detailed record is needed.

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2. It helps the analyst to visualise the process for examination as a means for better understanding and improvement of the process.

3. It shows relationship between different activities.

4. Actually an outline process chart is the first step or the beginning of detailed analysis.

5. It is used in the design stages to assist the layout of the plant and location of one department with respect to the other.

3. Two handed process chart

The two hand process chart is a chart in which the activities of the worker's hands (left hand and right hand) are recorded in their relationship to one another. Such a chart is generally used for repetitive works of short duration.

the same symbols are used as in case of other charts but with different meaning of symbols. The symbols and their descriptions are shown below :

Symbol	Activity	Description
○	Operation	For activities for grasp, position, use release, etc., of total, component or material
▽	Hold	Hold is used to represent the activity of holding work, tool or material
D	Delay	Time during which the hand or limb being charted as idle
⇨	Transport	Movement (hand or limb) from the work or a tool or material

Procedure for preparing two-handed process chart

1. First of all study the operation cycle few times.

2. Observe one hand at a time and record few symbols.

3. Start observing and recording at a position which could be easily distinguished.

4. Care must be taken while observing and recording. No activities should be left otherwise it will affect the whole study.

5. Avoid combining different activities unless they actually occur at the same time.

A two-handed process chart is shown in fig. (11).

Job. ***Assembling Nut and Bolt***

Left hand	Symbol		Right hand
	L.H.	R.H.	
Pick up bolt	○ 1	D 1	Idle
Hold	▽ 1	○ 1	Pick up nut
Hold	▽ 2	⇨ 1	To left hand
Hold	▽ 3	○ 2	Assemble (screw up)

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Summary of operations (*i.e.*, number of times an activity is performed)

L.H	Number	R.H	Number
○	1	○	2
▽	3	▽	–
⇨	–	⇨	1
D	–	D	1

Fig. (12) Two handed process chart

3.17 FLOW DIAGRAM

In a manufacturing shop or a repair shop or in any other department, there are movements of men and materials from one location to another location. ***A flow diagram is a drawing indicating the paths of men, material or components, on a scale plan of work, area, department or factory.*** The path of movement (*i.e.*, movement between two locations and the number of times movement is repeated) can be better visualised by drawing flow diagram.

Steps used in drawing a flow chart

Following steps are used :

(i) Draw to scale the plan of the work area.

(ii) Mark the relative positions of machine tools, benches, store, racks, inspection booths, etc.

(iii) From different observations, draw the actual path movements of the material or the worker on the diagram and indicate the direction of movement.

Example. Fig. (13) shows a flow diagram in which raw material from the store goes out of the factory.

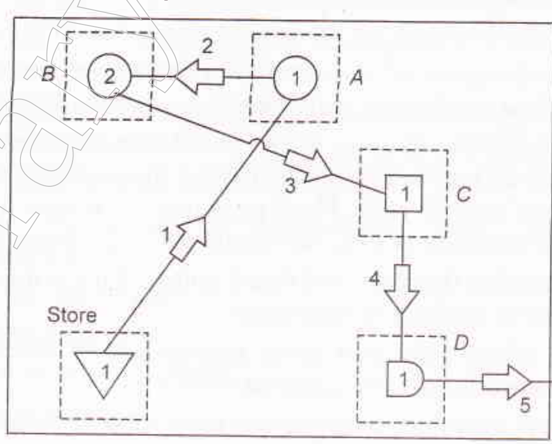

Fig. (13) Flow diagram

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The description is as follows :

(i) The raw material from the store moves to a station A. The movement is shown by arrow 1. The halting position of material in store is shown by reverse triangle 1.

(ii) At station A, an operation is performed. The material is semifinished. This operation is shown by circle 1 because this is the first operation.

(iii) The semi-finished product is sent to another place B. This is shown by arrow 2. At B, another operation is carried out which is denoted by circle 2 being second process.

(iii) Now the material is moved from B to C. This process is shown by arrow 3 because this is third shifting. At C, the material is inspected which is shown by square 1 as it is first process of inspection.

(iv) From C the material is sent to bench D. The process is shown by arrow 4 being fourth shifting. At D, the material halts. This process is shown by the letter D1 as it is first process of halting.

(v) Finally, the material goes to factory. This process is shown by arrow 5 being fifth shifting.

3.18 STRING DIAGRAM

When the paths are many and repetitive, a flow diagram of that process becomes complicated. It is neither traceable nor understandable. Under such a case string diagram is used.

String diagram is a simple tool for analysing and designing work spaces such that movements can be minimised.

String diagram is a model or a scale plan of the shop, in which every machine or equipment is marked and a peg or pin is struck. A continuous string or thread traces the path taken by the materials or workers while performing a particular operation.

Steps for construction of string diagram

The following steps are used for the construction of a string diagram :

(i) Draw the scale-layout of the shop (working) area and mark various features, such as machinery, work benches, other equipments, store, etc.

(ii) Mount this scale drawing on a soft board. Identify the points in the process where actions take place and make the positions of these on the map with map pins or pegs. More pegs may be struck in between the facilities to trace more or less, the actual path of men and materials.

(iii) Make the string at the start and finish points. This is done to make the path followed by workers or materials.

(iv) The thread when measured gives approximately the total distance travelled by a worker or the material.

(v) Rearrange the movable items on the map, aiming to reduce the total distance.

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Example. Fig. (14) shows a string diagram.

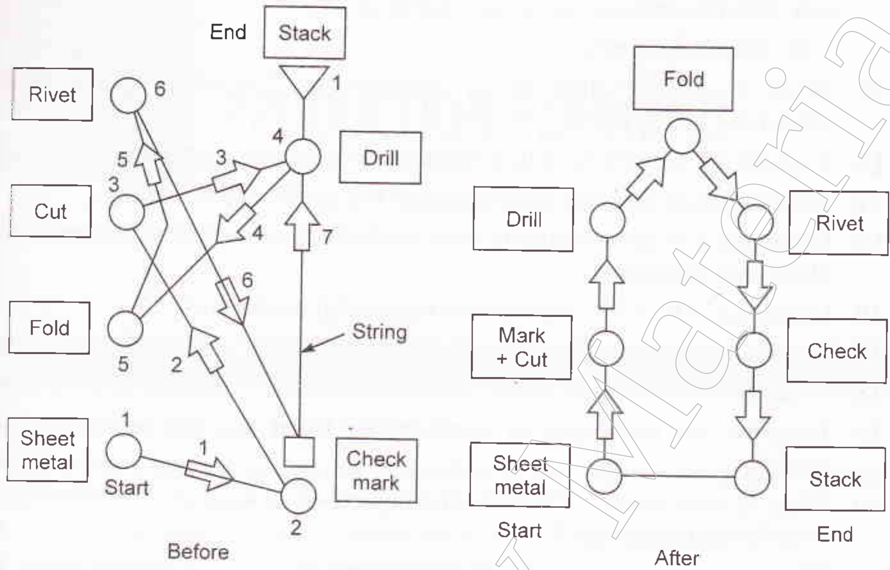

Fig. (14) String diagram

REVIEW QUestions

1. Define 'management', 'organisation' and 'administration'.
2. How is management important for running an organisation?
3. Explain the different characteristics of management.
4. what are the various objectives of management?
5. What are the various management skills necessary for managers?
6. Explain the different levels of management alongwith their duties.
7. Explain the various functions of management. How are these functions inter-related?
8. What is meant by Scientific Management? How does it influence various management functions?
9. Discuss the principles of management.
10. What do you mean by management tools? Name the different management tools.
11. Discuss the followings :
    (i) Affinity diagrams
    (ii) Inter-relation diagrams
    (iii) Tree diagrams
    (iv) Matrix diagram

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(v) Matrix data analysis

(vi) Process decision program charts (P.D.P.C.)

(vii) Arrow diagrams.

12. Draw an affinity diagram to imrpove the English speaking skills of students.

13. Explain an interrelationship diagram to improve customer satisfaction.

14. Discuss a tree diagram for maximize the profit of a company.

15. Construct a chart for matrix data analysis of customer requirement of an electronic component.

16. Construct a P.D.P.C. chart for a successful conference.

17. Represent an arrow diagram for stop smoking.

18. What is meant by work study? What is the basic procedure of work study?

19. Describe the technique of work study. What are the benefits of work study?

20. What is time study? What are the objectives of time study? What are the benefits of time study?

21. What do you mean by time study? Explain the time study procedure. Give some uses of time study.

22. Give the meaning and definition of motion study. What are the objectives of motion study?

23. Define motion study. Explain the basic procedure of motion study.

24. What do you mean by a process chart? Explain the symbols used in a process chart.

25. Give the classification of process chart. Explain any one of them.

26. Explain the following charts :

(i) Flow process chart

(ii) Outline process chart

(iii) Two handed process chart.

27. Draw and explain a material type flow process chart.

28. Draw and explain an outline process chart of changing refill of a ball point pen.

29. Explain the procedure for preparing two handed process chart. Draw two handed process chart for assembling nut and bolt.

30. What is a flow diagram? Discuss with example, the different steps used in drawing a flow diagram.

31. Explain with a suitable example a string diagram.

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4 PRODUCTION PLANNING

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Learning Objectives

After reading this chapter, you will understand :

- Meaning of production planning, production control and production planning and control
- Importance, objectives and characteristics of production planning
- Process and pre-requisite for production planning
- Objectives, characteristics, benefits and elements of production control
- Production planning and control—its objectives and process
- Routing process
- Scheduling process
- Techniques of scheduling
- Master Production Schedule (MPS)
- Specification of production requirements

4.1 INTRODUCTION

We know that production is a process by which goods or services are created. These goods or services are created by performing a set of manufacturing operations in a *pre-determined* sequence that transforms the raw material (inputs) to a desired form (output).

In simple language, planning means preparing a scheme in advance before starting the actual work. So, *production planning* essentially consists of planning production activities in an industry before actually starting the operations. Thus, it can be said that production planning is concerned with specifying how the production resources of the business enterprises are to be employed over a given future time period in response to the predicted/forecasted demand for the product or services. Production planning involves management decision relating to how much to produce, what materials, parts and tools will be needed, what steps should be followed in the production process, within what time limit the production is to be completed and how much work is to be done by each work station. Production planning is a pre-production activity involving arranging facilities and designing the production system. It is based on sales commitments as to quantity, delivery dates, price, quality, etc.

No matter how well one plans, objectives or goals can only be reached if plans are properly executed. This requires *control* during execution-phase. Control implies supervision of operations with the help of mechanisms that give feedback about the progress of the work. The control mechanism is responsible for subsequent adjustment, modification and redefining of plans and targets in order to ensure attainment of pre-specified goals. In our context *production control* means the process that measures current performance and ensures that production is as per standards laid down in advance. It is a directive which regulates for all orderly flow of materials and co-ordination of the different production operations. Production control is directing right from the time raw material is put to the production process till it comes out as a finished product. Under production control it is watched whether production is going according to the planning or not. The main purpose of production control is to produce the goods according to the levels set by plans through the best and cheapest way and also ensuring required standard and quality at the right time in the required quantity.

Relationship between Planning and Controlling

Many people are of the view that production planning embraces both planning and control. In a broader sense production planning also covers production control activities. But if we see more deeply we find that production control comes after production planning. It indicates that these two are distinct but interdependent and interrelated activities.

As already mentioned, planning will be useless if there is no control at the implementation stage and controlling will not be possible unless there is sufficient planning. Unplanned actions cannot be controlled. In reality, both these terms are complimentary to each other. Production planning and production control are independent activities which are closely associated with the planning function that contributes to the smooth discharge of controlling function as it provides objective, standards, programs, budgets, etc.

The aim of this chapter is to discuss various objects of production planning and production control.

4.2 OBJECTIVES OF PRODUCTION PLANNING

Production planning is very much important for todays industry. In this competitive age no firm can survive without innovation or creativity. Every firm has to keep a continuous overall upgradation in product. For this a firm is bound to produce those products which are fit for the consumers in both aspects, *i.e.*, quality and price.

These demands proves the real importance of production planning. A product which is made by selecting the best product design with best possible process are always competitive.

Various objectives of Production Planning are as follows :

(1) *Establish Co-ordination between various Production Activities :* To meet the demand of the product effectively various production related activities are integrated in a planned and systematic manner.

(2) *The best Utilization of Resources :* Resources like raw materials, man power are planned to be used in right quality and quantity at right time to get the best output.

(3) *To produce best Results :* Production planning ensures high but reasonable profits to the concern by planning the production of high quality goods in the right quantity at the right time for the customers.

(4) *Control over Market :* With the help of production planning, production can be increased to have a control over the market through the introduction of new products according to the demand of the customer. Here market research, analysis and forecasting techniques helps in production planning.

(5) *Efficiency :* The maximum efficiency of a plant can be achieved by production planning.

(6) *Smoothens Production Management :* Production planning assists workers engaged in production activities for doing right things. It helps to frame the guidelines for tackling the common problems for middle management.

4.3 IMPORTANCE OF PRODUCTION PLANNING

The importance of production planning may be judged from the following facts :

(1) *Production Planning sets Objectives :* Production planning sets objectives for an enterprise. In accomplishing its objectives for an enterprise, it chooses out best out of available alternatives considering the available resources of the plant. Production planning, in normal conditions, may be applied mathematically for selecting the best alternative course, which may yield the desired and predetermined results at the minimum cost on the basis of known facts. After selecting the best alternative it becomes imperative to prepare a plan to achieve the goal.

(2) *Facing the Unforeseen Conditions :* It helps in meeting out the risk of uncertainty at operational stage because production manager takes care of difficulties, which may be faced subsequently.

(3) *Best Utilization of Resources :* Production planning helps in utilizing the available resources in the best possible manner because it helps in coordination of the working of various individuals and department of the concern. This leads to better utilization of time, efforts and materials. It ensures the best use of available plants and regular supply of raw materials and other things for the production of goods and services.

(4) *Basis for Control :* Production planning provides the basis for production control, which is also major function of production manager. As a matter of fact, production planning and control are inseparable because unplanned work cannot be controlled. Production planning sets the targets quantitatively and also qualitatively and fixes the standard time for completing the job whereas production control keeps the operation along with the predetermined course of action by minimizing deviation from standards. Reasons for deviation are located and then removed in the next planning process.

4.4 CHARACTERISTICS OF PRODUCTION PLANNING

The characteristics of production planning may be summarized as follows :

(1) Production planning is a universal production activity.

(2) Production planning is the basis and pre-requisite of production control.

(3) Production planning includes routing of production activities and layout of production facilities such as buildings, machines, equipments, etc.

(4) Production planning is related to planning, directing and controlling of production methods for the manufacturing of products.

4.5 LEVELS OF PRODUCTION PLANNING

Production planning occurs at several levels in the organization and covers different time horizons. According to the hierarchical levels in which it is done in the organization, planning can be classified as *strategic* planning, *tactical* planning and *operational* planning. Another classification based on time span of planning is long range, intermediate range and short range planning.

(1) *Strategic Planning :* Strategic planning is a process of thinking through the organization's current mission and environment and then setting forth a guide for future decisions and results. For example, technology forecasting and choice of appropriate technology for the long range time horizon. Strategic plans are usually long range plans done at the top management level. The vice-president operations, together with the top executives of the firm developes long-range capacity and facility plans.

Objectives laid down through long range planning are :

(i) Production levels (Number of units produced).

(ii) Operating capacities.

(iii) Inventory policies.

(iv) Levels of manufacturing costs.

(2) *Tactical Planning :* Tactical planning is done over an intermediate term or medium range time horizon, by the middle level management (Operations managers at department level). These plans focus on aggregate products rather than individual specific product. These aggregate plans have a time span of 6 to 18 months. They specify the employment plans; machinery and utility plans, the sub-contractor and materials supply plans and facility modification/expansion plans.

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(3) ***Operational Planning :*** Operational planning is done over a short range time span developed by the junior level management. It is concerned with the utilization of existing facilities rather than the creation of new facilities. It involves proper utilization of key resources such as raw materials, machine capacity, energy, etc.

4.6 PRE-REQUISITE FOR PRODUCTION PLANNING

Pre-requisite for Production Planning are :

(i) Selection of best course of action for production after considering the different possible processes.

(ii) Data collection regarding the required and various available machinery set-up.

(iii) Choosing the best processing system and machines for production.

(iv) Sequence of operations which is most advantageous and with minimum production cost.

(v) Full information about the sources of raw materials, power generation system and transportation system.

(vi) Arrangement of skilled, unskilled and expert labour.

(vii) Information regarding the time fixed for each operation.

(viii) Estimation of production capacity of the plant.

(ix) Estimation of material cost, labour and overhead cost per unit and fixed rate of interest on invested capital.

(x) Continuous upgradation of knowledge regarding the recent techniques and production of those items which are fit for consumers.

The various factors determining production planning procedure are :

(1) *Volume of Production :* The amount and intensity of production planning is determined by the volume and character of the operations and the nature of the manufacturing processes. Production planning is expected to reduce manufacturing costs. The planning of production in case of custom order job shop is limited to planning for purchase of raw materials and components and determination of work centres, which have the capacity of manufacturing the product. In high volume operations, extensive production planning is necessary in planning for the design of both the product and the production processes. This is necessary in order to achieve substantial cost reduction when a large number of products are produced.

(2) *Nature of Production Processes :* In job shop, the production planning may be informal and the development of work methods is left to the individual workman who is highly skilled. In high volume production, many product designers, equipment designers, process engineers and methods engineers are involved. They put enormous amount of effort in designing the product and the manufacturing processes.

(3) *Nature of Operations :* Detailed production planning is required for repetitive operations. For example, in case of continuous production of a single standardized product.

4.7 PROCESS OF PRODUCTION PLANNING

The process of production planning involves :

(1) *Determination of Targets :* A decision regarding the type of product, quantity of product and period for which the product is to be used has to be decided before deciding a production plan.

(2) *Collection of Information :* Collection of information regarding the available raw materials, machines and equipments, capital market characteristics, etc. These data can be collected from the past records of the company or from the government and private agencies.

(3) *Interpretation of Information :* After collection of required data, the next step is the analysis of this statement and also their interpretation. Time fixed for each operation, loss in storage at handling, rate of output per hour, per day, per week, per month, economic order quantity, etc. are calculated from this data.

(4) *Development of Actual Plans :* After the analysis of information in the plan development, two things are decided :

(i) What is the object of production planning?

(ii) What is the production budget?

During development of production planning, future hurdles are also considered and solutions for them are finalised.

(5) *Execution Plan or Putting plan into Operation :* After developing the production plan, the next step is to act upon them and put them into operation. For this purpose concerned authorities and departments are informed so that a good quality product can be produced with minimum cost and within a given time period.

(6) *Follow up Action :* After the execution of the plan, the next step is to watch and control the production so that production planning can be followed. During follow up it is also considered that whether any deviation from planning are occurring or not. If they are occurring then what correct actions are to be taken.

4.8 PRODUCTION CONTROL

Objectives

The objectives of production control are :

(1) Arranging necessary raw materials, machines, equipments, tools and workers for production.

(2) Making necessary arrangement for the production of goods according to the pre-determined demand.

(3) Maintaining the inventory of raw materials.

(4) Utilising the production facilities at their optimum level.

(5) Co-ordination among various departments concerned with production.

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(6) Arrangements for product development and design process.

(7) Arrangements for inspection and quality control of production.

(8) Follow of process flow diagram.

(9) Arrangements for corrective actions to be taken during production if any deviation occurs.

Characteristics

Various features of Production Control are :

(1) Under production control, controls are done over production methods, types of products, cost of production and quantity of production.

(2) Under production control, various control techniques are used.

(3) Under production control, a co-ordination is built up between various concerned departments.

(4) Production control is a technique of production management by which a smooth production can be done.

Benefits

Various benefits which can be derived from production control are :

(1) *Improvement in profits through—*

(a) Maintenance of an adequate and balanced inventory of material parts, work-in-process and finished goods.

(b) Reduction in indirect costs.

(c) Optimum utilisation of manpower, equipment, tools and storage space.

(d) Reduction in inventory costs.

(e) Less capital investment in industry.

(f) Reduction in set-up costs.

(g) Elimination in scrap and rework costs.

(h) Balanced and stabilised production.

(2) *Competitive advantage—*

(a) Lower production costs and greater pricing flexibility.

(b) Orderly planning and marketing of new and improved products.

(c) Meeting delivery schedules to customers.

(d) Reliable delivery to customers.

4.8-1 ELEMENTS OF PRODUCTION CONTROL

Various elements of production control are :

(1) *Active Control :* It involves the release of manufacturing orders and release of resources through dispatching.

(2) *Control of Planning :* It assures receipt of latest forecasting data from sales and production planning, bill of material data from product engineering and routing information from process engineering.

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(3) *Control on Materials :* It involves control of inventory and providing/issue of materials to the shop and movement of materials within the shop.

(4) *Control on Tools :* It involves check on the availability of proper tools as necessary by the specification of production and provide issue of tools to manufacturing department from tool units.

(5) *Control on Timing of Production :* It involves observing stoppage, delays research arising in each operation and thus regulates the entire process of production so that the order may be executed on the delivery dates.

(6) *Control of Manufacturing Capacity :* It determines the availability of machinery and labour capacities and issue realistic production schedules and provides a means of recording completed production.

(7) *Quality Control :* It involves the observation in process work at predetermined stages to determine whether the right quality of acceptable work has been perceived. Also, it ensures that corrective action is initiated where work fails to pass each stage of operation.

(8) *Control of Material Handling :* It releases orders for movement of work to ensure availability of material, as necessary, at each step of operation.

(9) *Replacement Control :* It observes the rejected raw materials and work-in-progress not fulfilling the quality standard.

(10) *Control of the Due Dates :* It checks actual and planned schedules and determines the cause of delays and stoppages that interfere with weekly schedules of work assigned to each machine in work centre.

(11) *Labour Efficiency Control :* It observes the labour operations and records proper timing of labour operations.

(12) *Control on Machines and Equipments :* It strives to obtain the optimum utilisation of installed capacity. It keeps the machines working through proper arrangement of cleaning, oiling, repairing and replacing.

(13) *Control on Methods :* It observes the methods set for various operations and devices for better methods in the course of time.

(14) *Control of Information :* It distributes timely reports and information showing deviations from plan so that corrective actions can be implemented and provides data on production, performance, measurement of future planning.

4.9 COMPARISON BETWEEN PRODUCTION PLANNING AND PRODUCTION CONTROL

Production Planning	Production Control
1. Preparation of production budget.	1. To sub-divide the master schedule into manufacturing orders and subsidiary orders.
2. Devising manufacturing methods and sequence of process.	2. Routing.

3. Describe the type of machines and equipments.	3. Scheduling and machine loading.
4. To set plant layout.	4. Dispatching.
5. To design tools.	5. Follow up or expediting.
6. To prepare operation sheets and instruction cards.	6. Tool keeping.
7. To undertake time and motion study for the operations.	
8. To estimate materials requirements.	
9. Toe stimate manpower requirements.	
10. To prepare the master schedule of production.	

4.10 PRODUCTION PLANNING AND CONTROL

Production planning and control is the process of planning production in advance of operations. This is done by establishing the exact route of each individual item, part or assembly, setting starting and finishing dates for each important item or assembly and the finished products, and releasing and necessary orders. It also involves initiating the required follow-up to effectuate the smooth functioning of the enterprise.

Objectives

The objectives of Production Planning and Control are as follows :

(1) To establish production limit and requirements.

(2) To ensure smooth flow of production by removing problems in the production process.

(3) To co-ordinate machine and labour and other inputs for optimum utilisation of resources.

(4) To help purchase and supply for materials to suit production rate.

(5) To minimise cost of production and ensuring quality of output.

(6) To ensure that jobs are completed in time and the delivery schedule is proper.

Factors affecting Production Planning and Control

The following factors should be considered in production planning and control :

(1) *Type of Product :* Complex and uncommon products require much greater care and problems in production planning and control as compared to simple and common products.

(2) *Type of Manufacturing :* Continuous manufacturing system involves the problem of line balancing. In intermittent system, problems of optimum use of facilities is important.

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(3) *Market Forecast :* Market forecast will determines the volume and rate of production.

(4) *Customer Orders :* These serve as the basis of production scheduling.

4.11 PROCESS OF PRODUCTION PLANNING AND CONTROL

Production planning and control consists of following steps :

(1) Estimating

(2) Routing

(3) Scheduling

(4) Loading

(5) Dispatching

(6) Progressing/Follow up/Expediting

(1) Estimating

Estimating decides the quality of output to be produced and the cost involved in it. This is done on the basis of sales forecast. Manpower, machinery, material requirements to meet the anticipated targets of production are estimated. In other words, a production programme is made. A bill of materials is prepared listing all the items needed to manufacture the desired product or service. Time of supply of materials and various level of inventory are also determined.

(2) Routing

Routing is the process of determining the correct sequence of operations to be performed in the production process. Routing determines what work will be done, where and how it will be done. It specifies the operations to be performed, sequence of the operations and the proper types of machines, equipment and personnel required. The objective of routing is to choose the best and the cheapest method of work. Routing depends upon the nature of machines, the efficiency of employees, the availability of various facilities and the kind of manufacturing process.

(3) Scheduling

Scheduling is a process of ranking different jobs and fixing priorities of those jobs. Scheduling decides the starting and finishing time and date for each job. It prepares a complete time table which will state the total time required for manufacturing a product. It will also indicate the time required for each operation.

Various features of scheduling are :

(a) It prepares and issues schedule to plant after making co-ordination with sales department.

(b) It ensures timely delivery to the customer.

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(c) It considers existing workload of men and machines.

(d) It ranks various jobs and fix priorities.

(e) It starts with the preparation of master schedule.

(4) Loading

Loading is the element of production planning and control to assign specific jobs to specific men or machines. Hence, it is the process of converting operation schedule into practice. Loading is done after testing the capacities of men and machines. In the process of loading detailed exercise is done to get the data related to time to complete a job, maximum capacity of each worker and machine, etc. A machine-loading chart (Gantt chart discussed in detail later on) is prepared showing the planned utilization of men and machines by allocating the jobs to machines or workers as per priority sequencing established at the time of scheduling. Loading ensures maximum possible utilization of productive facilities and avoids bottlenecks in production. It is important to avoid either over-loading or under-loading the facilities, work centres or machines to ensure maximum utilization of resources. Various purposes of loading are :

(a) maximum utilisation of resources

(b) eliminating bottlenecks in production process

(c) eliminating overloading

(d) removing under-utilisation.

(5) Dispatching

Routing and scheduling are primary steps. Actual production begins when order is given to commence operations according to schedule. In dispatching instructions are issued and work is assigned to operations. Dispatching decides by whom the work shall be done. The dispatching department issues requisition for all the inputs in the production order and checks to see that these things are available on time.

Functions of Dispatching :

(a) Giving to supervisors—specifications, materials lists, job tickets, route cards, requisitions, etc.

(b) Ensuring that all the inputs are made available to the production departments at the right time.

(c) Informing the appropriate section that production is starting.

(d) Issuing work orders for the beginning of manufacturing operations.

(6) Progressing *Or* Expediting *Or* Follow-up

Progressing is an element which ensures that the work is going on as planned and delivery dates are met. The objective of this function is to control variations or deviations from the planned level. It ensures that production is proceding according to schedule.

Functions of progressing or follow up :

(a) To determine the reasons of variations from the programme.

(b) To helps in eliminating the problems causing the deviations.

(c) To be in touch with other departments supplying materials and components.

(d) To prepare a list of inputs which are required.

4.12 ROUTING

Routing is the first but the most important and difficult task of the production planning. Routing means determination of path or route on which manufacturing operations will travel, establishing the sequence of operations to be followed in manufacturing a particular product. This route path is determined in advance.

The *objectives* of routing are :

(1) Determining the most feasible sequence of operations and ensuring that this sequence must be followed.

(2) Utilizing the physical human resources, materials and machines employed in the production to the best.

(3) Exercising the influence upon the design of the factory building and the machines.

Activities in Routing

Routing may include the following activities :

(1) *Determination of What to Make and What to Buy :* The product is analyzed to determine its component parts. Decision is made whether to manufacture all these parts in the factory, or purchase some from outside.

(2) *Determination of Materials Requirements :* Each item in the product line is broken into its components and parts required for manufacturing it. Route sheets for the manufacturing of various parts are frequently accompanied by a master bill of materials specifying various components parts and their quantities required for production.

(3) *Determination of Manufacturing Operations and their Sequence :* Routing section now analyzes the product in order to determine the operations involved in the manufacturing of each of its parts, sub-assemblies and assemblies. These operations are then analyzed to determine which of them are to be performed sequentially, and which concurrently.

(4) *Determination of Lot Sizes :* Routing section also determines the number of units to be produced in any one lot. If products are made to customers' order, the lot size is generally equal to it. On the other hand, if production is done for stocking as in case of standardized, mass production items, the lot size is generally determined by economic order quantity.

(5) *Determination of Scrap Factors :* The number of pieces which come out of the production line is usually less than that which should come out. This happens because of manufacturing defects and failure of at least a portion of them to meet quality specifications. These defective pieces are called scrap. Routing should take this scrap factor into account when determining the lot size

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of various component parts, sub-assemblies and final assembly. It is generally done by establishing a standard scrap factor at every stage of manufacturing.

(6) ***Determination of Cost :*** Cost of the component parts and final product largely depends on the materials and manpower required for manufacturing. Although cost analysis is the responsibility of the accounting department, routing is involved in it as it determines the component parts and material requirements.

(7) ***Organization of Production Control Forms :*** The type of production control forms largely depends on the type of manufacture. Production control is organized around schedule form in case of mass manufacturing. Job order manufacturing requires the use of a number of control forms such as work order, factory order or production order. It also needs other documents such as job tickets, move tickets, tool tickets, inspection cards, material cards and labour cards, for performing and reporting the completion of operations.

Routing Procedure

Routing procedure consists of the following steps :

(a) An analysis of the product to determine the various requirement for its manufacture.

(b) Determination of the manufacturing operations required and sequence of those operations.

(c) Determination of the units to be manufactured in each lot or order.

(d) Deciding scrap or residual for each step of production.

(e) Preparing production orders, job cards, labour cards, inspection cards, tool tickets and other forms.

(f) Determination of the estimated cost of production.

The overall sequence of operations of routing has been shown in fig. (1).

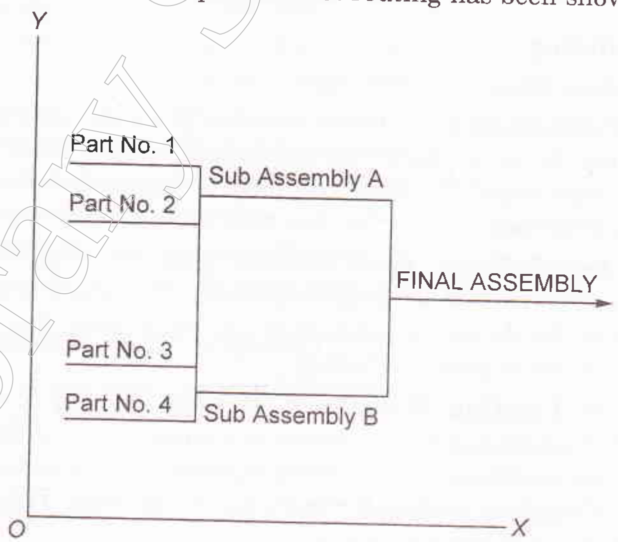

Fig. (1) Overall sequence of operations

Advantages of Routing

(1) Efficient use of available resources,

(2) Reduction in manufacturing costs,

(3) Improvement in quantity and quality of the output,

(4) Provides a basis for scheduling and loading.

4.13 SCHEDULING

Scheduling may be defined as the assignment of work to the facility with the specification of times, and the sequence in which the work is to be done. Scheduling is actually time phasing of loading. The facility may be man power, machine or both. Scheduling deals with orders and machines. It determines which order will be taken up on which machine in which department, at what time and by which operator.

Objectives

The various objectives of scheduling are :

(1) To achieve the required rate of output with a minimum of delay, and disruption in processing.

(2) To provide quantities of goods necessary to maintain finished inventories at levels predetermined to meet delivery commitments.

(3) To have maximum utilization of men, machines and materials by maintaining a free flow of materials along the production line.

(4) To prevent unbalanced allocation of time among production departments or work centres with a view to eliminate idle capacity.

(5) To keep the production cost to a minimum.

Types of Scheduling

There are three types of scheduling :

(1) *Master Scheduling :* Master schedule gives the number of units of different products to be produced for the whole year. It gives the units of production for every month for different products. Master schedule is based on the basis of sales forecast. This is the first step in production planning.

(2) *Parts Scheduling :* Parts schedule gives the number of units of different parts to be produced for the given product. The schedule is prepared for a month. It gives the details of production for every week. Parts schedule is prepared on the basis of master schedule.

(3) *Machine Loading Schedule :* Machine loading schedule is the process of work load allocation for various machines. It is a time table for the working of various machines. This schedule is prepared for a period of one week. It gives details of machine loading for every day of the week. This scheduling is prepared on the basis of parts schedule.

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Principles of Scheduling

(1) ***Principle of Optimum Task Size :*** The first principle has a tendency to not only give good results but also to be self-correcting. For example, if in a functional batch production machine shop, the loads imposed by different operations vary greatly in length, it is possible that it will be necessary to break many of the long operations into one or more small batches. This is required in order to get the other orders completed by due date. In effect, this principle only repeats the known advantage of maintaining a high rate of stock turnover and of single phase ordering. Scheduling tends to achieve its maximum efficiency when the task sizes are small and all tasks are of the same order of magnitude.

(2) ***Principle of the Optimum Production Plan :*** The second principle merely states that the obvious fact that there will be less idle time and waiting time, if all the plant is evenly loaded by the production planners. Then if some of the machines are over-loaded perhaps because direct labour cost on them are lower and others are idle for part of the time due to shortage of work. Scheduling tends to achieve its maximum efficiency when the work is planned, so that it imposes an equal/even load on all the plant.

(3) ***Principle of the Optimum Operation Sequence :*** The third principle says about principle of flow. Sometimes it is also true if we sequence some jobs, which need the same machine set-up at a time. This avoids machine ancillary time needed, in-case, the jobs of the above type are done at different times. For example, consider drilling a 10 mm hole in five different jobs may be done at a time so that the set-up time required for five jobs independently at different time are avoided. Scheduling tends to achieve its maximum efficiency when the work is planned so that the work centres are normally used in the same sequence.

Advantages of Scheduling

(1) Minimizes the production cost,
(2) Less investment of material-in-process,
(3) Minimum material storage cost,
(4) Customer satisfaction,
(5) No over-loading of men and machines,
(6) No under-utilization of men and machines,
(7) Good control of production,
(8) Goodwill of the company improved,
(9) Job satisfaction for the employees.

4.13-1 TECHNIQUES OF SCHEDULING

The various techniques of scheduling are :

(1) Bar chart
(2) Gantt chart
(3) PERT
(4) CPM

[I] Bar Chart

A pictorial chart, also known as the "Bar Chart" was developed by Henry L. Gantt and is used to deal with complex activities. Out of the various tools or techniques of project management, bar charts technique was probably one of the earliest one. A bar chart consists of two co-ordinate axes, one (usually horizontal axis) represents the time elapsed and the other (vertical axis) represents the jobs or activities to be performed. Each bar represents one specific job or activity of the project. The beginning and end of each bar represents the time of start and time of finish of that activity. The length of the bar shows the time required for the completion of that job or activity. Mostly, in every project there are some jobs/activities which can take place concurrently, while, there are some activities that succeed a preceding activity and cannot be started unless the preceding activity is complete. Hence, in a bar chart, some of the bars run parallel or overlap each other time-wise and some run serially with one bar beginning after another bar ends.

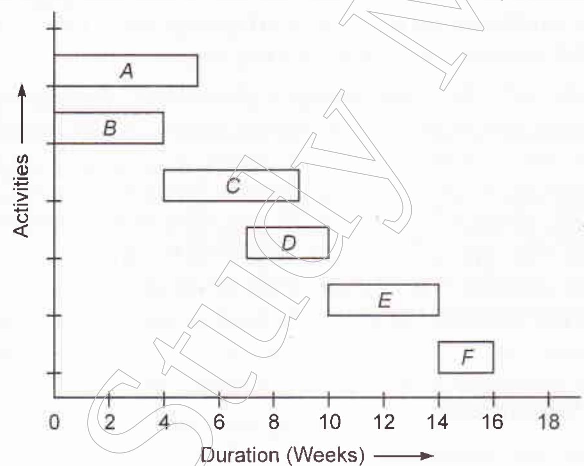

Fig. (2) Bar Chart

Figure (2) shows a bar chart for a project which has six distinct jobs or activities (A, B, C, D, E, F). The time required for the completion of these activities are 5, 4, 5, 3, 4 and 2 weeks respectively. From the chart we conclude that :

(1) Activities A and B can start simultaneously (at the same time). Both the activities are independent. They proceed in parallel, through they take different time for their completion.

(2) Activity C starts only when activity B is complete.

(3) However, activity D is independent of activity C. It starts 2 weeks later than C and

(4) Activity E starts only after activity D is completed.

(5) Activity F starts after all other activities are completed.

[II] Gantt Chart

The Gantt charts were also developed by Henry L. Gantt. Their purpose is to provide an immediate comparison between schedule and reality (*i.e.*, between planned work and actual progress of the work). This is achieved simply by marking on the chart the planned work and the actual progress of the work.

The Gantt chart is actually a modified bar chart in which horizontal bars are drawn for each activity in proportion to the time required for completing it. A cursor attached to the Gantt chart can be moved across the chart to compare between the actual progress and planned work till any particular date.

There are basically two *types of Gantt charts* :

(1) Order/Activity progress chart.

(2) Machine Load chart.

In Gantt chart, time in weeks or days is marked along the horizontal axis and the activities or orders are represented along the vertical axis. The amount of work planned or scheduled is marked by the firm lines or blank areas and the actual progress of the work by dotted lines or shaded areas.

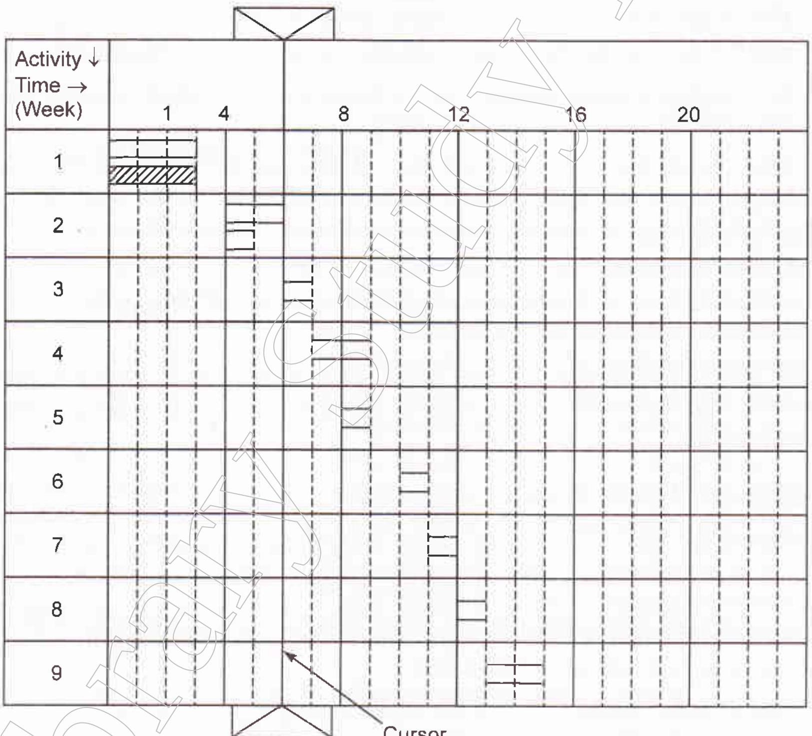

Fig. (3) Gantt Progress Chart

Figure (3), displays the schedule of manufacturing cast iron pulleys. The number of weeks which each activity will require for completion is also shown against each activity :

(1) Designing and drawing 4 Weeks.

(2) Preparing pattern 2 Weeks.

(3) Preparing the moulds	1 Week.
(4) Casting and cleaning	2 Weeks.
(5) Inspection (visual)	1 Week.
(6) Annealing	1 Week.
(7) Machining	1 Week.
(8) Making key ways	1 Week.
(9) Grinding	2 Weeks.

If we compare the planned work and the actual progress of the work at the end of 6 weeks, it is clear that designing and drawing pattern is completed as per the schedule whereas preparing the pattern is behind the schedule. This chart also helps the management to identify the areas where more attention is to be given and where less attention is sufficient.

Limitations of Gantt Chart

(i) If the project consists of too many activities, it becomes clumsy to draw the Gantt chart. Due to this, bar chart is not useful for big projects consisting of large number of complex activities.

(ii) The chart does not give any data about what exactly is completed and what is not as the chart does not show events between the bars.

(iii) As the chart combines plan and schedule, it is difficult to know whether the activities have optional starting dates.

(iv) The chart does not exhibit the dependencies or inter-relationships between the activities and as such it is difficult to say, what will be the effect of delay of one activity over the other or the entire project.

(v) Gantt charts are not at all useful in those projects where there are uncertainties in determination or estimation of time required for the completion of various activities.

These charts are useful for any small size conventional projects, specially construction and manufacturing projects, in which time estimates can be made with uncertainty.

[III] PERT

According to this theory, any given activity delineated in a network is unlikely to be completed on time. Sometimes all aspects of a job may be easier to complete than expected, while at other times, unexpected snags may occur causing unplanned delays. This method uses three time estimates for an activity rather than a single estimate. They are :

(i) ***Optimistic Time (a) :*** This is the shortest time the activity can take to complete. There is more than one chance in a hundred of completing the activity in this amount of time. It represents an ideal estimate.

(ii) ***Most Likely Time (m) :*** This refers to the time that would be expected to occur most often if the activity were frequently repeated under exactly the same conditions. It is the model time.

(iii) ***Pessimistic Time (b) :*** This is the longest time the activity could take to finish. It is the worst time estimate and represents the time the

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activity would take if bad luck was faced. It occurs with a probability of less than one per cent.

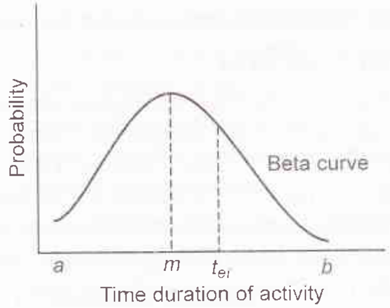

Fig. (4) Beta Distribution of Activity Times

Typically, completion of a given activity is assumed to follow beta distribution, as shown in figure (4). The three time estimates are reduced into a single expected time (t_{ei}) with the weighted average formula :

$$t_{ei} = \frac{a + 4m + b}{6}$$

where t_{ei} = expected time of the ith activity, a = optimistic time

m = most likely, or model time, b = pessimistic time

[IV] Critical Path Method (CPM)

It is observed that in a network one can enumerate many sequences of activities from starting event to end event. Each sequence will contain different combination of activities with different duration. One of the important objects of network analysis is to known the minimum possible time by which the project can be completed. This is done by determining the critical path, *i.e.*, the sequence of activities with longest duration. It is known as critical path because any delay in activities lying on this path would cause a delay in the whole project. To quicken the process, the activities lying on the critical path should be taken first.

The activities lying on Non-critical path have some flexibility in their starting time and their extension or delay in start is not likely to affect the final completion date. These are known as *Slack activities* and should be given priority in order of their float value.

CPM methods can be applied with notable success to large scale research and development programs, *e.g.*, construction work, industrial maintenance and installation operations.

Situations where CPM can be effectively used are :

(i) In production planning

(ii) Location of and deliveries from a warehouse

(iii) Road systems and traffic schedules

(iv) Communication network

Objectives of CPM Analysis

(i) To determine a route between two or more operations which optimizes some measure of performance.

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(ii) To locate the obstacles and difficulties involved in a production process.

(iii) To assign the starting and finishing times for each operation or activity.

(iv) To determine the float value associated with each non-critical activity.

Differences between PERT and CPM

(i) PERT is appropriate where time estimates are uncertain in the duration of activities as measured by optimistic time, most likely time, and pessimistic time, whereas CPM (Critical Path Method) is good when time estimates are found with certainty. CPM assumes that the duration of every activity is constant and therefore every activity is critical or not.

(ii) PERT is concerned with events which are the beginning or ending points of operation while CPM is concerned with activities.

(iii) PERT is suitable for non-repetitive projects while CPM is designed for repetitive projects.

(iv) PERT can be analyzed statistically whereas CPM cannot be analyzed.

(v) PERT is not concerned with the relationship between time and cost, whereas CPM establishes a relationship between time and cost. Note that cost is proportionate to time.

4.14 MASTER PRODUCTION SCHEDULE (MPS)

The master schedule (or master production schedule or MPS) sets the quantity of each end item (finished product) to be completed in each time period (week or month or quarter) of the short-range planning horizon.

Master production schedules (MPS) are developed by reviewing market forecasts, customer orders, inventory levels, facility loading and capacity information regularly.

The MPS is a plan for future production of end items over a short-range planning horizon that usually spans from a few weeks to several months. It is an important link between marketing and production.

Objectives of MPS are :

(1) To schedule end items to be completed promptly and when promised to customers.

(2) To avoid overloading or under-loading of the production facility so that production capacity is efficiently utilized and low production costs result.

Steps in Master Production Schedule

The process of master production scheduling involves the planning of activities to determine whether or not an operation can achieve the production objectives mentioned in the MPS.

The following are the sequential steps involved in the master production scheduling process :

(1) Determining the gross requirements of materials, components and sub-components (total demand in units of the end-product) for each product in the product line, using MRP.

(2) Obtaining the net requirements for each unit of materials, components and sub-components, after taking into consideration inventory on hand and inventory on order.

(3) Revising the preliminary master production schedule to accommodate the inadequacy of materials in inventory, if any.

(4) Converting adjusted net requirements into planned order releases (the order quantity for a specific time period) to determine unit or lot-sized production during the planning horizon.

(5) Developing load reports from the planned order releases. The load report contains information on the amount of work assigned to individual workers, machines and workstations.

(6) In the event of a mismatch between available capacity and required capacity, the MPS is modified or additional capacity is added.

Advantages of Master Production Schedule

(i) It is simple and easy to understand,

(ii) It can be kept running (*i.e.,* current),

(iii) It involves less cost to make it and maintain,

(iv) It can be maintained by non-technical staff, and

(v) A certain percentage of total weekly capacity can be allocated for rush orders.

Disadvantages of Master Production Schedule

(i) It provides only overall picture,

(ii) It does not give detailed information.

Applications of Master Production Schedule

It finds applications in the following :

(1) In big firms, for the purpose of loading the entire plant,

(2) In research and development organizations, and

(3) For the overall planning in foundaries, computer centres, repair shops, etc.

4.15 SPECIFICATION OF PRODUCTION REQUIREMENTS

From the discussion uptill now, we have seen that production planning involves selection of production process, selection of raw-materials, selection of various machines and tools, deciding process layout, etc. One other important function of production planning is to provide specifications for various production requirements. For example,

(i) Specifications regarding quality and quantity of raw materials which are to be arranged.

(ii) Specifications with regards to man power on different machines, man-hour required for a particular job or process.

(iii) Specifications regarding maintenance of various machines.

(iv) Specifications with regards to purchasing of materials and its payments.

(v) Specifications with regards to inventory control—how much of what material has to be maintained in store.

(vi) Specifications with regards to quality of product to be produced, etc.

The important thing to note is that the specifications provided through production planning and control department should be practically achievable.

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This means that these specifications should not be so strict that production suffers and wastages increases. On the other hand, they should not be so liberal that quality of the product suffers at the hands of quantity. The specifications should not result in increase in manufacturing costs or delay in the production. A proper balance must be maintained between quality and cost as well as quality and time-schedule.

REVIEW QUestions

1. What does "planning" and "control" in context of production? Explain how the three are related with each other.
2. Define production planning. What are its important characteristics?
3. What is the importance of production planning in industrial management?
4. What are the pre-requisites for production planning? On what factors does the production planning procedure depends?
5. Explain the process of production planning.
6. Define production control. What are the requirements of an efficient production control system? Explain the importance of production control.
7. What are the various elements of production control?
8. Comment on the statement :
   "Production control is the key to success of all business organizations".
9. Compare "production planning" with "production control".
10. Describe the role of production planning and control in industrial management.
11. How does production planning and control take place in an industry? Describe the various stages (or steps) in brief.
12. State the advantages of better production planning and control.
13. Explain the procedure of routing.
14. Define Scheduling. What are the principles and objectives of scheduling?
15. Distinguish between routing and scheduling.
16. What are the various techniques of scheduling?
17. Write short notes on :
   (a) Bar chart (b) Gantt chart (c) PERT (d) CPM
18. What is the difference between PERT and CPM?
19. What is master production schedule? What are its objectives?
20. What are the various steps in the master production scheduling?
21. Discuss the advantages and disadvantages of master production schedule (MPS).
22. What is the importance of specifications in production planning for production requirements?

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5 INVENTORY CONTROL

Learning Objectives

After reading this chapter, you will understand :

- Definition and concept of inventory and inventory control
- Need and classification of inventory
- Advantages and disadvantages of holding inventory
- Various levels of inventory
- Scope of inventory control
- Various elements of Inventory costs
- Inventory control systems
- Inventory control models
- Various deterministic model
- Inventory control techniques

5.1 INTRODUCTION

Conventionally, there are five M's associated with inputs to any organisation. They are Men, Machines, Materials, Money and Management. However, with the changing business scene, information and knowledge have also become important in today's world. Relative importance of these resources varies from organisation to organisation. Without doubt materials are the most vital input resource for any industry or business. However, it does not mean that plenty of material resources in any organisation will make it profitable as holding materials or "*inventory*" involves cost.

Meaning and definition of inventory

The dictionary meaning of inventory is "stock of goods" or "a list of goods". The term inventory can be used to mean several things. For example, in accounting language it may mean stock of finished goods only. In a manufacturing concern, it may include raw materials, work-in-process and stores, etc. To understand the exact meaning of the word 'inventory' we may study it from the usage side or from the 'side of point of entry' in the operations.

In this way inventory can mean :

(i) the stock in hand of materials at a given time.

(ii) a list of all physical assests (itemwise).

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(iii) as a verb to determine the quality of items on hand.

(iv) for financial and accounting records, the value of the stock of goods owned by an organisation at a particular time.

Definition : *Inventory can be defined as the stock of goods, commodities or other resources that are stored at any given period for future production.*

Inventory constitutes one of the most important elements of any system dealing with the supply, manufacturing and distribution of goods and services. In fact, inventories are common to farms, manufacturers, traders, hospitals, temples, prisons, zoos, universities and governments. The following are a few examples of the type of inventory held by various organizations. Since the final product (output) of a service organization such as bank, hospital, etc. cannot be stored for use in the near future, the concept of inventory for them is associated with the various forms of productive capacity.

Type of Organizations	Type of Inventories held
Manufacturer	Raw materials, spare parts, semi-furnished goods, furnished goods
Hospital	Number of beds, stock of drugs, specialized personnel
Bank	Cash reserves, tellers
Airline Company	Seating capacity, spare parts, specialized maintenance crew

Meaning and definition of inventory control

Inventory control is the process by which materials of the correct quality and correct quantity are made available as and when required with due regard to economy in storage and ordering costs, purchase prices and working capitals. In other words, it is the technique of maintaining the size of the inventory at some desired level keeping in mind the best economic interests of the production system. The desired level can neither be too high nor too low because high level of inventory will lead to increase in carrying cost while low level of inventory will lead to increase in ordering cost.

Inventory control makes use of available capital in a most effective way and ensures adequate supply of goods for production. Inventory control is the technique of maintaining stock keeping items at the desired level, whether they are raw materials, goods in process or finished products. Inventory control keeps track of inventory. The balance between high level and low level can be done by means of effective inventory control.

Thus, the inventory control includes the following aspects :

(i) *Size of inventory :* Determining maximum and minimum levels, establishing time schedules, procedures and lot of sizes for new orders, ascertaining minimum safety levels, coordinating sales, production and inventory policies.

(ii) Providing proper storage facilities, arranging the receipts, disbursements and procurement of materials, developing the forms of recording these transactions.

(iii) Assigning responsibilities for carrying out inventory control functions.

(iv) Providing for the reports necessary for supervising the overall activity.

5.2 NEED FOR INVENTORY

From the discussion in previous article it is clear that inventory involves cost. So a natural question which arises is that why do we want to hold an inventory? There are four main purposes of holding an inventory :

(1) *Transaction Motive :* Every firm has to maintain some level of inventory to meet the day to day requirements of sales, production process, customer demand, etc. This motive makes the firm to keep the inventory of finished goods as well as raw materials. The inventory level will provide smoothness to the operations of the firm. A business firm exists for business transactions which require stock of goods and raw materials.

The reasons for transaction motive are :

(i) *Economies of Scale :* Typically, unit costs are lowest when product is manufactured in long production runs at constant quantities.

(ii) *Specialization :* Manufacturing for stock does enables a business to permit specialization within its manufacturing facilities. Finished product is then shipped to distribution centres for the assortment process. Again, it is the potential for economies of scale to operate in manufacturing and transportation that has attraction.

(iii) *Permits Purchase and Transportation Economies :* The argument here is based on the notion that both product procurement and transportation costs will be reduced if lot sizes are large. The attempt is made to purchase in volumes which exceed immediate demand/consumption rates in order that economies may be obtained from lower transportation rates or perhaps large buying discounts.

(2) *Precautionary Motive :* A firm should keep some inventory for unforeseen circumstances also. For example, the fresh supply of raw material may not reach the factory due to strike of the transporters or due to natural calamities in a particular area. There may be labour problems in the factory and the production process may halt. So, the firm must have inventories of raw materials as well as finished goods for meeting such emergencies.

The reasons for such motive are :

(i) *Inventory as a Buffer :* Here the issue of interdependencies within the procurement–manufacturing–distribution–consumption process is highlighted. Here the argument is that because channel members are distanced geographically, philosophically and financially, often 'buffer stocks' are held at critical interfaces.

(ii) *Hedges against Price Changes :* In times of high inflation, volume purchases will minimize the impact of suppliers' price increases.

(iii) *Protects against Demand and Lead-time Uncertainties :* The argument made here considers the problems which confront logistics systems when both customer demand patterns and suppliers' replenishment lead times are not known with a reliable degree of certainty. It follows that if service is to be maintained at acceptable levels to customers then an investment in 'safety stock' would be necessary.

(3) *Speculative Motive :* The firm may be tempted to keep some inventory in order to capitalize an opportunity to make profit, *e.g.*, sufficient level of inventory may help the firm to earn extra profit in case of expected shortage in the market. Such inventory allocations are made to meet seasonal demand, sales promotion and to meet customer requirements during periods in which the production facility is in-operable.

(4) *To Maintain Customer's goodwill and Improve Customer Service :* Through a supporting role to marketing, once a market demand is created, it requires availability if sales are not to be effected and customer goodwill has to be maintained.

5.3 CLASSIFICATION OF INVENTORIES

Inventory can be classified according to :

[I] *Nature of material*–It can be further divided into

(1) Direct material (2) Indirect material

[II] *Uses of material*

Fig. (1) shows the various ways in which inventory can be classified.

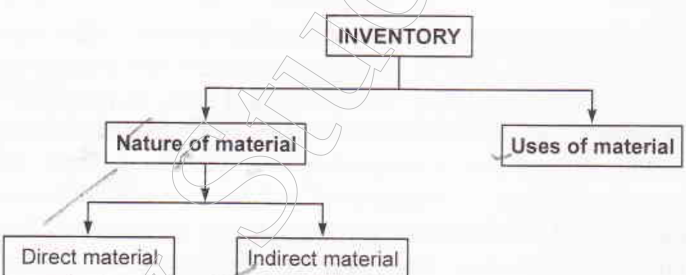

Fig. (1) Classification of inventories

[I] According to nature of materials

(1) *Direct material inventories :* These materials undergo transformation in the manufacturing operation and thereafter sent to distributors or final customers. The examples of such inventories include :

(i) *Production Inventories :* Raw materials, parts and components which are consumed in the production process of goods, come under the category of production material inventories. The purpose of holding these materials is to ensure uninterrupted production process.

(ii) *In-Process Inventories :* These goods are partially completed/finished goods that are still in the production operation, *i.e.*, semi-finished products found at various stages in the production process are called in-process inventories.

(iii) *Finished-goods Inventories :* These inventory items are final products, available for sale and distribution, *i.e.*, completed products ready for shipping. They help to reduce the risk associated with stoppage of output on account of strikes, breakdowns, shortage of materials, etc.

(2) *Indirect materials inventories :* These materials in the inventory are required for manufacturing process but do not undergo transformation in the process. Example of such inventories include :

(i) *MRO Inventories :* Maintenance, repair and operating supplies which are used in the production process but do not become a part of the products are called MRO items, and their stocking is called MRO inventories. Items like lubricating oil, old cloths, machine spare parts, etc. are not a part of the product produced but they are required for the smooth functioning of the production process and so their stock is maintained.

(ii) *Consumables :* Consumables are products that are required recurrently, *i.e.*, items which "get used-up" or discarded. For example, consumable office supplies are such products as paper, pens, file folders, computer disks, toner/ink cartridges and non-included capital goods such as computers, fax machines, and other business machines or office furniture.

[II] According to uses of materials

According to the cause or use of holding inventory, inventories are classified as :

(1) *Transaction inventory :* This type of inventory items are basically needed for transaction. For example, transaction of finished saleable products or raw materials. These inventories are also called *movement inventories* or *pipeline inventories*. Their existence is due to the fact that transportation time is involved in transferring substantial amounts of resources. For example, when coal is transported from the coalfields to an industrial town by trains, then the coal, while in the transit, cannot provide any service to the customers for power generation or for burning in furnaces.

(2) *Speculative inventory :* This type of inventory involves stocking of materials as a measure of speculation so as to get more price of goods in future.

(3) *Anticipation Inventories :* Anticipation inventories are held for the reason that a future demand for the product is anticipated. Production of specialized items like crackers well before Diwali, umbrellas and raincoats before rains set in, fans while summers are approaching; or the piling up of inventory stocks when a strike is on the anvil, are all examples of anticipation inventories.

(4) *Buffer Inventories or Precautionary Inventories :* Buffer inventories are held to protect against the uncertainties of demand and supply. An organization generally knows the average demand for various items that it needs. However, the actual demand may not exactly match the average and could well exceed it. To meet this kind of a situation, inventories may be held in excess of the average for expected demand. Similarly, the average delivery time (*i.e.*, the time elapsing between placing an order and having the goods in stock ready for use, and technically called as the *lead time*) may be known. But unpredictable events could cause the actual delivery time to be more than the average. Thus, excess stocks might be kept in order to meet the demand during the time for which the delivery is delayed. These inventories which are in excess of those necessary just to meet the average demand (during the average lead time period), are held for protecting against the fluctuations in demand and lead-time. They are also known by the term *safety stocks*.

(5) *Cycle Inventories :* Cycle inventories are held for the reason that purchases are usually made in lots rather than for the exact amounts which may be needed at a point of time. Of course, if all purchases are made exactly as and when the item is required, there would be no cycle inventories. But practically, purchases are made in lots, the reason being that if purchases are made frequently and in small numbers, then the cost involved in obtaining the items would be very large.

5.4 VARIOUS LEVELS OF INVENTORY [FIXATION OF STOCK LEVELS]

[I] Minimum Inventory Level

The minimum stock level represents the lowest quantitative balance of materials in hand which must be maintained in hand at all times so that the assembly line may not be stopped on account of non-availability of materials.

The minimum stock level is given by

Minimum Stock Level = Re-ordered level − (Average rate of consumption of × Lead time)

The factors affecting minimum stock level are :

(1) *Lead Time :* This is the time required to obtain the delivery of fresh supplies. If this time is more then the minimum inventory level will be high. Lead time has two components. *Administrative lead time* is the time taken from initiating the procurement action until the placing of an order. It also involves the time after the materials have been delivered and are inspected for quality and quantity checks, making entries in store ledger etc. *Delivery lead time* is the time taken from placing the order until the delivery of the ordered material.

(2) *Inland or Importable Inventory :* If the material is to be imported then the lead time will be more implying minimum inventory level is to be kept high.

(3) *Availability of Inventory :* If the material is not easily available then the minimum stock level is to be kept high.

(4) *Possibility of Interruption in Production :* If the production process is smooth then it is easy to determine the minimum stock level. However if production is not smooth due to some reasons such as frequent strike, power-cuts, etc., then it is not easy to find out exact level of minimum stock.

(5) *Nature of the Material :* Materials that are regularly required must be maintained at a minimum level. If on customer's order a special item of material is to be purchased, no minimum level is required to be fixed for that.

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(6) ***Rate of Consumption of the Material :*** The minimum rate, the maximum rate and the normal rate of consumption are to be taken into consideration while fixing the minimum stock level.

[II] Maximum Inventory Level

Maximum stock level represents the maximum quantity of inventory which can be kept in store at any time. This quantity is fixed keeping in view of disadvantages of over-stocking.

The following formula is used for computation of maximum stock level.

Maximum Level = Re-order level + Re-order quantity − Minimum consumption × Minimum Re-order period

Or

= Re-order level + Re-order Quantity − (Average rate of usage × Lead Time)

The factors affecting the maximum stock level are :

(1) Rate of consumption of the material.

(2) The lead time.

(3) The maximum requirement of the material at any point of time.

(4) ***Nature of the Material :*** The materials which deteriorate quickly are stored as minimum as possible.

(5) Storage space available for the material.

(6) ***Price Economy :*** Seasonal materials are cheap during the harvesting seasons. So maximum purchases is made during that season and as a result the maximum level is high.

(7) Cost of storage and insurance.

(8) ***Cost of the material and the finance available :*** When the material is costly the maximum level is likely to be relatively low. If the price is likely to go up maximum level should be high.

(9) ***Inventory Turnover :*** In case of slow moving materials the maximum level is low and in case of quick moving material it is high.

(10) ***Nature of Supply :*** If the supply is uncertain, the maximum level should be as high as possible.

(11) ***Economic Order Quantity (EOQ) :*** Maximum level largely depends on economic order quantity. The economic order quantity decides the quantity ordered and hence decides the maximum level.

[III] Re-order or Ordering Inventory level

This is the fixed point between the maximum stock level and minimum stock levels at which time the order for next supply of materials from the vendor is to be done.

This mainly depends upon two factors :

(i) Rate of maximum usage.

(ii) Maximum Re-order period or maximum delivery time.

Assumptions of Re-order level are :

(i) The time of delivery remains fixed.

(ii) Load time remains fixed.

(iii) The average rate of consumption of materials does not changes.

Re-order of ordering level is calculated by :

Ordering level or Re-order level

= Maximum usage per day × Maximum Re-order period or Maximum Delivery Time

Or

= Maximum Level + (Normal usage of average rate of consumption × Average Re-order period or Average delivery time)

[IV] Average Inventory Level

Average inventory level is the average quantity which must be available for a given period of time. It is calculated in the following manner :

Average stock level = [Minimum level + Maximum level]/2

or Average stock level = Minimum level + [Re-order Quantity]/2

[V] Danger Inventory level

In addition to the minimum, the maximum and reordering inventory levels there is another inventory level called *danger level*. This level is below the minimum level and when the actual stock reaches this inventory level immediate measure is to be taken to replenish stock. When the normal lead time is not available, the purchase quantity cannot be accurately determined. So, it is fixed in such a way that the actual stock does not fall below danger level by the actual lead time. This means that the minimum level contains a cushion to cover contingencies.

Some firms fix danger level below the re-ordering level but above the minimum level. If action for purchase is taken as soon as the stock reaches the re-ordering level, the danger level bears no importance except that when the stock reaches the danger level (but not yet the minimum level). A reference may be made to the purchase department to ensure that delivery is received before the actual stock reaches the minimum level.

When the danger level is fixed below the minimum, it being reached by the actual stock, the defect in the system is identified and corrective measure becomes necessary. When the danger level is fixed above the minimum, it being reached by the actual stock, preventive measure is to be taken so that the stock may not go below the minimum level.

It is the point or level of stock which the materials stock should never be allowed to reduce. It is generally a level below the minimum level. As soon as the stock of material reaches this point, urgent action is needed for replenishment of stock.

Usually, the danger level is determined as two days of normal consumption.

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Example 1 *From the following particulars, calculate : (a) Re-order Level (b) Minimum Level, (c) Maximum Level, (d) Average Level :*

Normal Usage	100 *units per day*
Minimum Usage	60 *units per day*
Maximum Usage	130 *units per day*
Economic Order Quantity	5,000 *units*
Re-order Period	25 *to* 30 *days*

Solution **(a)** Re-order Level = Maximum Usage × Maximum Re-order Period

$$= 130 \times 30 = 3{,}900 \text{ units}$$

(b) Minimum Level = Re-order Level – (Normal Usage × Average Re-order Period)

$$= 3{,}900 - (100 \times 27.5) = 1{,}150 \text{ units}$$

Note : Average Re-order Period $= \dfrac{25 + 30}{2} = 27.5$ days

(c) Maximum Level = (Re-order Level + Re-order Quantity Or EOQ) – (Minimum Usage × Minimum Re-order Period)

$$= (3{,}900 + 5{,}000) - (60 \times 25)$$

$$= 7{,}400 \text{ Units}$$

(d) Average Level $= \dfrac{\text{Minimum Level} + \text{Maximum Level}}{2} = 27.5$

$$= \frac{1{,}150 + 7{,}400}{2} = 4{,}275 \text{ Units}$$

5.4-1 OPTIMUM LEVEL OF INVENTORY

From the above discussion, it becomes important to know the factors which are responsible for maintaining optimum level of inventory. They are :

(1) *Rate of Inventory Turnover :* It is time period within which inventory completes the cycle of production and sales. When the turnover rate is high, investments in inventories tends to be low.

(2) *Type of Product :* Durable products are more susceptible to inventory holding as the risk of perishability and obsolescence is less. Perishable and fashion goods are not stocked in large amounts. Thus, the type of product also influences the inventory level.

(3) *Market Structure :* Under the conditions of imperfect competition, demand is uncertain and stocks must be held if the firm wants to take advantage of profitable sales opportunities. The optimum level of sales will depend upon the variability of sales and the cost revenue relationship. The level of inventory rises with increase in the difference between price and marginal cost. Thus, market structure influence the level of inventories.

(4) *Economies of Production :* It also determines the inventory level. Modern machinery is very costly and the the cost of idle machine time is

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considerable. Therefore, every business firm likes to maintain sufficient stock of raw materials to ensure uninterrupted production.

(5) *Costs :* There are certain costs of carrying stock. Some of these costs (storage costs, setup cost, change over costs, ordering costs and spoilage and obsolescence costs) are directly measurable. On the other hand, certain costs (opportunity cost of capital, costs caused by price level changes, cost of loss of sales due to shortage of stock) are not measurable. All these costs influence the level of inventories.

(6) *Financial Position of the Firm :* It has significant influence on inventory levels. A financially sound company may buy materials in bulk and hold them for future use. A firm starved of funds cannot maintain large stocks.

(7) *Inventory Policy and Attitude of Management :* The inventory policy and attitude of management also influence the inventory level.

5.5 INVENTORY COSTS

In determining an optimal inventory policy, the criterion most often is the cost function. The classical inventory analysis identifies four major cost components : (1) Purchase cost (2) Ordering cost (3) Carrying cost (4) Stock out cost. Fig. (2a) shows the relationship of order quantity on the cost of inventory.

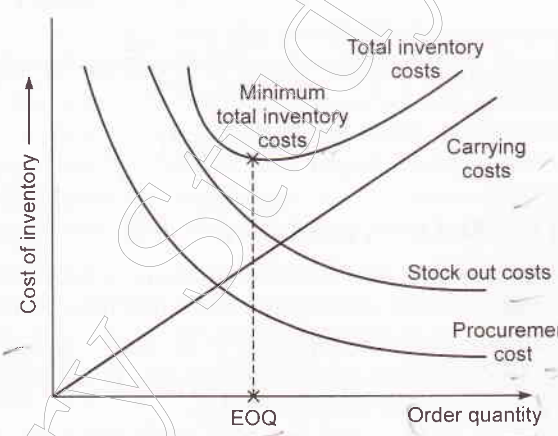

Fig. (2a) Total inventory costs

(1) Purchase Cost

This refers to the nominal cost of inventory. It is the purchase price for the items that are bought from outside sources, and the production cost if the items are produced within the organization. This may be constant per unit, or it may vary as the quantity purchased/produced increases or decreases. Quite often, situations are found when it may be stipulated that for example, the unit price is Rs. 20 for an order upto 100 units and Rs. 19.50 if, the order is for more than 100 units.

Unit price → Rs 20 order upto 100 unit | Rs 19.50 →

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80+80

(2) Ordering Cost/Set-up Cost

Ordering cost is incurred whenever the inventory is replenished. It includes costs associated with the processing and chasing of the purchase order, transportation, inspection for quality, expediting overdue orders and so on. It is also known as the *'procurement cost'*.

The parallel of the ordering cost, when units are produced within the organization, is the *set-up cost*. It refers to the cost incurred in relation to developing the production schedules, the resources employed in making the production system ready and so on.

(3) Carrying Cost

Inventory carrying costs comprise a range of items over which varying degrees of control may be exercised by management. The various carrying costs are shown in fig. (2b).

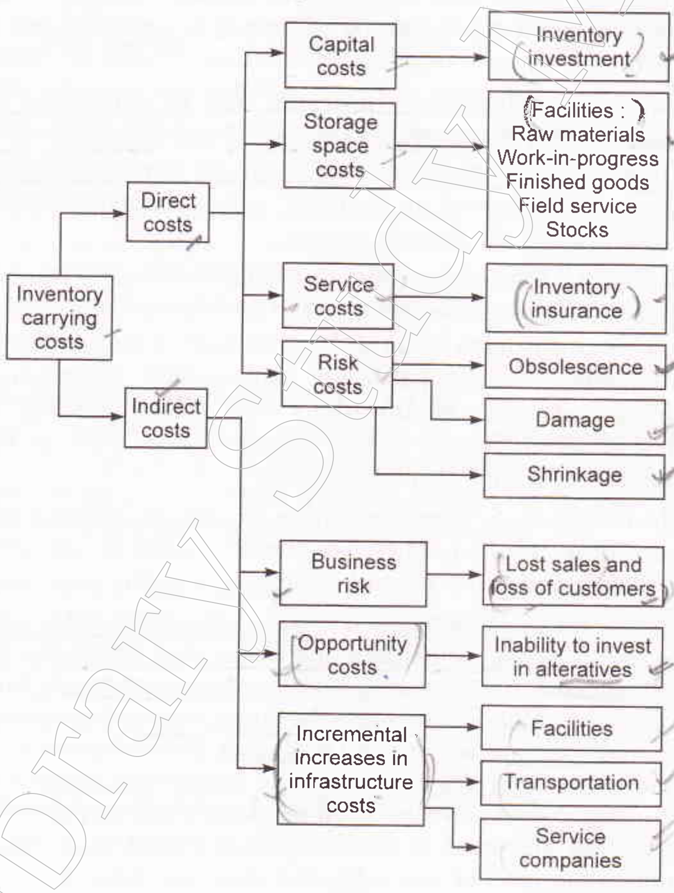

Fig. (2b) Inventory carrying costs

(i) ***Direct costs :*** There are four cost characteristics that are important in direct cost items. These are closely related to the levels of inventory carried in the system.

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(a) *Capital Costs* : The Capital Costs of inventory are influenced by customer service policy, which in turn is influenced by supply-chain (logistics pipeline) tasks and roles. As such they contribute a large amount to the overall costs of carrying inventory. To obtain an estimate of the amount of the investment it is not unusual for companies to apply a rate of interest which best reflects their view of the role of inventory. At the same time, it also reflects the opportunity cost of capital. An alternative measure may use the weighted cost of capital.

(b) *Storage Space Costs* : Storage Space Costs include the storage requirements for all categories of inventories. It is important to remember that the costs of company-owned facilities are primarily fixed costs. It is important to consider the relationship between storage space costs and inventory levels. An excess of stocks requires additional storage capacity, which may be available from outside service company (renting of space) for seasonal variations, but if it is increased unnecessarily for a long period of time it is a penalty cost that can be avoided.

(c) *Service Costs* : Inventory insurance may be considered in a similar manner. Such service costs are volume related and again can be regarded as a penalty on the business if the inventory levels are excessive. Clearly there is also an impact on facilities' insurance levels which reflect the size and value of the storage space.

(d) *Risk Costs* : Risk costs will vary with the nature of the business, and may extend beyond the value of the inventory. Obsolescence may not simply mark down the value of the stock item, it may render it worthless. For example, service parts for construction equipment are often modified and these modifications may render existing components valueless. Furthermore, if the replaced parts were to be used, the equipment warranty would be invalid.

(ii) ***Indirect Costs*** : There are three important indirect cost items of concern in inventory control. These are more related to the overall role of inventory within an inventory control system.

(a) *Business Risk* : Business risks are concerned with two issues. A company carrying insufficient inventory may be unable to meet and satisfy demand. The reverse situation is that too much inventory may satisfy demand but will increase the direct costs by increasing the capital costs, storage costs, service and risk costs. So management has to decide on the level of service or availability considered necessary to achieve their objectives and, in turn, their marketing and corporate objectives. It follows that the level of inventory investment seen as necessary to minimize the level of lost sales and maintain customer loyalty can be derived.

(b) *Opportunity Costs* : Dynamic companies usually have a range of investment alternatives they can pursue. Clearly, if the investment in inventory is accounting for too much capital investment, then the alternatives become limited in number and impose opportunity costs through the lack of capital available to invest in alternatives.

(c) *Incremental Increase in Infrastructure Costs :* An important aspect of indirect costs is the incremental increases in infrastructure costs caused by carrying excess inventory. Cost penalty of excess of stockholding can involve companies in an over-investment in facilities and transportation, together with incurring unnecessary charges from service companies. The cost penalties are both fixed and variable in their context.

(4) Stock-out Cost

Stock out cost means the cost associated with not serving the customers. Stock outs implies shortages. If the stock out is internal (that is, in the production system) it would imply that some production is lost, resulting in idle time for men and machines, or that the work is delayed which might attract some penalty. While if the stock out is external, it would result in a loss of potential sales and/or loss of customer goodwill. A shortage can evoke different reactions from customers. It would result in a 'backorder' or a 'lost sale'. In case of backorder the sales are not lost, they are only delayed.

The other costs of importance in Inventory control are :

(5) Warehousing Cost

This covers the cost related to product holding in warehouse. Depending on the kind of warehouse—private, public or contract—there will be a cost related to the space occupancy, based on the duration of storage. This cost varies from 1.5 to 4 per cent and may be taken into consideration while computing inventory related costs.

(6) Damage, Pilferage and Obsolescence Cost

The material stored carries the risk of damage, shrinkage, and loss of weight. The product also carries risk of pilferage or obsolescence due to technology change or availability of substitutes. The cost percentage for these eventualities varies from 0.5 to 2 per cent depending on the product.

(7) Exchange Rate Differentials

In case of imported inventories, the valuation is done based on the current currency exchange rates in the market. Any fluctuation may increase or decrease the value of inventory. Due to exchange rate fluctuations, there is a risk of selling the material at prices lower than the landed cost.

5.6 ADVANTAGES AND DISADVANTAGES OF HOLDING INVENTORY

Advantages

The various advantages of holding inventory are :

(1) ***Avoiding Lost Sales :*** Without goods on hand which are ready to be sold, most firms would lose business. Some customers are willing to wait,

particularly when an item must be made to order or is not widely available from competitors. In most cases, however, a firm must be prepared to deliver goods on demand. Shelf stock refers to items that are stored by the firm and sold with little or no modification to customers. An automobile is an item of shelf stock.

(2) *Gaining Quantity Discounts :* In return for making bulk purchases, many suppliers will reduce the price of supplies and component parts. The willingness to place large orders may allow the firm to achieve discounts on regular prices. These discounts will reduce the cost of input and increases the profits earned on a sale.

(3) *Reducing Ordering Costs :* Each time a firm places an order, it incurs certain expenses. Forms have to be completed, approvals have to be obtained and goods that arrive must be accepted, inspected, and counted. Later on invoice must be processed and payment made. Each of these costs will vary with the number of orders placed. By placing fewer orders, the firm will pay less to process each order.

(4) *Achieving Efficient Production Runs :* Each time a firm sets up workers and machines to produce an item, start-up costs are incurred. These are then absorbed as production begins. The longer the run, the smaller the costs to begin production of the goods. As an example, suppose, it costs Rs 12,000 to move machinery and begin an assembly line to produce electronic printers. If 1,200 printers are produced in a single three-day run, the cost of absorbing the start-up expenses is Rs. 10 per unit (12,000/1,200). If the run could be doubled to 2,400 units, the absorption cost would drop to Rs. 5 per unit (12,000/2,400). Frequent set-ups produce high start-up costs; longer runs involves lower costs.

(5) *Reducing Risk of Production Shortages :* Manufacturing firms frequently produce goods with hundreds or even thousands of components. If any of these are missing, the entire production operation can be halted, with consequent heavy expenses. To avoid starting a production run and then discovering the shortage of a vital raw material or other component, the firm can maintain larger than needed inventories.

Disadvantages

The various disadvantages associated with holding inventory are :

(1) *Increase in Carrying Costs :* The carrying cost of inventories will be more if materials are stored for longer time.

(2) *Unnecessary Capital Investment :* Unnecessary capital is invested in materials if large inventories are purchased and stored.

(3) *Increase in Maintenance Cost :* The safety of materials and its maintenance may be costly. The insurance charges, rent of stores and other costs of storage are involved in inventory such as cost of holding and record keeping the materials in stock.

(4) *Wastage of Materials :* Wastage, pilferages, deterioration and obsolescence of materials with time will unnecessarily be unprofitable to organization.

(5) *Loss To Company :* In case of reduction in cost of items in inventories, there will be great loss to the company.

5.7 OBJECTIVES OF INVENTORY CONTROL

Inventory control helps in attaining various objectives of an organization which can be categorised into two heads :

[I] Operating Objectives

(1) *Availability of Materials :* The first and the foremost objective of the inventory control is to make all types of materials available at all times whenever they are needed by the production departments so that the production may not be held up for want of materials. Therefore, it is advisable to maintain a minimum quantity of all types of materials to move on the production on schedule.

(2) *To Check Wastage :* Inventory control not only ensures uninterrupted material supply to production department but also ensures the control from purchasing to supply of finished goods to customers. So in this way it checks waste and wastage whether it is about time, money or material.

(3) *To Check Embezzlement and Theft :* Inventory control is necessary for protection from theft and embezzlement by maintaining necessary records.

(4) *For the Success of Business :* Customer's satisfaction is very much important for the success of business. Customer's satisfaction is directly related to the goods supplied to them. If the goods supplied to customers are low in cost with good quality at right time, it ensures the success of business. Inventory control helps in achieving this goal.

[II] Financial Objectives

(1) *Optimum Investment and Efficient use of Capital :* The prime objective of inventory control from financial point of view is to have an optimum level of investment in inventories. There should neither be any deficiency of stock of raw materials so as to hold up the production process nor there any excessive investment in inventories so as to block the capital that could be used in an efficient manner otherwise. It is, therefore, the responsibility of financial management to set up the maximum and minimum levels of stocks to avoid deficiency or surplus stock positions.

(2) *Reasonable Price :* Inventory control ensures the supply of raw materials at a relatively low price but without sacrificing the quality of it. It helps in controlling the cost of production and the quality of finished goods in order to maximize the profits of the concern.

(3) *Minimizing Costs :* Minimizing inventory costs such as handling, ordering and carrying costs, etc., is one of the main objectives of inventory management. Financial management should help controlling the inventory costs in a way that reduces the cost per unit of inventory. Inventory costs are the part of total cost of production. Hence cost of production can also be minimized by controlling the inventory costs.

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(4) *For Effective Cost Accounting System :* Cost accounting system is useful only when there is a tight control over cost. Note that inventory cost is a major part of total production cost.

5.8 SCOPE OF INVENTORY CONTROL

Inventory control can be used for :

(1) *Determination of Inventory Policies :* Inventories are the result of many interrelated decisions and policies within an organization. These policies depend on company's internal strengths and weaknesses and external opportunities and threats. The behaviour of inventories is the direct result of diverse policies and decisions within company. These relate to the investments, procurement, storage and finance which are directly influenced by inventory control system. Inventory control also follows up to examine the work of inventory policy and effect change as and when needed.

(2) *Determining Various Stock Levels :* Another important decision is maintaining inventory and determining the right inventory level. An inventory level is a quantitative limit, which should neither be much high nor too low. In both the cases, the total costs shall be higher. The critical inventory levels are re-order level, minimum level, maximum level, danger level and average stock level.

(3) *Determining Economic Order Size :* Economic order size is that size of the purchase order which gives maximum economy in purchasing any item of material. The other terms used for economic order size are 'economic lot quantity' and 'economic buying quantity'. The most advantageous economic quantity will be at a point where the acquisition cost and inventory storing costs are equal, *i.e.,* where total costs to order and to carry material are minimum.

(4) *Determining Safety or Buffer Stock :* The demand and supply can never be assessed exactly. There is always a discrepancy between actual and estimated demand and supply quantities with fair degree of uncertainty. A buffer stock can be defined as the average inventory stock available when the fresh supply arrives. It is presumed that this stock will be able to cope with the emergency if and when experienced. Generally, buffer stock is maintained at the desired level by discontinuous replenishments at varying intervals of time. Factors affecting choice of buffer stocks are uncertainty in demand, uncertainty in lead times and size of the batch. The larger the uncertainty associated with any factor, large should be the size.

(5) *Determining Lead Time :* This is the time gap between placement of an order and the time of actual supply. The determination of lead-time is a complicated matter. It is of core signification in determining the stock level.

Lead Time = Servicing Time + Delivery Time + Receiving Time

The minimum, maximum and average lead times differ from unit to unit and from time to time.

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5.9 FUNCTIONS OF INVENTORY CONTROL

From the discussion uptill now, we can summarize the functions of inventory control as under :

(1) To ensure smooth production operation by ensuring timely availability of material.

(2) To minimise capital investment in inventory by better use of financial resources.

(3) To helps in minimising loss by obsolescence, deterioration, damage, thefts, wastages, etc.

(4) To protect against the uncertainties of demand and supply.

(5) To help managers in decision making.

(6) Better utilization of storing capacity.

(7) To maintain reasonable stocks of materials at all times.

(8) To facilitate regular and timely supply to customers increasing customer satisfaction.

(9) To prepare accurate material reports.

(10) To help in checking national wastage.

5.10 ESSENTIALS OF A GOOD INVENTORY CONTROL SYSTEM

Following elements are essential for a good inventory control system :

(1) *Proper Co-ordination :* There should be a proper co-ordination between all the departments who use materials, such as purchase department, store department, inspection department, accounts department, production department and sales department. There should neither be a scarcity of material nor excess of material at all the times.

(2) *Proper Classification :* Classification and identification of inventories by allotting proper code number to each item and group should be done. This facilitates prompt recordings, locating and dealing of materials.

(3) *Use of Standard Forms :* Standard forms should be used so that any information can be sent to all department within no time.

(4) *Internal Check System :* Audit should be done by an independent party to check effectiveness of the inventory control system.

(5) *Proper Storing System :* Adequate and well organised warehouse facilities with well-equipped proper handling facilities must be there. Such facilities will reduce the wastage due to leakage, wear and tear, sustained dust and mishandling of materials. Store location should be in between the purchase department and production department, so that cost of internal transportation can be minimised.

(6) *Proper Store Accounting :* An efficient inventory control necessitates maintenance of proper inventory records. Any typical information regarding any particular item of inventory may be taken from such records.

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(7) *Proper Issuing System :* There should be a well organised issuing system of material so that production process does not suffer.

(8) *Perpetual Inventory System :* Daily stock position should be taken in this system.

(9) *Fixing of Various Stock Levels :* Minimum stock level, maximum stock level, re-order point, safety level, etc. should be pre-determined to ensure the continuity of smooth production.

(10) *Determination of Economic Order Quantity :* Economic order quantity should be determined to minimise the cost of inventory.

(11) *Regular Reporting System :* The information regarding the stock position, material quantity, etc. should be available to management regularly.

(12) *Intelligent and experienced personnel :* Another important requirement of a successful inventory control system is the appointment of intelligent and experienced personnel in the purchase department. These personnel should be expert in their field and negotiating the deals.

5.10-1 PERPETUAL INVENTORY CONTROL SYSTEM

The perpetual inventory system is a system of maintaining records of physical movement of stock, *i.e.,* the record of every purchase and issue and their current balance to facilitate regular checking and to obviate closing down of books for stock taking. This system saves the important time in stock's physical checking at the end of the year.

Procedure

Under this system as the material is received in the store, it is recorded immediately on the bin card, in store ledger and in accounts department. Entry in bin card is done by store-keeper, in store ledger it is done by store-incharge and in accounts department it is done by accounts official.

This system can be utilised in its full if an external auditor checks the records of all the three places, described above. If the difference is found in any one of the record then its reasons should be discussed. Step should be taken to remove discrepencies.

Difference in the physical quantity of materials in the store with the quantities shown in the bin card and store ledger can be due to the following two reasons :

(1) *Contrable Loss :* These may be as follows :

(i) Mistake in calculating balance in receipt or issue.

(ii) Loss due to breakage during loading-unloading of material.

(iii) Wrong entry in bin card or store ledger.

(iv) Mistake in calculation due to wrong placement of materials.

(2) *Uncontrolable Causes :* These may be as follows :

(i) Loss due to cutting, breaking or weighing of materials.

(ii) Evaporation of material etc.

(iii) Loss due to weather and climatic or Atmospheric conditions.

(iv) Expired material.

By close control and regular checking these can be prevented.

Advantages

The advantages of perpetual inventory system are :

(1) A complete and dependable check is obtained on the stores.

(2) The normal work of the factory need not be kept suspended for the purpose of stock-taking.

(3) Preparation of profit and loss account and Balance Sheet.

(4) Discrepancies can be readily detected and adjusted. Measures to avoid such discrepancies, wherever possible, may be taken.

(5) Stocks can be kept within the limits prescribed because stores audit extends to this aspect also.

(6) Since the stocks are kept within the limit, there are no chances of capital being unnecessarily blocked, bottleneck in supply for production, loss due to deterioration, obsolescence etc.

(7) It creats a moral check upon the stores personnel.

(8) Experienced personnel can be employed to work on the system.

(9) For fire insurance etc. reliable stock figures can be obtained.

(10) Systematic review of perpetual inventory helps detection of obsolete and slow moving materials.

5.11 PROCESS OF INVENTORY CONTROL

The process of inventory control may be divided into three stages as under :

State I : Process of purchasing of materials or ordering.

State II : Inventory storing procedure.

State III: Process of issue of material.

[I] Process of Purchasing of Materials

The various steps in the process of purchasing of materials are :

(1) *Establishment of Purchase Department* : A different department should be established for purchase of materials. This department should not only ensure the availability of raw material at all times but also purchase machines, stationary, etc.

Purchase of materials should be centralised. All purchases should be under a single department. Concept of centralised purchase is generally possible only in those industries, which are located at a single place and nature of production is of same type. But if an industry has different production centres which are located at different places, then it becomes compulsory to follow decentralised purchase system. Thus, it is necessary to have a complete knowledge about the nature of production, location and capacity of each location, etc.

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(2) *Preparation of Purchasing Budget* : First of all the production target of the company should be determined. On the basis of this the budget for purchasing of material is prepared.

Following points should be kept in mind while preparing purchase budget :

(i) System to receive the materials.

(ii) The quantity and quality of the material according to the production requirements.

(iii) Source of supply.

(iv) Present balance of materials and estimated time to receive the materials ordered.

(v) Available cash for debtors.

(vi) On which date the indent (purchase requirement) is made by concerned department.

(vii) The conditions regarding the value of the material and rebate or discount on it.

(3) *Preparation of Purchase Requisition Slip* : The initiations of purchase begins with the formal request from the various sections or departments to the purchase department to order goods. The request is made in a prescribed form to the purchase department by the departments needing the goods, authorising the purchase department for procuring the goods as per the specifications given in the slip by the date mentioned on it.

The requisitions are generally prepared in triplicate. The original copy is sent to the purchase department, the second copy is retained by the store or the department initiating the purchase requisition and third one is sent to the costing department.

(4) *Obtaining the Tender or Quotations* : After the decision for purchase, tenders or quotations are invited from the prospective suppliers. On studying the terms of supply and the quantity and quality of the goods, vender is selected after the comparative study of tenders.

(5) *Sending Purchase Order* : After comparing the different tenders or quotations, the best vendor is decided and the order of required material is placed to him.

Purchase order is prepared in prescribed form by the purchase department and sent to the vendor authorising him to supply a specified quantity and quality of the materials at the stipulated terms at the time and place mentioned there in.

(6) *Receiving and Inspection of Materials* : When goods arrive they are taken delivery of and parcels or packets are unpacked. The contents of the packages are checked by the receiving clerk with the order placed by the purchasing department to the vendor. After proper checking, goods should be delivered to the laboratory or inspection department or the people from these departments should be called for carrying inspection. Goods received note is prepared at this time.

(7) *Returning the Defective Materials* : On checking, if any discrepency is found with regards to quality and quantity, it should immediately

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be referred to the purchase department so that the discrepancy may be adjusted or steps may be taken to return the defective or damaged goods in exchange of proper quality material on credit note.

(8) *Payment of Purchased Material* : After required inspection, etc. final report is sent to purchase officer, who sends it to payment officer after placing required entries in the report. After checking the ledger, payment officer authorise accounts clerk for payment.

[II] Inventory Storing Procedure

Inventory storing procedure is an important part of inventory control. Following procedure is followed in inventory storing :

(1) *Receipt of Material in Store* : The storekeeper receives the material along with the goods received note from the receiving section. The material are then classified according to the nature of the material. The material should be arranged in bins especially meant for the materials. A bin card is attached with each bin or rack displaying the identification mark or code, minimum, maximum and ordering levels of materials and receipts, issues and balance of materials in hand, so that the exact position may be known at any time whenever desired.

(2) *Issue of Material from Store* : The store undertakes the responsibility of issuing the material to the using departments. In order to prevent malpractices, the materials must be issued only against the properly authorised requisition slips. These requisition must be properly checked and scrutinised to avoid over-issue of materials. All requisition received must be posted immediately on daily basis on the bin cards and on the stock control cards. Generally three copies of requisition slips are prepared—first two copies are given to the stores and third copy kept with the demanding department. Store in-charge keeps one copy of requisition slip for himself and other copy is sent to accounts department.

(3) *Return of Material to Store* : If a department uses less material than its demand, then it returns the material to stores. Goods return slips are sent along with the materials. The same specifications and details of materials are given in goods return slips as they were mentioned in requisition slips. Three copies of goods return slips are prepared. First two copies are sent to stores department and third copy is kept by the goods returning department itself. Store keeper sends one copy to accounts department. The colour of both requisition slip and return slips are kept different to identify them easily.

(4) *Transfer of Material* : The transfer of materials from one department to another department is generally not appreciated, because it creates problems in material control process. But sometime when there is an emergency, the transfer of material from one department to other department is allowed. The department transferring the material makes four copies of material transfer slips. First copy is sent to the needy department along with material. Second and third copies are sent to stores department and accounts department for their information and further necessary action. Fourth copy is retained by the department transferring the material.

(5) *Material Abstract* : In big industries where large quantity of materials are received, issued and transferred daily, "material abstract" is prepared weekly or fortnightly to control the inventory. A physical verification of quantity in stores and other departments is done by material abstract.

If any discrepency is found in physical verification of quantity in store or other department, it is brought to the notice of top management. This type of check plays a very important role in inventory control. Thus, material abstract is a summary of materials received, issued and transferred, for a given time period.

[III] Process of Issue of Materials

To control the issue of materials following procedure is followed :

(1) *Issue of Material* : When any production department needs materials from store, it prepares three copies of goods requisition slip. If the material is costly and important, then factory manager also signs these copies. One copy of requisition slip is kept by foreman himself and other two copies are given to stores. According to the requisition slip, the store-keeper issues the materials to foreman. Foreman signs the two copy of store's requisition slips to verify that he has received the material. Then storekeeper makes the required entries in the bin card. After signing both these copies of requisition slip, storekeeper sends one copy to accountant of store. After recording the issue of materials, store accountant sends this copy to costing department.

(2) *Record of Materials Issued in the Costing Department* : After receiving one copy of requisition slip from stores, cost clerk writes the rate and amount of materials in requisition slip and makes an entry in stores ledger.

(3) *Return of Materials Issued* : If some quantity is left with the issuing department unused, then it is returned to the stores department. For this purpose, the foreman prepares three copies of Material Return Slips or Goods Return Slips. All these three copies are sent to storekeeper along with material. All the three copies of Goods Return Slip are duly signed by the storekeeper. One copy is sent to department returning the material, second copy is sent to store accountant and the third copy remains with storekeeper. Store accountant records the goods returned in store control records and sends the goods return slip to cost department.

(4) *Periodical Checking of Materials* : To control the issue of materials it is very much necessary that bin cards, store control records and store ledgers are checked regularly and if any discrepency is found, proper corrective actions should be taken.

(5) *Physical Stock Checking of Materials* : Physical stock checking in stores should be done periodically to prevent materials loss, material damage, theft and determine inventory balance in hand. This checking can be done weekly, monthly, etc. Physical stock checking means the verification of actual quantity in stores. This checking should be done surprisingly or at random basis. If any discrepency is found, corrective actions should be taken to reduce or eliminate them. The possible reasons for discrepency may be wear and tear of materials, absorption of moisture, evaporation, waste, breakage, theft or wrong recordings. This is assumed to be the best method of inventory control. However, this method is applicable only for insignificant items on a regular basis or for all items in a big industry on a yearly basis.

5.12 INVENTORY CONTROL SYSTEMS

From the discussion uptill now, we can conclude that for the proper control of level of inventory, two issues are important :

(i) *Order quantity* : The issue here is how much to order of each material. This is also called "*Lot-size*" or "*Economic Order Quantity* (EOQ)".

(ii) *Order points* : The issue here is when to place the order. It is also called "*reorder point*".

Based on these two issues, there are two inventory control systems or approaches :

(1) Q-system (2) P-system

(1) Fixed Order Quantity System (Q-System) :

According to this system, inventory is continuously checked and a new order is placed when the level of inventory reaches a certain point, called the reorder point. In this system, the order quantity (Q) is always constant and the order is placed when the level of inventory reaches the reorder point. This system is also referred to as *reorder point sytem*. The quantity to be ordered is determined by demand and cost considerations.

The fixed order quantity system assumes that the demand for inventories over a period of time (*i.e.*, the usage rate of materials) is constant and the lead-time for replenishment of inventories is zero (*i.e.*, materials are received immediately after they are ordered). With the passage of time, the level of stock gets steadily depleted until it reaches the point R (reorder point) and then the order is placed for Q units and the stock reaches the initial level.

***Advantages* :**

(i) Each individual item can be purchased in its most EOQ.

(ii) Record of the current stock balance of each inventory item is maintained.

(iii) Helps in preparing the pattern of demand data

(iv) Most useful for low-valued inventory items. They can be ordered in large quantities without much managerial concern.

***Disadvantages* :**

(i) Requires continuous reviewing of item and maintenance of inventory balance records.

(ii) Each item is ordered at a different time. Therefore, economic advantages of bulk-buying is lost.

(iii) System becomes difficult to operate in case the prices of items and demand varies rapidly and continuously.

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The assumptions like no lead time, constant product demand, constant price per unit of product, constant ordering or set-up costs may not be applicable in real life situations. Thus, to improve the applicability of this system, firms adopt a more practical approach wherein the time between two successive orders is varied to accommodate the changes in demand.

(2) Fixed Order Period System (P-System)

In the fixed order period system, the order period is fixed, but the order quantity varies with the requirement. The quantity ordered each time depends on the current inventory level or inventory in hand and future inventory requirements. Here, orders are placed at equal intervals of time ($T_1 = T_2 = T_3$) and the quantity ordered during T_1 is different from the quantity ordered at T_2. The level of inventory in this system is counted during the review period. The order size is determined on the basis of available and required inventory level. As this system is based on periodic review of inventory level, the cost involved in constant review can be saved. But the system requires higher levels of safety stocks to tide over any unexpected demand variations.

Advantages :

(i) Eliminates a lot of clerical work since levels are checked periodically only.

(ii) Suitable for items that exhibit an irregular or seasonal variation.

(iii) Ordering cost is reduced when many items are purchased from the same source.

(iv) Most useful for high-valued inventory items. They are ordered in relatively small quantities but periodically.

Disadvantages :

(i) Periodic review of all items is required.

(ii) Leads to peak purchasing workload around the review dates.

(iii) Inventory carrying cost are higher as compared to Q-system because reserve stock maintained is usually higher in P-system as compared to Q-system.

5.13 INVENTORY CONTROL MODELS

Inventory control models can be classified as shown in fig. (3)

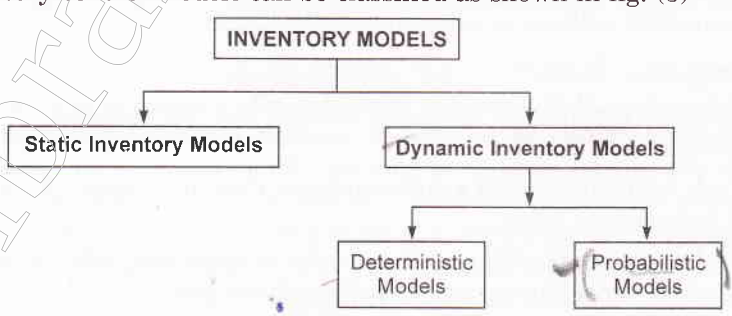

Fig. (3) Classification of Inventory Control Models

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[I] Static Inventory Models

These models are applicable in cases where only one order can be placed to meet the demand. Repeat orders are either impossible or too expensive. Typical examples of items under this group are persishable goods (like bread, vegetables, etc.) and seasonal products (like coolers, unbrellas, crackers, sweaters, rain coats, etc.)

[II] Dynamic Inventory Models

These models are applicable for items where repeat orders can be placed. Dynamic inventory models are further classified as :

(1) Deterministic models (2) Probabilistic models

(1) *Deterministic models* : These items are based on the assumption that the demand as well as lead-time of an item are known with certainty (*i.e.*, deterministic/can be determined). In these models, the stock is replenished as soon as the stock reaches the point of exhaustion because of the assumptions underlying them. Under such idealistic situations, there is no need to maintain any extra stock because the supplies are assumed to arrive the moment the stock level reduces to zero. Hence, there are no stock-outs unless they are intentionally allowed to occur.

The various assumptions in deterministic models are :

(i) The demand of the item is known exactly for a given period.

(ii) The demand of the item occurs uniformly over a period of time.

(iii) Orders are received instantaneously.

(iv) The item can be purchased freely, *i.e.*, there are no restrictions of any kind.

(v) The item has fairly long shelf life. There is no fear of deterioration or spoilage.

(vi) The cost of placing an order is fixed. It does not vary with the lot size.

(vii) The inventory carrying charges are directly proportional to the order quantity.

(viii) The price per unit is fixed and is independent of the order size.

(2) *Probabilistic models* : These models take into account the variations in demand and lead time of an item.

5.14 ECONOMIC ORDER QUANTITY (EOQ)

There is no single formula which can be used for the determination of EOQ due to different factors or conditions which play a major role in determining it. According to Newman, the most prevailing conditions lead to following three deterministic models :

(1) MODEL-I (Basic EOQ)

(2) MODEL-II (EOQ for LOTS)

(3) MODEL-III (EOQ with Quantity Discount)

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5.14-1 MODEL-I (BASIC EOQ)

This model for determination of EOQ is based on the following assumptions :

(i) Annual demand, carrying cost and ordering cost for a material can be estimated;

(ii) Average inventory level for a material is half of order quantity, i.e., there is no safety stock;

(iii) Stock-out, customer responsiveness and other cost have no effect; and

(iv) Quantity discount does not exist.

Let D = annual demand for a product

Q = quantity of product ordered each time.

C = cost of carrying one unit of inventory for one year (Rupees per unit per year)

S = average cost of completing an order for a product (Rupees per order).

Now,

(a) Annual Carrying Cost = Average Inventory Level × Carrying Cost

$$= \frac{Q}{2} \times C$$

(b) Annual Ordering Cost = Order per year × Ordering Cost

$$= \frac{D}{Q} \times S$$

(c) Total Annual Stocking Cost (TSC)

= Annual Carrying Cost + Annual Ordering Cost

$$= \left(\frac{Q}{2}\right)C + \left(\frac{D}{Q}\right)S$$

(d) To get the value of optimal quantity, the total stocking cost should be minimum, which can be possibles when

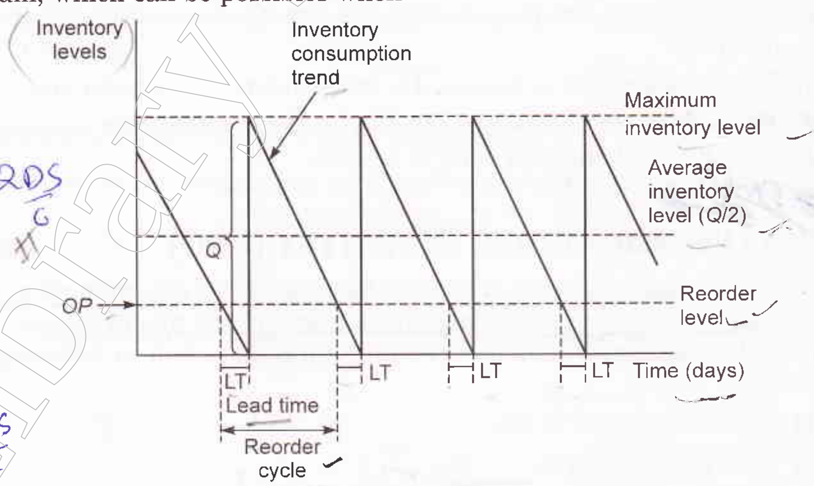

Fig. (4) Basic EOQ Model

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$$Q^2 = \frac{2DS}{C} \text{ or } Q = \sqrt{\frac{2DS}{C}} = EOQ$$

(e) Average Inventory Level $= \dfrac{\text{Maximum Inventory} + \text{Minimum Inventory}}{2}$

$$= (Q + 0)/2 = Q/2$$

Fig. (4) shows the basic economic order quantity model.

As shown in figure, an average inventory of $Q/2$ implies that there is no safety stocks; orders are received all at once; goods are used at a uniform rate and materials are entirely used up when the next order arrives. This is generally not possible in practice. Even if there is a minor deviation, $Q/2$ may still be a reasonable estimate of average inventory levels for some goods.

Example *Calculate EOQ if it is given that—annual usage = 60 units, procurement cost = Rs 15 per order, cost per piece = Rs 100 and cost of carrying inventory is 10%.*

Solution We know that $\text{EOQ} = Q = \sqrt{\dfrac{2DS}{C}}$

Here, $D = 60, S = 15, C = 100 \times (10/100) = 10$

Therefore, $\text{EOQ} = \sqrt{\dfrac{2 \times 60 \times 15}{10}} = 13.41 \cong$ **13 units**

5.14-2 MODEL-II (EOQ FOR LOTS)

This model is useful to determine the economic size of orders if a product is procured at one stage, stored as an inventory, and then transmitted to the customers. In other words, when the rate of flow of inventory is greater than the demand rate, this model is most appropriate for determining the size of lots. The major assumptions of this model are as follows :

Assumptions

(i) Annual demand, carrying cost, and ordering/procurement cost for a product/material can be estimated.

(ii) No safety stock is utilized, goods are supplied at a uniform rate (p) and used at a uniform rate (d), and goods entirely used up when the next order begins to arrive.

(iii) Stock-out, customer responsiveness, and other costs have no effect.

(iv) Quantity discounts do not exist.

(v) Supply rate (p) is greater than usage rate (d).

Let D = Annual demand for a product

Q = Quantity of the product ordered each time

C = Cost of carrying one unit of inventory for one year (Rupees per unit per year)

S = Average cost of completing an order for a product (Rupees per order).

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d = Rate of which units are used out of the inventory (Units per time period).

p = Rate at which units are supplied to inventory (Same units as d).

Now,

$(P-d) \times \frac{Q}{P}$

(a) Maximum inventory level

$$= \text{Inventory build up rate} \times \text{Period of delivery}$$

$$= (p-d)\,(Q/p)$$

(b) Minimum inventory level = 0

(c) Average inventory level

$$= \text{Maximum inventory level} + \text{minimum inventory level}$$

$$= \frac{(p-d)\left(\frac{Q}{p}\right)+0}{2} = \frac{Q}{2} \times \left[\frac{(p-d)}{p}\right]$$

(d) Annual carrying cost = Average inventory level × carrying cost

$$= \frac{Q}{2}\left[\frac{(p-d)}{p}\right]C$$

(e) Annual ordering cost = Orders per year × Ordering cost

$$= \frac{D}{Q} \times S$$

(f) Total Annual Stocking Cost (TSC)

$$= \text{Annual carrying cost} + \text{Annual ordering cost}$$

$$= \frac{Q}{2}\left(\frac{p-d}{p}\right)C + \frac{D}{Q}S$$

(g) To get the formula of optimal quantity, the total stocking cost should be minimum, which will be possible when

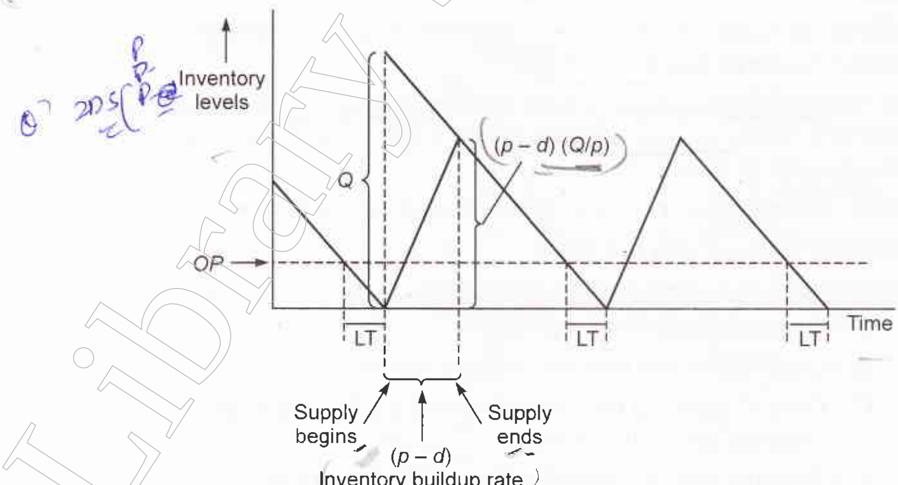

Fig. (5) EOQ for Lots Model

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$$Q^2 = \left(\frac{2DS}{C}\right)\left(\frac{p}{p-d}\right)$$

or

$$\text{EOQ} = Q = \sqrt{\left(\frac{2DS}{C}\right)\left(\frac{p}{p-d}\right)}$$

From the figure, it is observed that this model is only a slight modification of Model-I. The only point of difference in this model is that it is based on the assumption that procurement and supplies are at a uniform rate than they are in Model-I.

5.14-3 MODEL-III (EOQ WITH QUANTITY DISCOUNT)

Generally, when goods are procured or sold in bulk quantity, the prices in such cases are charged at a lower rate which is referred as quantity discount. This occurs because a larger order quantity may be less expensive to produce and sale. The most critical issue of the decision regarding buying large quantities is ordering enough material on each order to qualify for the best price possible, but not buying so much that carrying costs consume the saving in purchase costs. This is the main objective of this model. The quantity purchased does not necessarily have to be the EOQ amount as formulated from Model-I and Model-II. Rather, it is the quantity that minimizes the sum of annual carrying, ordering and acquisition costs.

Model-III uses either Model-I or Model-II formulae. When deliveries are made at once, then Model-I is used and when the deliveries are gradual, Model-II is applied. Feasible EOQ and the quantity at any price break with lower prices are most important factors to determine the optimum quantity.

Assumptions

(i) Annual demand, carrying cost, and ordering cost for a material can be estimated.

(ii) Average inventory levels can be estimated at either :

$Q/2$—if the assumptions of Model-I prevail : no safety stock, orders are received all at once, materials are used at a uniform rate, and materials are entirely used up when the next order arrives.

$Q/2\ [(p-d)/p]$—if the assumptions of Model-II prevail; no safety stock, materials are supplied at a uniform rate (p) and used at a uniform rate (d), and materials are entirely used up when the next order arrives.

(iii) Stock-out, customer responsiveness and other costs have no effect.

(iv) Quantity discounts do not exist. As larger quantities are ordered, price breaks, apply to all units ordered.

Now all the definitions in the previous models apply to Model-III. Additionally :

TMC = total annual material costs (Rupees per year)

ac = Acquisition cost of either purchasing or producing one unit of a material (Rupees per unit)

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Formulae

The EOQ and TSC formulae from either Model-I or Model-II are applied to Model-III, depending on which assumptions best fit the inventory situation.

Annual acquisition costs = Annual demand × Acquisition cost = $(D)_{ac}$

Total annual materials costs (TMC) = Total annual stocking costs + Annual acquisition cost

Dac +

= TSC + $(D)_{ac}$

Model-I	Model-II
Order Delivered All at One Time	Gradual Deliveries
EOQ = $\sqrt{2DS/C}$	EOQ = $\sqrt{(2DS/C)[p/(p-d)]}$
TMC = $(Q/2)\,C + (D/Q)\,S + (D)_{ac}$	TMC = $(Q/2)\,[(p-d)/p]\,C + (D/Q)\,S + (D)_{ac}$

(a) Compute the EOQ using each of the sales prices. Note that C is usually a function of sales price or production cost. For example, C may be defined as 20 per cent of sales price. Therefore, EOQ will change with C and ac.

(b) Determine which EOQ from Step 1 above is feasible. In other words, is the computed EOQ in the quantity range for its price?

(c) The total annual material cost (TMC) is computed for the feasible EOQ and the quantity at any price break with lower sales prices.

(d) The order quantity with the lowest total annual material cost (TMC) is the economic order quantity for the material.

The EOQ formulae, in the case of quantity discount, begins to build more realism into these models of analysis. Despite having some restrictive assumptions, Model-III is the most appropriate approach to inventory control.

***Determination of Reorder Point** (When to Order)?*

The re-order point refers to the timing at which the resupply process should be initiated. In other words, reorder point is the determination of the most appropriate timing for placing an order for the supply/procurement of goods/products. The basic reorder point formula can be derived under the assumption that demand and replenishment cycle time are known as well as predetermined and there is no buffer/safety stock.

Suppose, R = Reorder Point in Unit

D = Average Daily Demand

T = Average Replenishment Cycle time

Hence, $R = D \times T$

When the demand and replenishment cycle time is uncertain, then there is requirement of buffer/safety stock to meet requirements of a sudden increase in either the demand or the replenishment cycle time.

Suppose, safety stock is SS, then in this case,

$$R = D \times T + SS$$

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Example :

If $d = 5$ units per day, $T = 10$ days,

Then $R = 5 \times 10 = 50$ units.

i.e., order should be placed for the next replenishment when inventory level is 50 units.

5.14-4 LIMITATIONS OF EOQ MODELS

(1) *Erratic Usages :* The formulae we have used assume that the usage of materials is both predictable and evenly distributed. When this is not the case, the formulae are useless. Different and far more complex formulae can be developed for wide swings in usage, so long as these swings can be predicted. But if usage varies unpredictably, as it often does, no formula will work well.

(2) *Faulty-Basic Information :* EOQ calculations are only as accurate as the order cost and carrying cost information on which they are based. It is not an easy job to calculate order cost. In practice, order cost varies from commodity to commodity. Carrying cost can vary with the company's opportunity cost of capital.

(3) *Costly Calculations :* It is not an easy job to estimate the cost of acquisition and cost of possession accurately. This requires hours of work by skilled cost accountants. Actual calculation of EOQ can be time-consuming even when the simple formulae for steady usage are used. More elaborate formulas are even more expensive. In many cases, the cost of estimating cost of possession and acquisition and calculating EOQ exceeds the savings made by buying that quantity.

(4) *No Formula Substitute for Commonsense :* Therefore, it is desirable to include a number of modifiers. The formula may suggest that, we order six years supply, based on the assumption that we will continue to require the item at the same rate for the next six years. The modifier is a maximum'limit, not more than one year's supply or two year's supply. The formula may suggest that we order every week, and for these volumes we would adopt a different ordering method.

(5) EOQ *Ordering must be Tempered with Judgment :* Certain corporate operating goals must be followed in managing an inventory. Sometimes, the guidelines provide a conflict in ordering. Where an order strategy conflicts with an operating goal, order strategy restrictions should be developed to permit honoring the goal. EOQ restrictions might include the following :

(i) Items purchased to order, and items subject to rapid product improvement will be restricted from EOQ use.

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(ii) Shelf life items (those goods having only a specific life time) should be restricted to a quantity, not greater than one fourth of their age limitation.

(iii) Items with unusual sales will be identified, with annual sales reduced by appropriate quantities, prior to calculating EOQ.

(iv) Critical supply items (those having most effect on customer's service), will be ordered in greater than normal quantities. The time of supply of quantities selected will over-ride EOQ.

5.15 INVENTORY CONTROL TECHNIQUES

Inventory control techniques are employed by the inventory control organization within the framework of one of the basic inventory systems, viz., fixed order quantity system or fixed order period system. Inventory control techniques represent the operational aspect of inventory control management and help realize the objectives of inventory management and control.

Several techniques of inventory control are in use and it depends on the convenience of the firm to adopt any of the techniques. The techniques most commonly used are :

(1) ABC (Always Better Control) analysis
(2) SDE (Scarce, Difficult, Easy to obtain) analysis
(3) VED (Vital, Essential, Desirable) analysis
(4) HML (High, Medium, Low) analysis
(5) FSN (Fast moving, Slow moving, Non-moving) analysis
(6) SOS (Seasonal, Off-Seasonal) analysis
(7) XYZ analysis

2

5.15-1 ABC ANALYSIS

Where there are a large number of items in the inventory, it becomes essential to have an efficient control over all items of stores. However, comparatively, greater care should be given to items of higher value. The movement of certain manufacturing firms may consist of a small number of items representing a major portion of inventory value and a large number of items may represent a minor portion of inventory value. In such cases, a selective approach for inventory control should be followed.

Under A-B-C analysis, the materials are divided into three categories *viz.*, A, B and C. Past experience has shown that almost 10% of the items contributes to 70% of value consumption and this category is called 'A' category. About 20% of the items contribute to about 20% of value of consumption and this is known as category 'B' materials. Category 'C' covers about 70% of items of materials, which contribute only 10% of value of consumption. There may be some variation in different organizations and an adjustment can be made in these percentages.

The information is shown in fig. (6) :

Class	Number of Items (%)	Value of Items (%)
A	10	70
B	20	20
C	70	10

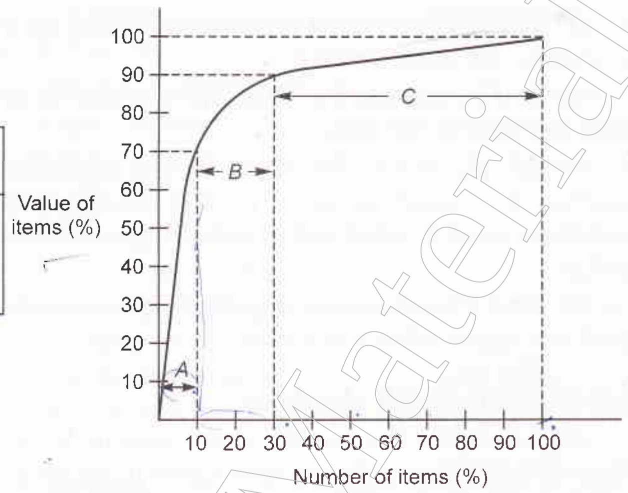

Fig. (6) A-B-C Analysis

A-B-C analysis helps to concentrate more efforts on category A since greatest monetary advantage will come by controlling these items. An attention should be paid in estimating requirements, purchasing, maintaining safety stocks and properly storing of 'A' category materials. These items are kept under a constant review so that a substantial material cost may be controlled. The control of 'C' items may be relaxed and these stocks may be purchased for the year. A little more attention should be given towards 'B' category items and their purchase should be undertaken at quarterly or half-yearly intervals.

Steps followed in ABC analysis

No definite procedure can be laid down for classifying the inventories into A, B and C categories. This will depend upon a number of factors such as nature and varieties of items, specific requirements of the business, place of items in the production, etc. These factors vary from business to business and item to item. However, following procedure can be followed :

(i) First, the quantity of each material expected to be used in a given period should be estimated.

(ii) Secondly, the money value of the items of materials, so chosen, should be calculated by multiplying the quantity of each item with the price.

(iii) Thirdly, the items should be rearranged in the descending order of their value irrespective of their quantities.

(iv) Fourthly, a running total of all the values and items should be taken. The figure so obtained should be converted into percentage of the gross total.

(v) It is possible that we will find that a small number of few items may amount to a large percentage of the total value of the items. The management, then, will have to take a decision as to percentage of the total value or the total number of items which have to be covered by A, B and C categories.

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The following points should be kept in mind for ABC analysis :

(1) Where items can be substituted for each other, they should be preferably treated as one item.

(2) More emphasis should be given to the value of consumption and not to price per unit of the item.

(3) All the items consumed by an organization should be considered together for classifying as A, B or C instead of taking them as spares, raw materials, semi-finished and finished items and then classifying them as A, B and C.

(4) There can be more than three classes and the period of consumption need not necessarily be one year.

Applications of ABC Analysis

ABC analysis can be effectively used in Inventory Control and Material Management. The various stages where it can be applied are :

(1) Information of items which require higher degree of control.

(2) To evolve useful re-ordering strategy.

(3) Stock records.

(4) Priority treatment to different items.

(5) Determination of safety stock items.

(6) Stores layout.

(7) Value analysis.

Benefits of ABC Analysis

The success of a company depends upon how well it improves its efficiency in terms of materials efficiency. ABC analysis enables the management to improve its materials efficiency by applying the following eight methods :

(1) *Level of Control :* 'A' items account for about 70 per cent of the annual usage value and merit maximum attention. A manager should be entrusted with taking good care of 'A' items. Good record-keeping and the application of scientific methods of inventory control such as EOQ formula application, staggered deliveries are needed for category 'A' items.

'C' items do not demand any control, except avoidance of their pilferage. They can be suitably placed in stock rooms.

(2) *Gradual Delivery of Material :* Staggering of delivery lowers the inventory level and blocked capital.

(3) *Careful Accounting :* Detailed records of goods ordered, received, issued and goods on hand should be maintained for 'A' category of items. Tight control and accurate records are also required for scrap, loss and rejection of such items. No such detailed records are necessary for C category items.

(4) *Safety Stock :* Safety stock is kept by inventory controllers to take care of variation in demand, particularly during larger lead time. This is a must

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for 'A' as well as 'B' and 'C' category items used in producing an assembled product. The purpose of keeping safety stock is to increase inventory level of items of A, B and C caterogy if they have larger lead-time.

(5) *Quantity Discount Factor :* Clever suppliers may offer quantity discount on the purchase of category A items. The inventory controller should verify through calculation if there is really some real gain or that the discount is just an eyewash.

(6) *Layout of Stores :* Ready accessibility of fast-moving items is a virtue of a good layout. 'A' category items are high cost items with a fast consumption and categorized under F (Fast) as well as H (High cost) category. A good layout enables tracking and avoids misplacement of such items. Most of the 'C' items can be put in the less accessible areas, except those few which might have fallen in 'C' category, because of their low unit price and not because of their low consumption.

(7) *Stock-taking :* Management by exception should be applied to stock taking also. 'A' items may be checked more often than 'C' items. One of the decisions could be to check 'A' items every month, 'B' items every two months and 'C' items every four months.

(8) *Value Analysis Projects :* It is futile to carry out value analysis for 'B' and 'C' category items. Value analysis is a cost reduction project. To secure maximum benefits, it is essential to select those items for value analysis which offer the highest scope for cost reduction.

Limitations of ABC Analysis

(1) In big industries, the items are in thousands. Hence the listing and calculation is a bit difficult.

(2) The analysis takes care of annual consumption values and hence importance of items is not taken care of.

(3) Price factor, fluctuations, seasonal variations in prices and consumption pattern is not taken care of.

(4) There could be excess stock of C-category items leading to deterioration, obsolescence.

(5) Some B-category items could be vital. Hence they need more attention.

5.15-2 SDE ANALYSIS

SDE analysis takes into account various purchasing problems. The various purchasing problems may be non-availability, scarcity, long lead time, unreliable supply sources, etc. This analysis uses the criterion of the availability of items. In this analysis,

S stands for *Scarce items* which are in short supply,

D refers to the *Difficult items*–meaning that the items might be available in the indigenous market but cannot be procured easily, E represents *Easily available items* from the local markets.

This analysis helps in inventory control by the formulation of purchase policies. For scarce materials, forward purchasing policies; for difficult materials, schedule purchasing policies and; for easy materials, contract purchasing policies are commonly adopted.

5.15-3 VED ANALYSIS

In VED analysis, the items are classified on the basis of their criticality to the production process or other services. In the VED classification of materials, V stands for *Vital items* without which the production process would come to a standstill. E in the system denotes *Essential items* whose stock out would adversely affect the efficiency of the production system. Although the system would not altogether stop for want of these items, yet their non-availability might cause temporary losses in, or dislocation, of production. The D items are the *Desirable items* which are required but do not immediately cause a loss of production.

The VED analysis is done mainly in respect of spare parts.

Steps in VED Analysis

(1) Analyze and identify the factors to be reckoned for VED analysis. The commonly considered factors are effect on production, *i.e.*, penalty cost due to non-availability, delivery lead time, nature of the item (customize or standard) and sources of supply, *i.e.*, whether easy to get or hard to get.

(2) Assign points or weight to the factors according to their importance to the company. Typical examples of the weight to the above four factors may be 30, 30, 20 and 20 points. These values are more or less standardized.

(3) Divide each factor into three categories and allocate points to each category. Usually, the first category is asigned points equal to the weight of its factor, the second degree is allocated points equal to twice the weight of the factor and the third degree is assigned points equal to thrice the weight of the factor.

(4) Prepare categorization plan which provides the basis of classification of items into vital, essential and desirable categories.

(5) Evaluate items one by one against each factor and assign points to the item, depending upon the extent of presence of the factor in the item.

(6) Place the items into V, E and D categories, depending upon the points secored by them and the basis of classification set under step (4).

5.15-4 ABC-VED MATRIX

The ABC-VED matrix is a hybrid model where in every category (A, B and C) of items is further classified into three sub-categories (V, E and D). In this way an in-depth consideration and due recognization can be given to various items for their inventory control.

Table-I shows an ABC-VED matrix sample.

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Table-I

ABC Classification	VED Classification		
	V	E	D
A	Constant control; Regular follow-up, Low stocks and ordering more frequent	Average stock; No risk of stock outs	No stock.
B	Moderate stocks; No risk of stock outs	Average stock; Some risk can be taken	Very low stock; Some risk can be taken.
C	High stocks. Restricted orders. No risk.	Average stock; Some risk can be taken	Low Stock; Some risk can be taken.

Fig. (7) shows the principles of ABC-VED matrix

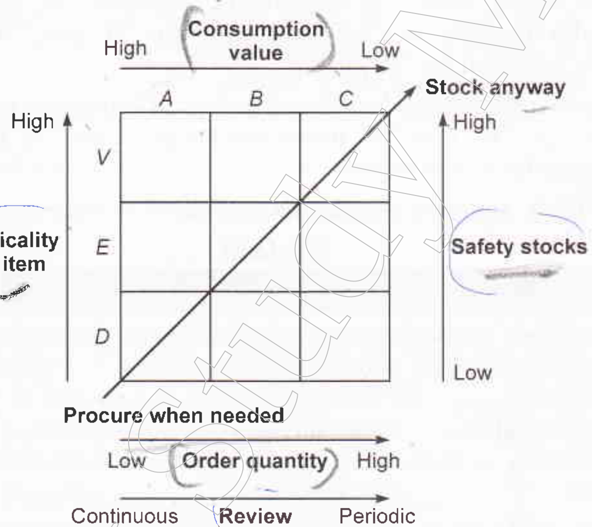

Fig. (7) Principles of ABC-VED Matrix

5.15-5 HML ANALYSIS

This is similar to the ABC analysis except that, in the analysis, the items are classified on the basis of unit cost rather than their usage value.

The items are classified accordingly, as their cost per unit is,

H-High,

M-Medium, or

L-Low

This type of analysis is useful for keeping control over materials consumption at the departmental level. For example, the management may determine that all items of the unit value above Rs. 2000 will be H items, between Rs. 500 and Rs. 2000 will be M items and those below Rs. 500 will be L

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items. On this basis the management may delegate authorities to various subordinate officers to buy petty cash items. The management may also decide that items of unit value above Rs. 20,000 will only be sanctioned by the General Manager.

Benefits of HML Analysis

HML analysis helps to :

(1) Estimate storage and security requirements, *e.g.*, high-priced items such as bearings, gears, cranks, etc., require to be kept in almirahs.

(2) Keep control over consumption at the departmental head level, *e.g.*, order and issue of high-and medium-priced items are authorized only by the departmental head after a cautious study of the consumption figures.

(3) Estimate the schedule of stock verification, *e.g.*, high-priced items are checked more frequently than low-priced items.

(4) Evolve buying strategies to control purchases, *e.g.*, excess supply than the order quantity may not be accepted for "H" and "M" groups while it may be accepted for "L" group.

(5) Delegate authorities to different cadres of buyers as per their seniority status, *e.g.*, "H" and "M" items may be purchased by senior buyers and "L" items by junior buyers.

VED and HML analysis can also be combined as shown in table II.

Table-II

	V	E	D
H	High price vital items must be available in the store.	High price essential items may be ordered frequently.	High price desirable may be economically ordered.
M	Medium price vital items whose availability in the store is must.	Medium price essential items always available in the store.	Medium price desirable ordered once or twice in a year.
L	Low price vital items availability assured.	Low price essential items stored in large number.	Low price desirable items ordered once in a year.

5.15-6 FSN ANALYSIS

Based on the consumption pattern of the items, the FSN classification of items is

F-Fast-moving,

S-Slow-moving, and

N-Non-moving

Some analysts classify the items an FSND; Fast moving, Normal-moving, Slow-moving, and Dead (or non-moving). This 'speed' classification helps in the arrangement of stocks in the stores and in determining the distribution and handling patterns. When analysis is carried out on the basis of the rate of movement of materials in stores or on the basis of consumption pattern of components, it is known as the FSN analysis. The classification comes in very handy when it is necessary to control obsolescence. The demand for fast moving items is generally high. Thus, special care should be taken in respect of these items; otherwise, the production may be interrupted due to the shortage of such materials. Inventories which have only a low turnover are brought under the category of slow-moving items. These items are not issued at frequent intervals.

The items with almost nil consumption are brought under the category of non-moving items. All obsolete inventories constitute this category. These may be several reasons for bringing an item into the Non-moving category, *e.g.*, there might have been a change in technology or change in the specification of a particular spare part or the item might no longer be in use.

Stores department which is concerned with the moving of items would like to know and classify the items in the categories F-S-N so that they can manage, operate and plan stores activity accordingly. For example, for efficient operations it would be necessary that fast moving items should be stored as near as possible to the point of issue so that it can be issued with minimum of handling. Also such items must be stored at the floor level avoiding storing them at high heights. Similarly, if the items are slow moving or issued once in a while in a given period of time, they can be stored in the interior of the stores and even at the higher heights because handling of these items becomes very rare.

5.15-7 SOS ANALYSIS

SOS analysis is based on the nature of supplies, where in,

S represents the *Seasonal items* and

OS represents the *Off-Seasonal items*.

This classification of items is done with the aim of determining proper procurement strategies. The SOS analysis is made on the basis of the nature of supplies. As such it classifies the items into two groups—S (seasonal) and OS (Off-Seasonal). The analysis identifies items into :

(i) Seasonal, but available only for a limited period,

(ii) Seasonal but available throughout the year, and

(iii) Off-seasonal items whose quantity is determined on different considerations.

The seasonal items which are available only for a limited period should be produced and stocked for meeting the needs of the full year. The agriculture produce like raw mangoes, raw materials for cigarette and paper industries, etc. are examples of such items. The prices of the seasonal items which are available throughout the year are generally less during the harvest season. The quantity required of such items should, therefore, be determined after comparing the cost savings on account of lower prices, if purchased during season, with the higher cost of carrying inventories to that if purchased throughout the year. The quantity required of off-seasonal items are required to be decided on different considerations.

5.15-8 XYZ ANALYSIS

XYZ analysis is based on the closing inventory value of different items.

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Items,

Whose inventory values are high, are classed as *X items*.

Those with low investment in them are termed as *Z items*.

Other items are the *Y items* whose inventory value is neither too-high nor too-low.

It can be easily visualized that the various types of analysis discussed are not mutually exclusive. They can be and often are, used jointly to ensure better control over materials. For example, ABC and XYZ analysis may be combined to classify and control depending on whether the items are AX, BY, CZ, AY... and so on.

5.15-8 SUMMARY OF INVENTORY CONTROL TECHNIQUES

S. No.	Technique	Basis	Main Use
1.	ABC (Always Better Control)	Value of conception	To control raw material, components and work-in-progress inventories in the normal course of business.
2.	SDE (Scarce, Difficult, Easy to obtain)	Problems faced in procurement	Lead-time analysis and purchasing strategies
3.	VED (Vital, Essential, Desirable)	Criticality of the component	To determine the stocking levels of spare parts.
4.	HML (High, Medium, Low)	Unit price of the material	Mainly to control purchases.
5.	FSN (Fast moving, Slow moving, Non-moving)	Consumption pattern of the components	To control obsolescence.
6.	SOS (Seasonal, Off-Seasonal)	Nature of supplies	Procurement/holding strategies for seasonal items like agricultural products.
7.	XYZ	Value of the items in storage	To review the inventories and their uses at scheduled intervals.

5.16 MATERIAL REQUIREMENT PLANNING (MRP)

MRP is an inventory control system that determines how much of each material should be purchased or produced in each time period to support the master production schedule (MPS). The purpose of MRP is to ensure that materials and components are available in the right quantities and at the right time so that finished products can be completed according to the master production schedule. It is often considered to be a subset of inventory control because it minimizes unnecessary inventory costs. MRP is also useful in production scheduling and purchasing of materials.

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Manufacturers are now using MRP more frequently because they want to reduce inventory levels, increase production capacity, and enhance profit. Material requirement planning begins with the principle that many materials held in an inventory have dependent demands. Dependent demand is the result of the requirements generated for their use in the production of other items, as in the case of raw materials, parts, etc., used in the manufacturing of a finished product, *e.g.*, two wheels are required for the manufacturing of one bike. Thus, demand for wheels are dependent to the demand of bike.

In manufacturing organizations, there is requirement of a variety of dependent demand items to facilitate manufacturing of the finished product. So, proper inventory management of those dependent demand items is critical for the smooth flow of total production system. MRP is, by necessity, a computer-based system which is designed to :

(i) release production and purchase orders to regulate the flow of raw materials, in-process inventories necessary to meet the production schedules for finished goods;

(ii) ensure availability of materials, components and products for planned production and customer delivery; and

(iii) maintain minimum levels of dependent demand items.

MRP enables an organization to develop and implement realistic plans for meeting delivery schedules of dependent items by proper timing of order placement.

Objectives

The major objectives of MRP are :

(1) *Improve Customer Service :* MRP ensures not only timely delivery of goods to customers as per delivery committment, but it also brings the replenishment-cycle time down by the proper implementation of information system.

(2) *Reduce Inventory Costs :* MRP brings better control of quality, quantity and timing of deliveries of raw materials, components, sub-assemblies, assemblies to production operation with flexibility resulting into considerable reduction in inventory cost.

(3) *Enhancing Operating Efficiency :* MRP improves efficiency by means of :

- reduced number of stock-outs and delivery delays, resulting into more production without increase in the number of employees and machines;
- reduction of sub-standard products due to use of quality-ensured inputs;
- efficient movement of goods leads to decreased idle time and confusion.

The chief benefit of MRP system is that production operation works on those parts that are really needed on their due dates so that production capacity is being used to directly support the master production schedule.

Elements of MRP

The operation of MRP system consists of various elements, which are shown in Fig. (8) in terms of inputs MRP computer programme, and outputs. Master

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production schedule (MPS) is the driver of the entire MRP system. Apart from the MPS, other input informations are provided by the inventory status file, bills of material file. These input informations are fed into the MRP computer programme, which after processing and manipulation, generates the outputs in the form planned order release coupled with exception, performance and planning reports for the use of management.

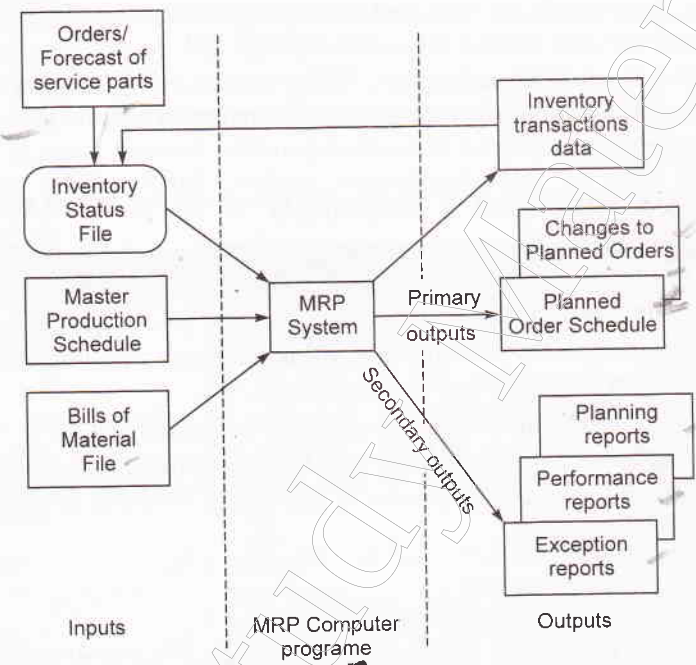

Fig. (8) The MRP System

Master Production Schedule (MPS)

A master production schedule (MPS) is devised to either replenish finished good inventories or to fill customer orders. It is a schedule of the number and timing of all end items to be produced in a manufacturing plant over a specific planning horizon. MRP explodes the master schedule in the material

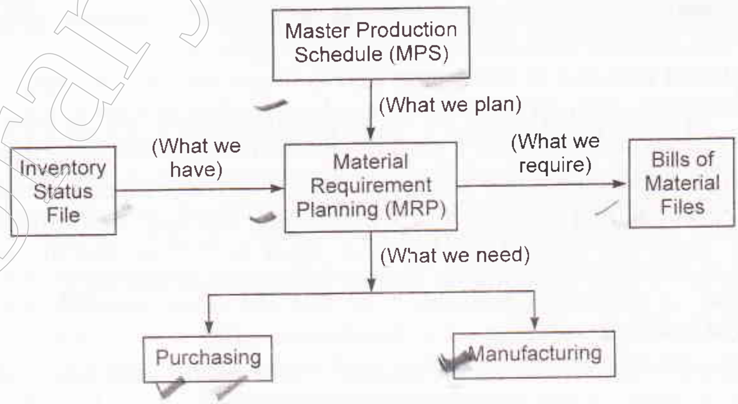

Fig. (9) MPS system

requirements. If these requirements cannot be met by the materials available from inventory or from materials in order, or if insufficient time is available for new orders, then the MRS will need to be modified to a new MPS. The flow chart of MPS system is shown in the Fig. (9).

Bills of Material File

Another major input element of MRP system is the Bills of Material file. A bills of material file is a computerized file containing a complete list of materials along with their quantity and specification required in the production of one unit of a finished product. Therefore, each material such as assemblies, sub-assemblies, parts and raw materials has a bill of material, which is regularly updated if there is any redesign of the product.

For the smooth application of MRP system, an accurate bills of material files is a prerequisite, stating the product structure records coupled with specification and quantity requirement of each material.

Inventory Status File

An inventory status file is a computerized file containing a complete record of each material held in inventory. A material record includes the low-level coding, on-hand balance, open orders, lot sizes, lead times, safety stock, and customer order for the item. These records are kept up to date by inventory transactions such as receipts, disbursements, scrapped materials, planned orders, and order releases.

MRP Computer Program

The MRP computer program operates in the following manner :

(1) First, with the MRS, it begins to determine the number of end items needed in each time period. Time periods are sometimes called *buckets* in MRP terminology.

(2) Next, the number of service parts not included in the MPS but deduced from customer orders are included as end items.

(3) Next, the MPS and service parts are exploded into gross requirements for all materials by the time period into the future by consulting the bills of material file.

(4) Next, the gross materials requirements are modified by the amount of materials on hand and on order for each period by consulting the inventory status file. The net requirements of each material for each; bucket are computed as follows :

$$\begin{matrix}\text{Net}\\ \text{requirements}\end{matrix} = \begin{matrix}\text{Gross}\\ \text{requirements}\end{matrix} - \left[\begin{matrix}\text{Inventory}\\ \text{on hand}\end{matrix} - \begin{matrix}\text{Safety}\\ \text{stock}\end{matrix} - \begin{matrix}\text{inventory allocated}\\ \text{to other uses}\end{matrix}\right]$$

If the net requirements are greater than zero, orders for the material must be placed.

(5) Finally, the orders are offset to earlier time periods in order to allow for lead times at each step in the production process and supplier lead times.

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This procedure results in inventory transactions data (orders released, changes in orders, and so on), which are used to update the inventory status file, the primary output reports, and secondary output reports.

MRP Output Reports

The outputs of MRP systems dynamically provide the schedule of materials for the future—amount of each material required in each time period to support the MPS.

(a) ***Primary Outputs :*** Two primary outputs result in :

(1) *Planned Order Schedule :* This is a plan of the quantity of each material to be ordered in each time period. This schedule is used by purchasing department to place orders with suppliers and by production department to order parts, sub-assemblies, or assemblies from upstream production departments. The planned orders become a guide for future production at the suppliers and for in-house production schedules.

(2) *Changes in Planned Orders :* This is a modification of previous planned orders. Quantities of orders can be changed, orders can be cancelled, or the orders can be dealyed or advanced to different time periods through the updating process.

(b) ***Secondary Outputs :*** The secondary MRP outputs provide this information :

(1) *Exception Reports :* They report the flag items requiring management attention in order to provide the right quantity of materials in each time period. Typical exceptions noted are reporting errors, late orders, and excessive scrap.

(2) *Performance Reports :* These reports indicate how well the system is operating. Example of performance measures utilized are inventory turns, percentage of delivery promises kept, and stock-out incidences.

(3) *Planning Reports :* These reports are to be used in future inventory-planning activities. Examples of such planning information are inventory forecasts, purchase commitment reports, trace to demand sources (pegging), and long-range material requirements planning.

Benefits of MRP

MRP system takes the master schedule for the production of end item and calculates the requirements of dependent items for the production of those end items. As already explained, for the execution of the overall material plans, certain materials are procured from the suppliers and other are produced in house. MRP combines product explosion, lot sizing, timing of purchase and other operations into one coordinated procedure so as to calculate material requirements on real-time basis. Thus, MRP is a valuable tool for :

- inventory control;
- scheduling for setting of priorities; and
- determining MPS capacity flexibility.

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5.17 INVENTORY CONTROL IN INDIA

All the well-known inventory control techniques have a basic assumption; "free availability of materials" as and when required in any quantity. However, this is not true for Indian conditions. We operate in a seller's market for most of the materials. There is a perpetual scarcity of key raw materials and the prices fluctuate widely. However, the techniques should not be discarded but used judiciously as a broad guideline, keeping in mind their limitations.

The Indian industry tends to stress a lot on production and machine utilisation—this focus of attention in the context of scarcity of materials leads to hoarding of stocks. The inflation that prevails in the country, prompts hoarding.

In view of the shortage of foreign exchange, strict import procedures are enforced. The time taken for import clearance is high and the inventory of imported materials is therefore usually very high.

In its initial stage of industrial development, the country relied solely on foreign collaboration. Machinery and spare parts were readily imported. The lack of technological knowledge made the country rely on the collaborators for the estimation of the requirements of spare parts. This stock of spares is abnormally high. It is extremely evident that these spares are useless and should be written off. However, for financial reasons they continue to exist on inventory records.

Inventory control systems are built on the foundation laid by materials management techniques such as ABC-VED analysis, standardisation and codification. Setting up an inventory control system without the pre-use of these techniques is a must. The importance of ABC-VED analysis is brought out in the light of the inability to measure precise costs on the basis of which inventory levels could be set. Standardisation and Codification help in variety reduction and make inventory control purposeful.

Inventories, built to act as a cushion between supply and demand, serve the following needs; it is sufficient to take care of the requirements of demand till the next supply arrives, it is sufficient to take care of probable delays in supply as well as probable variations in demand.

The problems that need to be tackled are; the determination of the level of inventory for placing a replenishment order, the quantity to be ordered, the amount of delay in supplies and the amount of variations in demand which the inventory should be able to withstand. The problems can be resolved by the cost implications.

REVIEW QUestions

1. Define and explain the meaning of inventory and inventory control. Giving examples, explain the concept of inventory as applicable to service organisations.
2. What is the importance of inventory control?
3. How are inventories classified? Describe in brief.

4. Explain the following types of inventories describing their respective advantages.
   (a) Theoretical inventory (b) Cycle inventory.
   (b) Seasonal inventory (d) Safety inventory
   (c) Speculative inventory
5. How does uncertainty in demand and lead time affect inventory levels?
6. What are the various factors responsible for maintaining optimum level of inventory?
7. What are the various advantages and disadvantages of holding inventory?
8. What factors are essentials for a good inventory control system?
9. What are the prominent costs associated with inventory?
10. What are the various elements of inventory cost?
11. Justify the statement that "*Best buying results when annual procurement cost equals annual inventory carrying cost*".
12. Describe the complete process of inventory control.
13. Name the various inventory control systems. Explain any two of them with their advantages and disadvantages.
14. What are the main systems of inventory control recommended for a very large manufacturing organisation?
15. What do you understand by deterministic inventory control models? What are the various assumptions in deterministic models of inventory control?
16. What is Economic Order Quantity (EOQ)? Derive the formula for determining EOQ.
17. What are the various models for determination of EOQ?
18. What are the various limitations of EOQ models?
19. What is ABC analysis? Is it applicable in all cases?
20. Explain ABC, HML and VED analysis for inventory control.
21. What is Material Requirement Planning (MRP)? What is its purpose?
22. Define the concept and objectives of MRP.
23. Discuss the MRP system in the context of a large heavy commercial vehicle manufacturing company.
24. Describe the various inputs and outputs of MRP system.
25. What are the various peculiarities associated with inventory control in India?
26. Write short notes on :
   (a) Functional purposes of inventory
   (b) Reorder point (c) EOQ model for lots
   (d) ABC-VED matrix (e) SOS analysis
   (f) XYZ analysis

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6 SUPPLY CHAIN MANAGEMENT (SCM)

Learning Objectives

After reading this chapter, you will understand :

- Meaning and definition of supply chain and supply chain management
- Process views of a supply chain
- Issues involved in SCM
- Value chain
- Elements of SCM
- Prerequisites for SCM
- Components of SCM
- Process of SCM
- Functions of SCM
- Performance measures for SCM
- Just-in-Time (JIT) philosophy
- Kanban System

6.1 SUPPLY CHAIN

A *supply chain* consists of all parties involved in fulfilling a customer request or demand. Note that these parties may be directly or indirectly involved in supplying the product or service. Hence, the supply chain includes not only the manufacturers and suppliers but also transporters, warehouses, retailers and even customers themselves. For any organization, the supply chain includes all functions involved in receiving and filling a customer request.

A supply chain is a network of supplier, manufacturing, assembly, distribution and logistics facilities that perform the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these products to customers. All organizations have supply chains of varying degrees, depending upon the size of the organization and the type of product manufactured. These networks obtain supplies and components, change these materials into finished products and then distribute them to the customer. As already mentioned supply chains arise in both manufacturing and service organizations.

The Supply Chain (SC) encompasses all activities associated with the flow and transformation of goods from the raw materials stage (extraction), through to the end user, as well as the associated information flows. Materials and information flow both up and down the supply chain. A typical supply chain may involve a variety of stages such as customers, retailers, wholesalers or distributors, manufacturers, raw material suppliers, transporters, etc. The supply chain is gaining prominence as manufacturer's control less of the speed at which products are manufactured and distributed. The main reasons for decreasing manufacturing control are the parity across the board in product quality and price wars arising with the emergence of global competition.

Goals of a Supply Chain

The goal of a supply chain should be to maximize overall supply chain profitability. Supply chain profitability is the difference between the revenue generated from the customer and the total cost incurred across all stages of the supply chain. Supply chain decisions have a large impact on the success or failure of each firm because they significantly influence both the revenue generated and the cost incurred. Successful supply chains manage flows of product, information, and funds to provide a high level of product availability to the customer while keeping costs low. The performance of supply chain can directly create an impact on the productivity and profitability of the company.

Decision phases in supply chain

Depending on the time period during which they apply, supply chain decisions may be characterized as :

(i) Strategic (design), (ii) Planning, (iii) Operational

(1) *Strategic decisions* relate to supply chain configuration. These decisions have a long-term impact lasting several years.

Strategic decisions made by companies includes,

(i) The location and capacities of production and warehousing facilities,
(ii) The products to be manufactured or stored at various locations.
(iii) The modes of transportation to be made available along different shipping legs, and
(iv) The type of information system to be utilized.

(2) *Planning decisions* cover a period of a few months to a year and include decisions such as production plans, subcontracting, and promotions over that period.

Planning Decisions includes,

(i) Decisions regarding which markets will be supplied from which locations,
(ii) The subcontracting of manufacturing,
(iii) The inventory policies to be followed, and
(iv) The timing and size of marketing promotions.

(3) *Operational decisions* span from minutes to days and include sequencing production and filling specific orders.

Operation decisions include,

(i) Firms allocate inventory or production to individual orders,

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(ii) Set a date that an order is to be filled,

(iii) Generate pick lists at a warehouse,

(iv) Allocate an order to a particular shipping mode and shipment,

(v) Set delivery schedules of trucks, and

(vi) Place replenishment orders.

Because operational decisions are being made in the short term (minutes, hours, or days), there is less uncertainty about demand information. Given the constraints established by the configuration and planning policies, the goal during the operation phase is to exploit the reduction of uncertainty and optimize performance.

Note that Strategic decisions define the constraints for planning decisions and planning decisions define the constraints for operational decisions.

6.2 PROCESS VIEWS OF A SUPPLY CHAIN

A supply chain is a sequence of processes and flows that take place within and between different stages. These processes and flows combine to fill a customer need for a product. There are two different ways to view the processes performed in a supply chain :

(1) Cycle view of supply chain processes.

(2) Push/pull view of supply chain processes.

[I] Cycle View

A cycle view of a supply chain divides processes into cycles, each performed at the interface between two successive stages of a supply chain. Each cycle starts with an order placed by one stage of the supply chain and ends when the order is received from the supplier stage. The processes in a supply chain are divided into a series of cycles, each performed at the interface between two successive stages of a supply chain.

All supply chain processes can be broken down into the following four process cycles, as shown in fig. (1) :

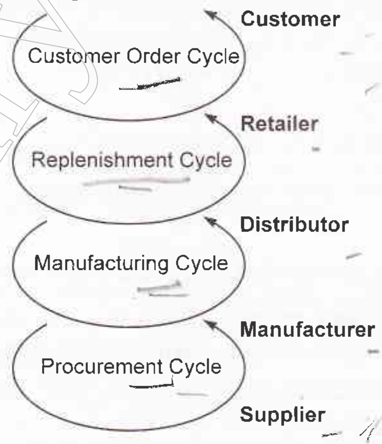

Fig. (1) Supply Chain Process Cycles

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- Customer order cycle
- Replenishment cycle
- Manufacturing cycle
- Procurement cycle

A cycle view of the supply chain clearly defines the processes involved and the owners of each process. This view is very useful when considering operational decisions because it specifies the roles and responsibilities of each member of the supply chain and the desired outcome for each process.

[II] Push/pull view

A push/pull view of a supply chain characterizes processes based on their timing relative to that of a customer order.

Push processes are performed in anticipation of customer's order/s. At the time of execution of a push process, demand is not known and must be forecast. Therefore, push processes are also referred to as *speculative processes* because they respond to speculated (or forecasted) rather than actual demand. Push processes operate in an uncertain environment because customer demand is not yet known.

Pull processes are performed in response to a customer order. At the time of execution of a pull process, customer demand is known with certainty. They are also referred to as *reactive process* because they react to customer's demand. Pull processes operate in an environment in which customer demand is known. However, they are often constrained by inventory and capacity decisions that were made in the push phase.

The push/pull boundary in a supply chain separates push processes from pull processes as shown in fig. (2).

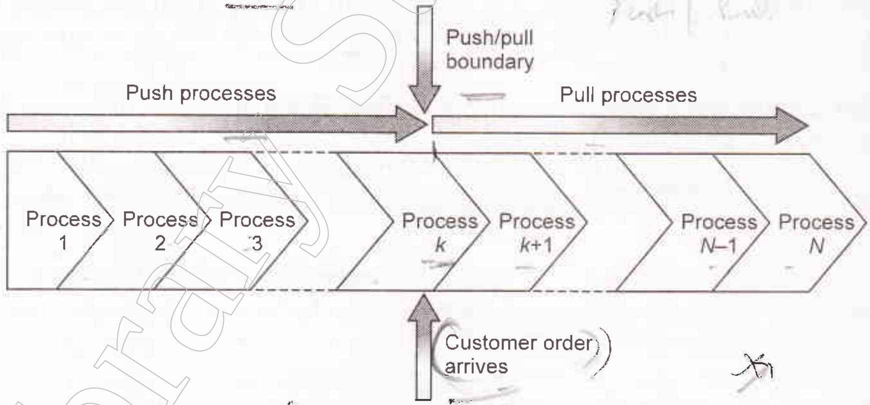

Fig. (2) Push/Pull view of the supply chain

A push/pull view of the supply chain is very useful when considering strategic decisions relating to supply chain design. The goal is to identify and appropriate push/pull boundary such that the supply chain can match supply and demand effectively.

6.3 SUPPLY CHAIN MANAGEMENT

Supply Chain Management is the control of the supply chain as a process from supplier to manufacturer to wholesaler to retailer to consumer. Supply chain management does not involve only the movement of a physical product (such as a microchip) through the chain but also any data that goes along with the product (such as order status information, payment schedules and ownership titles) and the actual entities that handle the product from one stage to another stage of the supply chain. Managing the chain of events in this process is known as supply chain management. Effective management must take into account coordinating all the different pieces of this chain as quickly as possible without losing any of the quality or customer satisfaction, while still keeping costs down.

Supply chain management is the systematic, strategic co-ordination of the traditional business functions and the tactics across these business functions within a particular company and across business within the supply chain. The purpose is of improving the long-term performance of the individual companies and the supply chain as a whole.

Supply Chain Management (SCM) is a systems approach to managing the entire flow of information, materials, and services from raw materials suppliers through factories and warehouses to the end customer. SCM is different from supply management, which emphasizes only the buyer-supplier relationship. Fig. (3) shows the concept of supply chain management.

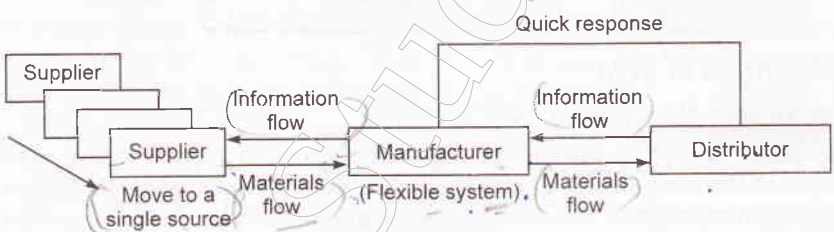

Fig. (3) Concept of Supply Chain Management

Supply chain management has emerged as the new key to productivity and competitiveness of manufacturing and service enterprises. There are essentially three goals of SCM :

- To reduce inventory,
- To increase the speed of transactions with real-time data exchange,
- To increase revenue by satisfying customer demands more efficiently.

Nature and Concept

SCM is an integrated management of various functions in the areas of materials, operations, distributions, marketing and after-sales service with a customer focus in mind. This is done so as to synergize various processes in the organization with a view of optimizing the total cost. Hence, SCM refers to a managerial process of a joint approach of all supply chain participants to design, develop and operate a system which responds to customer expectations. This is possible by making available the right quantity of right quality products at the right time and place in the right physical form at a right cost. In short, SCM facilitates to offer best customer service in a cost-efficient manner. It stresses not only an efficient internal distribution system but also the existing parallel distribution capabilities.

Philosophy of SCM

As a philosophy, SCM takes a systems approach to viewing the channel as a single entity, rather than as a set of fragmented parts, each performing its own function. In other words, the philosophy of supply chain management extends the concept of partnerships into a multi-firm effort to manage the total flow of goods from the supplier to the ultimate customer. Thus, SCM is a set of beliefs that each firm in the supply chain directly and indirectly affects the performance of all the other supply chain members, as well as ultimate, overall channel performance.

SCM as a management philosophy has the following characteristics :

(1) A system approach to viewing the channel as a whole and to manage the total flow of goods inventory from the supplier to the ultimate customer.

(2) A strategic orientation towards co-operative efforts to synchronize and converge intra-firm and inter-firm operational and strategic capabilities into a unified whole.

(3) A customer focus to create unique and individualized sources of customer value, leading to customer satisfaction.

The Objectives of SCM

The various objectives of SCM are :

(1) *Maximize value and inturn profitability*. The main objective of SCM is to maximize the overall value generated. The value generated by a supply chain is the difference between what the final product is worth to the customer and the costs the supply chain incurs in filling the customer's request. In supply chains, mostly the value is directly related to profitability of the organisation.

(2) To provide superior customer service.

(3) *System's orientation* : The main gain from SCM is that of cooperation and coordination. Optimal results are possible because no one is neglected and no one's interests are undercut.

(4) To provide competitiveness and improved efficiency.

(5) To reduce the time required for converting orders into cash.

(6) To improve the quality of operations of the organisation.

(7) To reduce transportation and warehousing costs.

(8) To rationalize supplier base.

(9) To minimize work-in-progress and improve pipeline visibility.

(10) To improve life-cycle support by increasing rigid quality standards, product expiration dating and fixing responsibility for hazardous consequences.

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6.4 ISSUES INVOLVED IN SCM

The various issues involved in SCM can be explained on the basis of the pyramid structure for the SCM paradigm as shown in fig. (4). Accordingly, the issues can be analyzed on four levels :

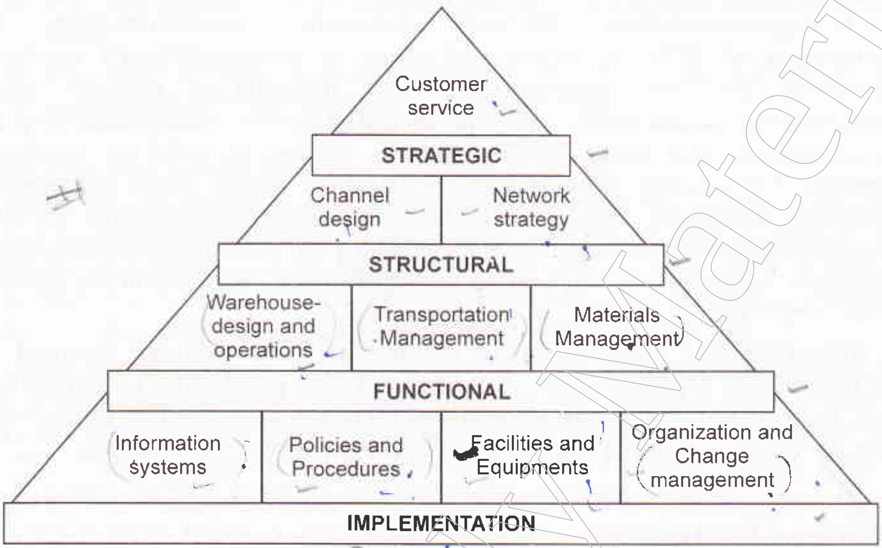

Fig. (4) SCM Framework Pyramid

(1) *Strategic :* On the strategic level it is important to know how SCM can contribute to the enterprises' basic 'value proposition' to the customers. Important questions that are addressed at this level are :

- What are the basic and distinctive service needs of the customers?
- What can SCM do to meet these needs?
- Can the SCM capabilities be used to provide unique services to the customers? etc.

(2) *Structural :* After the strategic issues are dealt with, the next level question(s) that should be asked are :

- Should the organization market directly or should it use distributors or other intermediataries to reach the customers?
- What should the SCM network look like?
- What products should be sourced from which manufacturing locations?
- How many warehouses should the company have and where they should be located?
- What is the mission of each facility (full stocking, fast moving items only, cross-docking)? etc.

(3) *Functional :* This is the level where operational details are decided upon. Functional excellence requires that the optimal operating practices for transportation management, warehouse operations, and materials management which includes forecasting, inventory management, production scheduling and

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purchasing) are designed. These strategies should keep in view the trade-offs that may need to be made for the overall efficiency of the system. Achieving functional excellence also entails development of a process-oriented perspective on replenishment and order fulfillment so that all activities involved in these functions can be well integrated.

(4) ***Implementation :*** Without successful implementation, the development of SCM strategies and plans is meaningless. Of particular importance are the organizational and information systems issues. Organizational issues centres on the overall structure, individual roles and responsibilities, and measurement systems needed to build an integrated operation. Information systems are 'enablers' for supply chain management operations. Therefore, they must be carefully designed to support the SCM strategy. Supply chain managers must consider their information needs relative to decision support tools, application software's data capture and the system's overall structure.

Note that the decisions made within the SCM strategy pyramid are interdependent. That is, it must be understood what capabilities and limitations affect the functional and implementation decisions and consider these factors while developing a supply chain management strategy and structure.

6.5 VALUE CHAIN

Supply chain systems are developed in various organisations in order to gain a competitive edge in the market place due to its value addition capability in cost-efficient ways. SCM ensures superior customer value through quality services at minimum costs. The value chain of SCM focuses on speedier flow of goods, cash, value and related information within the complete supply chain process as shown in fig. (5).

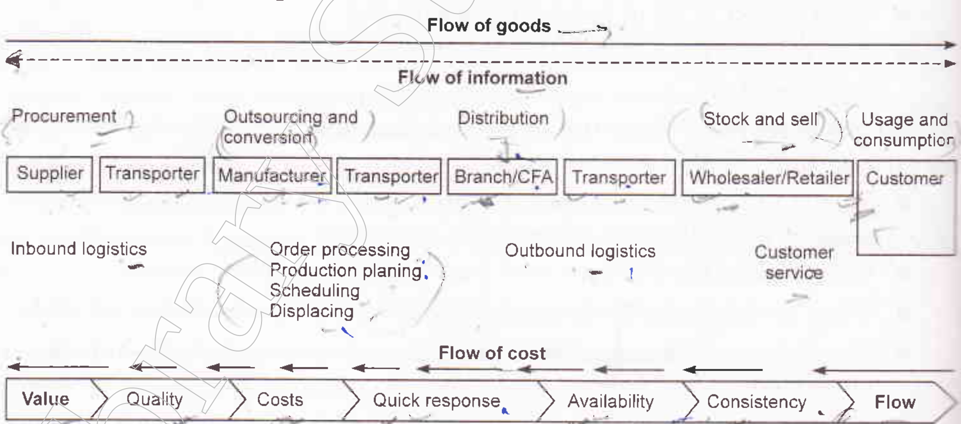

Fig. (5) Value chain of SCM

Observe from the figure that :

- Value chain of SCM starts with suppliers (or vendors) and ends with consumers via the transporters, producers (manufacturers), distribution warehouses, transportation from there to customers and finally to the ends user (consumer).

- The flow of goods and value are in forward direction for greater market dominance.
- The flow of cash is in a backward direction to keep the business system alive.
- The flow of information is in both directions for activation and improvement of the total supply chain system.

Value flow and Goods flow

Goods flow is the most obvious and visible part of the supply chain. It is moving largely from the vendor to the customer. Goods flow constitute raw materials (including material being stored or transported), work in process (including what is being converted and what is in between operations), finished goods (includes material being stored or transported), spares, etc.

Value is delivered through the defined business activity of the firm in the form of goods and services. The value addition may be in the form of quality, costs, quick response, availability and consistency of the SCM system. The flow of value and goods is always in the forward direction. Occasionally, there could be small reverse flows of material due to returns, network or recycling.

Service flows follow a similar sequence, but being intangible cannot be stored. This brings the transactions between actors more into focus. For convenience, we refer to the vendor side as the upstream end and the customer side as the downstream end of a supply chain.

Cash flow

This is the commercially significant part of the supply chain, which is largely in a direction opposite that of the major value flow. The major part of this flow is the money paid for goods and services received. But there are other features to the cash flow, such as credit periods/advances for payments from customers/dealers, and to vendors. Any credit/advance is with respect to the transfer of title and/or service delivery in the supply chain. The cash flow determines how a given value flow is financed by the various actors in the supply chain.

Information flow

This is a significant part of the supply chain in that it is the enabler and driver of the concept of a supply chain. It consists of flows both from vendor to the customer and from the customer to the vendor. The major components of the backward flow (against the direction of the major value flow) are inputs for forecasts, marketing plans, dispatch plans, production plans and procurement quantities and timing, orders from customers and dealers, quality feedback, warranties that are invoked, etc. In the forward direction (in the direction of the major value flow) there are important components like capacity estimates for plans, stocks available, dispatch advises, stock transfer notes, quality assurance reports, warranties, etc.

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(Three System)

6.6 ELEMENTS OF SUPPLY CHAIN MANAGEMENT

The various systems needed for supply chain management are :

(1) *Planning Systems :* Planning systems focus on having the right product at the right place and at the right time. These systems facilitate order taking and information gathering form the customer and require the flow of information along the entire supply chain, from initial order to raw material procurement to final consumption. This requires understanding demand-what customers want, when they want it, and where they want it—and is fundamental to successfully managing all parts of the supply chain.

(2) *Execution Systems :* Execution systems facilitate the physical movement of goods and services through a supply chain. This focus traditionally includes some application-based systems such as customer order fulfillment, inventory control and manufacturing and logistics.

Execution systems focus on operational efficiency, which entails finding new ways to streamline and automate day-to-day business operations to reduce costs and improve productivity.

(3) *Performance Measurement Systems :* Performance measurement process keeps track of the health of the supply chain. This is necessary in order to make more informed decisions and respond to changing market conditions. Here, accounting and financial management systems are the real focus point. These applications utilize electronic commerce tools such as data warehousing to allow for effective information auditing and analysis. But this is not easy. Most operational business systems and traditional reporting tools are designed for transaction processing; they are not designed for easy access to information for decision supported purposes.

6.7 PREREQUISITES FOR SUPPLY CHAIN MANAGEMENT

The SCM can be implemented only if following are in place or at least detailed plans are set out to accomplish them :

(1) *Top management understanding and commitment :* Chain management always starts at the top. The bottom layers can never force it.

(2) *Quest for excellence :* SCM can be successful only when the organisation has a longing for excellence. Supply chain succeeds if all the members of the supply chain have the same goal and the same focus of serving customers. Establishing the same goal and the same focus among supply chain members is a form of policy integration.

(3) *Integration of Processes :* The implementation of SCM needs the integration of processes from sourcing, to manufacturing and to distribution across the supply chain. The integration can be accomplished through cross-functional teams, in-plant supplier personnel and third-party service providers.

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(4) *Philosophy to Build and Maintain Long-term Relationships :* Successful relationships aim to integrate channel policy to avoid redundancy and overlap while seeking a level of co-operation that allows participants to be more effective at lower cost levels. Policy integration is possible if there are compatible cultures and management techniques among the chain members.

(5) *Integrated Behaviour :* SCM incorporates integration of stakeholders from suppliers to customers.

(6) *Mutual Information Sharing :* For effective SCM mutually sharing information among channel members is required, especially for planning and monitoring processes.

(7) *Sharing of Channel Risks and Rewards :* Effective SCM also requires mutually sharing channel risks and rewards that yield a competitive advantage. Risk and reward sharing should happen over the long-term.

(8) *Co-operation :* Co-operation among the channel members is required for effective SCM. Co-operation refers to similar or complementary co-ordinated activities performed by firms in a business relationship to produce superior mutual outcomes or singular outcomes that are mutually expected over time. Co-operation is not limited to the needs of the current transaction and happens at several management levels (*e.g.*, both top and operational managers), involving cross-functional co-ordination across the channel members.

6.8 COMPONENTS OF SUPPLY CHAIN MANAGEMENT

Integrating the supply chain to improve efficiency is a key challenge. The competition today is not between individual companies but between supply chains. Hence, for the supply chain to be successful, it should integrate the three individual business processes of procurement, manufacturing and distribution by consolidating the sub-components in each of the above functional areas as shown in fig. (6).

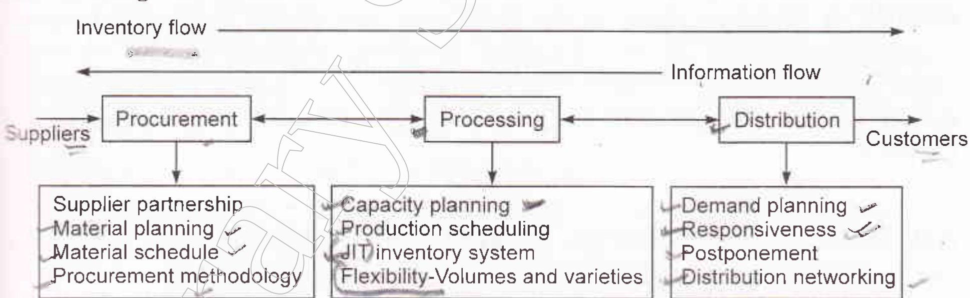

Fig. (6) Components of Supply Chain Management

[I] Procurement

This is one of the major cost drivers in the supply chain. Procurement cost is influenced by the following factors :

(i) The way procurement decisions are made,

(ii) Procedures adopted in the procurement process,

(iii) Relationship with suppliers,

(iv) Firm's credibility,

(v) Market intelligence.

Procurement cost can be controlled through long-term relationships with suppliers, by considering the supplier as an extension of the manufacturing facility. The philosophy of co-partnership is based on the sharing of both resources and benefits on a long-term basis. Material requirement planning is a critical element in the procurement process. Material flow across the supply chain is done in close co-ordination with the suppliers. The actual shipment is scheduled as per the firms' production programmes. The operation is planned to take care of any eventualities so as to deliver the material on time, and with both reliability and consistency in performance.

[II] Processing

For a lean supply chain the emphasis today is not on curtailing the processing/manufacturing cost through economies of scale, but by curtailing the huge inventory carrying cost resulting from mass production ahead of demand. In the past the emphasis was on building mega capacity factories to produce standard products in millions in order to reduce manufacturing costs and flood the market with low priced products. The emphasis was on focused factories to manufacture standard products for global consumption. This approach resulted in the build up of a large reservoir of finished goods, which remain unsold and dead due to its inability to respond to the changing needs of the customers.

[III] Distribution

Traditionally the role of distribution in the business process is warehousing transportation. However, in the supply chain model the major task of distribution is the management of demand, *i.e.*, to make available the right product, at the right place, at the right time and at the least cost. Demand management covers all the activities involving anticipating the customer requirements of products and fulfills that requirement against defined customer service norms. Requirement fulfilment is done through proper distribution network.

6.9 PROCESS OF SUPPLY CHAIN MANAGEMENT

The process of supply chain management is shown in fig. (7).

(1) *Customer Relationship Management :* Customer relationship management involves establishing a framework for building and maintaining relationships with customers. This involves identifying the customer groups which form the target for achieving the firm's business objectives. Then the customer service teams design the product or service agreements specifying the level of service that is to be offered to each of these customer groups. These teams work in close co-ordination with the key account customers to reduce demand variability. Performance reports are designed in order to measure levels of service made available to the customer and the profits resulting from serving each of the customer groups.

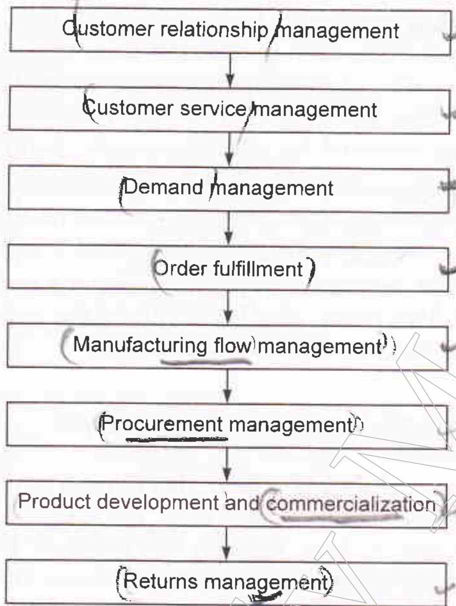

Fig. (7) Process of Supply Chain Management

(2) ***Customer Service Management :*** Customer service management is concerned with providing the customer with up-do-date information relating to shipping dates, product availability, product application, etc. The customer service management teams act as an interface between the customers and the functional departments like production and logistics in administering product and service agreements.

(3) ***Demand Management :*** Demand management is the key to effective supply chain management. It plays a major role in balancing the customer's requirements with the firm's supply capabilities. Demand management involves determining forecasting methods to gauge customer demand, synchronizing demand with the supply capabilities of the firm, and developing contingency management systems to handle variations in demand.

(4) ***Customer Order Fulfillment :*** The effectiveness of a supply chain is determined by its ability to fill customer orders on time. A high order fulfillment rate with low costs requires co-ordination between various organizations across the supply chain and their internal functions like manufacturing, distribution and transportation. The order fulfillment process includes activities like receiving orders, defining the requirements for order fulfillment, evaluating the logistics network, developing plans for order fulfillment, etc.

(5) ***Manufacturing Flow Management :*** Manufacturing flow management is concerned with ensuring the smooth production of goods. It also involves developing flexible production processes that can respond to the demands of the target markets. This supply chain process includes activities like determining the degree of manufacturing flexibility required, manufacturing

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and material planning, determining manufacturing capabilities, synchronizing production and demand, etc.

(6) ***Procurement Management/Supplier Relationship Management :*** Supplier relationship management guides the interactions of the firm with its suppliers. This process aims at developing long-term relations with suppliers to ensure uninterrupted flow of supplies for the firm's manufacturing processes. Such relationships are essential for effective supply chain management.

(7) ***Product Development and Commercialization :*** Reducing the time to market is one of the objectives of supply chain management. The product development and commercialization process involves establishing cross-functional product development teams, designing and building prototypes, developing product rollout plans, etc. The requires the integration of customers and suppliers into the product development process to ensure speedy rollout of new products.

(8) ***Returns Management :*** Many companies are forced to recall products to rectify defects, upgrade the products or recycle them. Thus, the returns management capability of a firm also plays a major role in providing a competitive edge to the firm. There may be many environmental issues associated with the way a firm handles its returns. Hence, managing the products returned is also a major part of supply chain management.

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6.10 FUNCTIONS OF SUPPLY CHAIN MANAGEMENT

Supply chain management is a cross-functional approach to manage the movement of raw materials into an organization, certain aspects of the internal processing of materials into finished goods, and then the movement of finished goods out of the organization toward the end-consumer. As organizations strive to focus on core competencies and becoming more flexible, they have reduced their ownership of raw materials sources and distribution channels.

Supply chain activities can be grouped into strategic, tactical and operational levels of activities :

(1) Strategic Functions

- (i) Strategic network optimization, including the number, location and size of warehouses, distribution centres and facilities.
- (ii) Strategic partnership with suppliers, distributors and customers, creating communication channels for critical information and operational improvements such as cross docking, direct shipping and third-party logistics.
- (iii) Product designs co-ordination, so that new and existing products can be optimally integrated into the supply chain load management.
- (iv) Information Technology infrastructure, to support supply chain operations.
- (v) Where-to-make and what-to-make-or-buy decisions.
- (vi) Aligning overall organizational strategy with supply strategy.

(2) Tactical Functions

(i) Sourcing contracts and other purchasing decisions.

(ii) Production decisions, including contracting, scheduling and planning process definition.

(iii) Inventory decisions, including quantity, location and quality of inventory.

(iv) Transportation strategy, including frequency, routes and contracting.

(v) Benchmarking of all operations against competitors and implementation of best practices throughout the enterprise.

(vi) Milestone payments.

(vii) Focus on customer demand.

(3) Operational Functions

(i) Daily production and distribution planning, including all nodes in the supply chain.

(ii) Production scheduling for each manufacturing facility in the supply chain (minute by minute).

(iii) Demand planning and forecasting, co-ordinating the demand forecast of all customers and sharing the forecast with all suppliers.

(iv) Source planning, including current inventory and forecast demand, in collaboration with all suppliers.

(v) Inbound operations, including transportation from suppliers and receiving inventory.

(vi) Production operations, including the consumption of materials and flow of finished goods.

(vii) Outbound operations, including all fulfillment activities and transportation to customers.

(viii) Order promising, accounting for all constraints in the supply chain, including all suppliers, manufacturing facilities, distribution centres and other customers.

6.11 PERFORMANCE MEASURES FOR SCM

The measures according to which supply chain performance is judged is still a matter of debate. Financial performance indicators of individual firms in the supply chain will tell the story of the past, but that alone is not enough to give managers the information on which to base their actions. Lack of good supply chain metrics has been identified in the literature as one of the major pitfalls of SCM. Others surveys have proposed a number of performance measures. These include total supply chain cost, process capability, customer retention measures and lead-time as some primary indicators of supply chain performance.

(1) *Total Supply Chain Cost :* The total supply chain cost alerts managers to the fact that it is not just one element of cost (among ordering cost, inbound transportation cost, storage cost, conversion cost, holding cost,

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distribution cost, etc.) that is important, but the totality of costs incurred at various points in the supply chain. A simple example of this is that transportation cost can often be reduced by insisting on large batch shipments and negotiating bulk movements rates with transporters. However, the relevant inventory holding costs incurred both by the dispatcher in building up the load and by the receiver in using the load may outweigh transportation cost savings.

(2) *Process Capability :* Process capability is usually measured in terms of variability of the outcome with respect to the desired target. Improving process capability is the basic quality control tool that has a long-run impact on effectiveness by reducing wastes and decreasing uncertainty over yields at any stage in conversion. In addition to conversion activities, it is essential to view storage, transportation and other activities also as processes where capability can be built up.

(3) *Customer Retention :* Customer retention is another attribute that modern supply chain management must explicitly focus on, in order to stay competitive. This captures the value aspect of the supply chain process. Therefore, it must be viewed in all the dimensions that value implies. For example, if availability or reliable supply is a value, then a measure such as fill rate (proportion of ordered items met from available inventory and which is not backordered) may be important which is then translated into a logistical service parameter.

(4) *Lead Time :* Process lead-time is another measure of basic supply chain capability. If process capability captures the technology and engineering aspect of the activity, lead times captures the organizational aspect of the activity. Lead-time to deliver a certain promised range of products indicates how quickly and reliably the supply chain can respond to needs as and when they arise. Process lead times would measure the primary effectiveness of the demand fulfillment process.

6.12 JIT (JUST-IN-TIME)

Just-in-time is both a philosophy and a set of methods for manufacturing. Although it has no single, agreed-upon definition, JIT emphasizes waste reduction, total quality control and devotion to the customer.

This approach was first developed in Japan by Toyota, the automobile manufacturer, in the 1970s. In its early days it was known as the 'Toyota manufacturing system' or 'Toyoterism'. The label 'just-in-time' was applied later.

One of the central ideas of this system is the elimination of waste ('muda' in Japanese) from the manufacturing process. In this context 'waste' does not refer simply to reworking or scrapping substandard products. Waste within the just-in-time environment means waste in all its manifestations. It seeks to reduce what are known as 'the seven wastes'.

Thus, JIT is a manufacturing system whose goal is to optimize processes and procedures by continuous pursuing waste reduction.

JIT aims to meet demand instantaneously, with perfect quality and no waste. Strictly speaking, this is not much a clearly defined system of materials management but more a set of management philosophies that work together to create the desired effect.

Toyota Motor Company identifies *seven wastes* as being the targets of continuous improvement in production processes. By attending to these wastes, improvement is achieved. They are :

(1) *Waste of Overproduction :* Eliminate by reducing setup times, synchronizing quantities and timing between processes, compacting layout, visibility, and so forth. Make only what is needed now.

(2) *Waste of Waiting :* Eliminate through synchronizing work flow as much as possible, and balance uneven loads by flexible workers are equipment.

(3) *Waste of Transportation :* Establish layouts and locations to make transport and handling unnecessary, if possible. They rationalize transport and material handling that cannot be eliminated.

(4) *Waste of Processing Itself :* First question why this part or product should be made at all, then why each process is necessary. Extend thinking beyond economy of scale or speed.

(5) *Waste of Stocks :* Reduce by shortening setup times and reducing lead times, by synchronizing work flows and improving work skills, and even by smoothing fluctuations in demand for the product. Reducing all the other wastes reduces the waste of stocks.

(6) *Waste of Motion :* Study motion for economy and consistency. Economy improves productivity and consistency improves quality. First improve the motions, then mechanize or automate. Otherwise there is danger of automating waste.

(7) *Waste of Making Defective Products :* Develop the production process to prevent defects from being made so as to eliminate inspection. At each process, accept no defects and make no defects. Make processes failsafe to do this. From a quality process comes a quality product—automatically.

Characteristics of JIT System

JIT systems display certain unique characteristics that help achieve a smooth flow of production and benefits. Key characteristics of the JIT system include :

(1) *Pull System :* Purchase of the final product by the customer pulls output from the final stage of production, which in turn pulls output from the preceding stages of production. Each production stage pulls output from the preceding stages when it is needed. Hence, a JIT system is considered a pull system.

(2) *Quality :* JIT systems require high-quality levels for product design, production process and raw materials/parts supplied by the vendors. Also, workers are provided with adequate tools, training, support, encouragement and authority for ensuring production of high-quality goods.

(3) *Small Lot Sizes :* JIT systems use small lot sizes in the production process. Therefore, it require small deliveries from suppliers. Small lot sizes permit greater flexibility in scheduling and reduce in-process inventory. Flexibility enables quick response to changing customer demands. Reduced

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inventory levels help minimize holding costs, space and clutter. Also, smaller lots require less inspection and lower rework costs.

(4) ***Quick Setups :*** Setup procedures are simple and standardized to enable frequent and quick setups due to smaller lot sizes.

(5) ***Production Smoothing :*** To ensure a smooth flow of goods from the supplier to the final stage of production, all activities are carefully co-ordinated and changes to the production plan are minimized.

(6) ***Suppliers :*** Since, the JIT system requires high-quality materials delivered on-time and uses small lot sizes, it also requires reliable suppliers who are willing to ship high-quality materials and parts on a regular basis.

(7) ***Kanban Card :*** Communication between a production stage and the preceding stages is carried out in various ways to ensure timely and smooth movement of parts and materials. The Kanban card (explained in next article) is a commonly used tool (*e.g.*, at Toyota) for communicating the need for parts or work from a preceding production stage. Without this card, which serves as an authorization, no part or lot can be moved.

Benefits of JIT System

Many U.S. Manufacturing firms are implementing JIT systems to realize benefits such as :

(1) Reduced inventory levels.

(2) Reduced manufacturing lead times.

(3) Encouragement of worker participation in problem-solving.

(4) Improved relations with suppliers.

(5) Smooth production flow by removing disruptions and inefficiency. This also leads to improving product quality.

(6) Overall better quality of whatever is produced.

(7) Less scrap because mistakes are reduced and hopefully eliminated at some point.

(8) Less raw material is used because employees are making the product right at the first time itself.

(9) Less work-in-process inventory is found because production and delivery quantities approach one single unit, *i.e.*, it is a piece-by-piece production.

(10) Less finished goods sitting because they ideally are sold as they come off the production line.

(11) Employees run the process and discover process problems. Therefore there is teamwork.

(12) Employees are highly motivated because of management respect for them.

(13) Increased employee and equipment efficiency.

(14) Facility floor space is saved because there are no rework lines to correct production mistakes.

(15) An overall increase in employee and equipment productivity is evident.

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Disadvantages of JIT

(1) High risk is involved due to short-term planning and a minimum level of inventory.

(2) Suppliers of input materials need to be educated about the quality by the customers/company.

(3) Needs continuous and close-evaluation and follow-up of the whole process.

(4) Needs establishment of long-term business partnership with suppliers.

(5) Not able to meet any unforeseen requirement/demand.

6.13 KANBAN SYSTEM

Kanban is a Japanese word, meaning card. A kanban system is a simple, self-regulatory and paperless system for scheduling and shop floor control.

The design of kanban systems which lie at the heart of a JIT manufacturing system, involves determining :

(1) The number of kanban cards for each part;

(2) The capacity of each container;

(3) Assigning operations of part types to different machines; and

(4) Allocation of resources such as pallets and fixtures.

Kanban systems are often associated with JIT implementation. In fact, some people have the misimpression that JIT requires the use of a Kanban system. Having a Kanban system is not a strict requirement of JIT implementation, but their use as a tool for practicing JIT has become quite popular owing to its simplicity. The word *Kanban* literally means "visual record". Usually, *kanban* is loosely referred to as a card system. It can be either a two-card system as introduced and practiced in Toyota Motor Company's Takahama plant or it can be more popular one-card system. *Kanban* is the production control system that "pulls" JIT production allowing production with smaller inventories.

Material flow and work-in-progress is regulated in production shops through these Kanbans (cards). A typical process is shown in fig. (8)

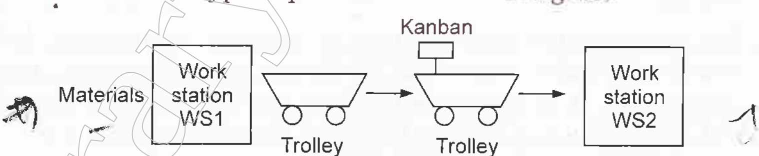

Fig. (8)

Work Station (WS-2) is the customer. He will decide when he needs the next lot of materials. For this, the Kanban has to be transferred by customer to WS-1 only when its incoming trolley is nearly empty-the worker at WS-1 cannot transfer the material until he receives the Kanban from his customer stage. By controlling the number of Kanbans in production process, work-in-progress is reduced and materials arrive into the next workstation just-in-time.

Prerequisites for Kanban System

The following are the prerequisites for the Kanban system :

(1) Production plans and schedules should be uniform. Seasonal variations, patterns in demand and anticipated large variations are required to be levelled in advance to minimize the impact on upstream processes. For a Kanban system to work efficiently, the demand variation should not exceed ±8 to 10%.

(2) Availability, dependability, flexibility and reliability of man, material and machines for operations should be assured.

(3) Workers must be flexible; cross-functionally trained and firm believer in teamwork rather than have an individualistic approach to work.

(4) Maintenance breakdown of machines should be zero. Scheduling and loading activities should be planned in a manner to accommodate preventive maintenance activities.

(5) Source inspection techniques, capability studies, sensors and transducers, Pokayoke devices and visual management techniques should be actively used. Quality assurance efforts should be aimed at defect prevention.

(6) All the concerned parties should appreciate implications of line stoppage. Workers must be prompt in taking corrective actions, rather than finding fault with someone else and delaying defect correction.

(7) Quality support systems and production support should be able to take care of quick identification of defects and abnormalities; die or setup changeover activities. The necessary remedial measures for the elimination of defects and waste should also be focused continuously.

(8) Departments and activities should be networked so that adequate and timely actions can be taken. It is not necessary to go in for computer networking. Even good team effort is adequate.

(9) The layout should facilitate linking of all the relevent operations of the process. For the smooth flow of material between operations, every operation should have approximately the same production capacity and be capable of producing at a rate that is dictated by the final stage of the process.

(10) The organization should have a reliable, committed and quality conscious vendor base and a strong overall vendor development programme. It is advisable to share production schedule information with vendor and keep them informed about changes, if any.

Advantages of Kanban System

The following are the advantages of the Kanban system :

(1) Makes scheduling simple and straightforward. The Kanban system reduces the need for planners and forecasters to a great extent. It helps integrate the flow of sales information from dealers as a clear indicator for when, how and which product/material is needed, owing to its 'pull' concept.

(2) Reduces WIP (Work-in-Progress) and finished goods inventory significantly.

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(3) Smoothens production system and reduces manufacturing, delivery and administration lead times.

(4) Provides flexibility by quick response to change in the product mix demand.

(5) Helps fixing responsibility and results in auto-control. This, in turn, reduces administration and planning obstacles.

(6) Develops concern for both internal and external customers.

(7) Fairly simple and easy to implement and does not need costly computers, software and specially trained personnel.

(8) Does not allow movement of defective products or items to the next stage. This prevents further wastage of money, time, man-hour, machine-hour and a lot more.

(9) Helps attain better discipline at the workplace by simplifying scheduling, stabilizing and rationalizing processes through the Kanban system.

(10) Promotes continuous improvement, keeping both internal and external customer satisfaction in mind.

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(11) Provides an efficient lot tracking mechanism using the inexpensive JIT.

(12) Reduces administrative overheads significantly. This not only reduces the cost of the product, but also improves profit margins.

Limitations of Kanban System

Limitations of the Kanban system include the following :

(1) The system is fairly slow to react in gross demand due to product and process design. However, it can take care of the changes in product mix, keeping the total demand the same as it assumes stabilty and linearity.

(2) Underplays the known information about future demand patterns, especially if they are fluctuating.

(3) A major shortcoming is the time required to transmit changes in product and process designs through the system.

(4) There are many types and versions of Kanban and Kanban techniques. Therefore, it is very critical to choose the right Kanban technique on the basis of the requirements of the environment. Mixing at a later stage may create confusion.

(5) It is suitable for repetitive operations, mostly in large volume and low product variety situations.

(6) Kanban, under JIT environment, demands the existence of good standardization practices, ground activities and housekeeping activities. This also requires some changes in the design of the manufacturing system, standardization of operations and the smoothening of the production system. If any of these items are missing or partial in nature, the success of Kanban is affected.

(7) If the supplier cannot guarantee timely delivery of components, the company will have to carry high stock levels to reduce the risk of stock-outs and interruption in production. But high inventory translates into high cost and inefficiency, which in turn reduces the benefits of Kanban.

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(8) Cultural barriers, belief in functional specialization, union pressures, etc., often obstruct the introduction of multi-skill, job rotation practices and flexible work concepts.

(9) It is useful mostly in repetitive discrete manufacturing scenarios. Kanbans are not applicable to flow/continuous processes industries such as oil refineries and breweries.

(10) Difficult to implement if the products are often redesigned.

(11) It is very likely for the suppliers to suffer due to increased delivery frequencies unless they are geographically in close proximity to the customer company.

REVIEW QUestions

1. What do you understand by *"supply chain"* and *"supply chain management"*?
2. Discuss the goals of a supply chain. What is the impact of SCM decisions on the success of a firm?
3. What are the three key supply chain decision phases? Also give the significance of each one of them.
4. Elaborate the basic concept and philosophy of supply chain management.
5. Comment on the statement : *"Supply chain management is a systems approach to distribution"*.
6. What are the various thrust areas that should be focused upon while managing supply chain management?
7. Describe the cycle and push/pull view of a supply chain process.
8. Define the value-chain of SCM. Explain the flow of various things in it alongwith their relevance.
9. What is the importance of information in the management of supply chain?
10. What are the various elements of supply chain management?
11. What are the prerequisites for supply chain management?
12. Discuss the three components of supply chain management?
13. Explain the role of inventory control (management) in the supply chain.
14. Examine the role of safety inventory in supply chain.
15. Explain the various sub-processes in the SCM.
16. What are various functions of SCM?
17. How do we measure the performance of SCM?
18. What is JIT? Discuss its characteristics and advantages.
19. What is a Kanban system? How is it associated with JIT implementation?
20. What are the advantages and limitations of Kanban system?

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7 QUALITY CONTROL

Learning Objectives

After reading this chapter, you will understand :

- Meaning and Definition of quality control
- Objectives of quality control
- Steps in quality control
- Process control
- Statistical Quality Control (SQC)
- Control charts ($\bar{X}$-chart, *R*-chart, *p*-chart, *n*-*p*-chart and *C*-chart)
- Sampling and Sampling plans
- Single, double and sequential sampling

INTRODUCTION

Before defining quality control, let us define quality. The ***quality is defined as the degree to which a product meets the requirements of customers.*** The quality may also be defined as the totality of features and characteristics of a product or service that bear on its ability to satisfy a given need.

The quality of a product consists of the following attributes :

(i) Appearance of product
(ii) Product design
(iii) Performance of the product
(iv) Reliability of the product
(v) Durability of the product
(vi) Serviceability
(vii) Maintainability
(viii) Suitability from customer's point of view
(ix) Degree to which it conforms the product specifications
(x) Marketing and after sales service.

Quality of a product or service influences the factors such as market, technology, labour, cost and management.

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7.1 MEANING AND DEFINITION OF QUALITY CONTROL

Meaning

The term 'Quality Control' consists of two words 'Quality' and 'Control'. Quality is a relative term. It is the characteristic or a combination of characteristics that distinguishes one product from the other product or goods or one manufacturer from that of competitors. Thus ***quality is defined as fitness for purpose.*** The quality of an article may include such elements as *design, size, materials, chemical composition, mechanical functioning, electrical properties, finish* and *appearance.*

Control is referred to as the comparison of actual results (finished product) ***with the predetermined standards and specifications.*** Thus control is a system for measuring and checking (inspecting) a phenomenon. Control is the correction in the quality of the product, when deviations in the quality are more than expected in the process.

Control differs from inspection. The control ascertains quality characteristics of an item, compares the same with prescribed quality standards and separates defective items from non-defective ones. Inspection, however, does not involve any mechanism to take corrective action.

Definition

Quality control is the process of control where the management tries to conform the quality of product in accordance with the pre-determined standards and specifications. So, the ***quality control is defined as a process of checking the products to ensure that they meet the required quality standards and specifications.***

The quality control may also be defined as industrial management technique or group of techniques by means of which products of uniform acceptable quality are manufactured. (Alford and Beatty)

According to J.A. Shobin, ***quality control means the recognition and removal of the identifiable causes of defects and variations from the pre-sets standards.***

7.2 OBJECTIVES OF QUALITY CONTROL

Following are the objectives of quality control :

1. To assess the quality of raw materials, semi-finished goods and finished products at various stages of production process.
2. To see whether the product confirms to the predetermined standards and specifications or not.
3. In case the product does not satisfy the standards, then to suggest necessary remedial steps.
4. To suggest suitable improvements in the quality of product without much increase in the cost of production. For this purpose, new techniques and methods and machines may be applied.

5. To develop quality consciousness in various sections of manufacturing unit.
6. To reduce the wastage of raw materials, men and machine during the process of production.

7.3 BENEFITS/ADVANTAGES OF QUALITY CONTROL

Following are the benefits of quality control :

1. An efficient quality control system reduces the cost of production of the product due to following factors:
   (i) Reduction in wastage of raw material
   (ii) Large-scale production
   (iii) Minimisation of rework cost of substandard goods
2. By quality control programme, the employees become quality conscious, *i.e.*, the morale of employees is improved.
3. There is maximum utilization of resources, *i.e.*, the necessary control over the machine, equipment, men and materials and all other resources is exercised.
4. Uniformity and reliability of products help in increasing sale.
5. Inspection costs and customers complaints are minimised.
6. Consumers get the quality product of standard specifications, *i.e.* there is consumers satisfaction.

7.4 STEPS IN QUALITY CONTROL

The process of quality control consists of the following steps :

1. ***Design of production system***
2. ***Determination of quality standard-specification***
3. ***Control action***
4. ***Inspection of produced products***

1. The design of production system concerns with the achievement of specified quality.
2. This refers to the desired quality levels in terms of weight, specific dimension, strength, chemical composition, etc.
3. The control action is used to ensure that established quality standards are met.
4. Inspection of products means to see if the overall quality of lots satisfies the specifications.

7.5 PROCESS CONTROL

During the stage of processing materials, random samples of the product are taken. Their quality is checked against the predetermined standards and

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specifications of quality. There may be certain defects in the production process. Now corrective measures are taken to ensure that right quality products are manufactured.

The process control helps in building the revised quality into the finished product and prevents production of substandards product.

A process is considered satisfactory till it produces the products of desired quality and specification.

The process control techniques are engaged in evaluation of process standards in terms of scrap, rework, dimensions, rejection, etc.

Therefore, the ***process control consists of all the procedures employed to evaluate, maintain and improve quality standard at different stages of manufacture.***

7.6 STATISTICAL QUALITY CONTROL (SQC)

Statistical quality control (SQC) is a ***scientific technique of controlling quality by means of statistical methods.*** Statistical quality control makes inspection more reliable and at the same time less costly. It controls the quality level of outgoing products.

SQC is defined into a number of ways. Here we present few definitions :

SQC is defined as the ***technique of applying statistical methods based upon the mathematical theory of probability to quality control problems with the purpose of establishing quality standards and maintaining adherence to those standards in most economical manner.***

(Alfred)

SCQ may be broadly defined ***as that industrial management technique by means of which products of uniform acceptable quality are manufactured. It is mainly concern with making things right rather than discovering and rejecting those made wrong.***

(Alfred and Beatty)

SCQ is a ***simple statistical method for determining the extent to which quality goals are being met without necessarily checking every item produced and for indicating whether or not the variations which occur are exceeding normal expectations.*** (Grant)

7.7 FUNDAMENTAL BASIS OF SQC

Using statistical techniques, S.Q.C collects and analyses data in assessing and controlling product quality.

The fundamental basic of statistical quality control is the ***theory of probability.*** According to probability theory, the dimensions of the components made on the same machine and in one batch may vary from component to component. The condition that a batch will represent the entire batch is developed on the basis of theory of probability.

Statistical quality control uses the following three scientific techniques, namely

1. Sampling inspection
2. Analysis of the data, and
3. Control charting.

7.8 SIGNIFICANCE OF STATISTICAL QUALITY CONTROL

Following are the main advantages of S.Q.C. : Defect

1. It gives an early signals of defects.
2. It provides a means of detecting errors at inception.
3. It helps to maintain customer relations by ensuring very high quality.
4. It helps to avoid unwanted machine adjustments so long as the process is in a state of control.
5. It serves as a means of determining the capability of the manufacturing process to turn out products with prescribed specifications.
6. The rework and scrap are reduced.

7.9 CONTROL CHARTS

A control chart is a graphical presentation of the collected information. The information pertains to the measured or otherwise judged quality characteristics of the items or the samples. Therefore, *a control chart is a diagnostic technique.*

A control chart detects variations in the processing and warns if there is any departure from specified tolerance limits. It depicts whether there is any change in the characteristics of items since the start of the production run.

Successively revised and plotted control chart immediately tells the undesired variations. So, it helps a lot in exploring the cause and eliminating manufacturing troubles.

Purpose and Advantages

1. A control chart indicates whether the process is in control or out of control.
2. It detects variations taking place in the process.
3. It ensures about the product quality level.
4. It warns in time about the defect. If the defect is rectified, then scrap or percentage rejection can be reduced.
5. Control charts built-up the reputation of the organization through customer's satisfaction.

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Types of Control Charts

The control charts are of the following types :

- Control charts
  - Process control
    - Variables
      - $\overline{X}$ chart
      - R chart
    - Attributes
  - Product control
    - Variables
    - Attributes
      - p-chart
      - np chart
      - C-chart

Variables charts involve the measurement of job dimensions. It tells whether an item is accepted or rejected if the dimensions are within or beyond the fixed tolerance limits.

The attributed chart only differentiates between a defective item and a non-defective item without going into the measurement of its dimensions. So these charts are only a way to control quality in those cases where measurement of quality characteristics is either not possible or they are very complicated and costly.

7.10 CONTROL CHARTS FOR VARIABLES

Following are the control charts for variables :

1. ***$\overline{X}$-chart*** or ***Mean chart***
2. ***R-Chart :***

1. $\overline{X}$-chart or Mean chart

To plot $\overline{X}$ chart, a good number of items coming out of a machine are collected at random at different intervals of time. Their quality characteristics (may be diameter, length, etc.) are measured.

The following steps are used :

(i) *Preparation of mean value ($\overline{X}$) and range (R) table*

For each sample, mean value $\overline{X}$ and range (R) is found out.

Let us consider the example that a sample contains 4 itsms (sample size 4) whose lengths are l_1, l_2, l_3 and l_4. The sample average

$$\overline{X} = \frac{l_1 + l_2 + l_3 + l_4}{4} \qquad (\because K = 4)$$

The sample average

$$R = \text{maximum length}\,(l_{max}) - \text{minimum length}\,(l_{min})$$

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A number of samples are selected (say 10). Their average values and ranges are tabulated as shown in table 1.

Table 1. Sample average and range

Sample No. (Sample size 4)	$\overline{X}$	R
1	7.0	2
2	7.5	3
3	8.0	2
4	10.0	2
5	9.5	3
6	11.0	4
7	11.5	3
8	4.0	2
9	3.5	3
10	4.0	2
$n = 10$	$\Sigma \overline{X} = 76$	$\Sigma R = 26$

(ii) ***Calculation of mean of the means (Grand mean) of samples***

The mean of means is expressed by putting double bar on X, *i.e.*, $\overline{\overline{X}}$. This is given by

$$\overline{\overline{X}} = \frac{\Sigma \overline{X}}{\text{No. of samples}}$$

where $\Sigma \overline{X}$ = sum of means of samples

and n = number of samples

In above example,

$$\overline{\overline{X}} = \frac{76}{10} = 7.6$$

and $$\overline{R} = \frac{\Sigma R}{\text{No. of samples}} = \frac{26}{10} = 2.6$$

Here, $\overline{\overline{X}}$ represents the central line of the $\overline{X}$ chart.

(iii) ***Calculation of upper control limit* (UCL) *and lower control limit* (LCL)**

$$\text{Upper control limit (UCL)} = \overline{\overline{X}} + A_2 \overline{R}$$

and $$\text{Lower control limit (LCL)} = \overline{\overline{X}} - A_2 \overline{R}$$

where A_2 is limit average.

The values of A_2 are given in table 2.

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Table 2. Sample size and limit average

Sample size (No. of items in a sample) K	A_2 Limit average
2	1.88
3	1.02
4	0.73
5	0.58
6	0.48
8	0.37
10	0.31
12	0.27

In the given problem,

$$UCL = 7.6 + 0.73 \times 2.6 = 9.498 \qquad (\because A_2 \text{ for 4 samples} = 0.73)$$

$$LCL = 7.6 - 0.73 \times 2.6 = 5.702$$

With these value, $\overline{X}$ chart is drawn. This is shown in fig. (1).

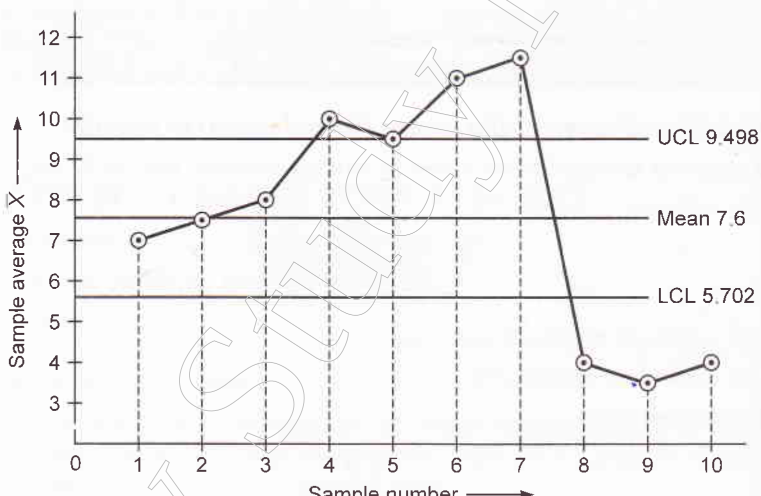

Fig. (1) Showing $\overline{X}$ chart

Note. Upper control limit (UCL) and Lower control limit (LCL) can also be calculated by using standard deviation of population of universe. We have

$$UCL = \overline{\overline{X}} + 3\frac{\sigma_P}{\sqrt{K}}$$

$$LCL = \overline{\overline{X}} - 3\frac{\sigma_P}{\sqrt{K}}$$

where σ_P = standard deviation of population

K = number of items in a sample or size of sample

$$\sigma_P = \frac{\overline{R}}{d_2} \quad \text{or} \quad \frac{\overline{\sigma}}{c_2}$$

where d_2 is quality control factor, $\overline{\sigma}$ is mean of standard deviations and c_2 is quality f...

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Formulae used in $\overline{X}$ chart

Sample average $(\overline{X}) = \dfrac{x_1 + x_2 + x_3 + \ldots + x_n}{\text{Sample size } (K)} = \Sigma \overline{X}$

Range $R = \text{maximum value} - \text{minimum value}$

The mean of the means of samples

Grand mean $\overline{\overline{X}} = \dfrac{\text{Sum of means of samples}}{\text{Number of samples}} = \dfrac{\Sigma \overline{X}}{n}$

Mean range $\overline{R} = \dfrac{\Sigma R}{n}$

Upper control limit $\text{UCL} = \overline{\overline{X}} + A_2 \overline{R}$

Lower control limit $\text{LCL} = \overline{\overline{X}} - A_2 \overline{R}$

The values of A_2 can be obtained from table 2.

2. Range chart or R-chart

In case, of R-chart, we have

$$R = \text{Range} = \text{Highest value} - \text{Lowest value}$$

The central line (C.L.) is given by

$$\text{C.L.} = \overline{R} = \frac{\Sigma R}{n} \quad (n = \text{number of samples})$$

Upper control limit $\text{U.C.L.} = D_4 \overline{R}$

Lower control limit $\text{L.C.L.} = D_3 \overline{R}$

Table 3 shows the values of D_3 and D_4 for different number of items.

Table 3

No. of items in a sample (K)	D_3 Range lower limit	D_4 Range upper limit
2	0	3.27
3	0	2.57
4	0	2.28
5	0	2.11
6	0	2.00
7	0.14	1.86
10	0.22	1.78
12	0.28	1.72

Calculations of R-chart

Now we shall draw R-chart using R values given in table 1.

$$\overline{R} = \frac{26}{10} = 2.6 \text{ (Central line)}$$

$$\text{U.C.L.} = 2.28 \times 2.6 = 5.928 \qquad (\because D_4 = 2.28)$$

$$\text{L.C.L.} = 0 \times 2.6 = 0$$

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The R-chart is shown in fig. (2).

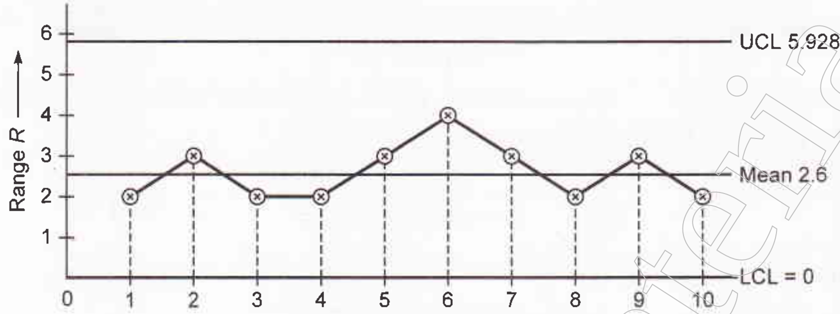

Fig. (2) Showing *R*-chart

> **Formulae used in *R*-chart**
>
> $$\text{Range } R = \text{Highest value} - \text{Lowest value}$$
>
> $$\text{Central line} = \overline{R} = \frac{\Sigma R}{n}$$
>
> where n = number of samples
>
> Upper control limit (UCL) $= D_4\,\overline{R}$, Lower control limit (LCL) $= D_3\,\overline{R}$
>
> where D_3 and D_4 are range lower limit and range upper limit respectively. Their values are given in table 3.

7.11 CONTROL CHARTS FOR ATTRIBUTES

Following are the control charts for attributes :

1. ***p*-chart (Control chart of fraction)**
2. ***n-p*-chart (Control chart of defective items)**
3. ***C*-chart (Control chart of number of defects per unit)**

1. Control chart of fraction (p-chart)

This is a fraction defective chart or % defective chart. In this chart each item is classified as ***good*** (non-defective) or ***bad*** (defective). This chart is used to control the general quality of the component parts. In this chart

$$\text{Central line} = \overline{p} = \frac{\text{Total number of pieces found defective}}{\text{Total number of pieces inspected}}$$

Upper control limit (UCL) is given by

$$\text{UCL} = \overline{p} + 3\sqrt{\left[\frac{\overline{p}\,(1-\overline{p})}{n}\right]}$$

where n = number of pieces inspected every day.

The lower control limit (LCL) is given by

$$\text{LCL} = \overline{p} - 3\sqrt{\left[\frac{\overline{p}\,(1-\overline{p})}{n}\right]}$$

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Calculations for p-chart

Let us draw a p-chart with the following specifications.

Table 4

Date	Number of pieces inspected (a)	Number of pieces found defective (b)	Fraction defective ($p = b/a$)
November 1	300	25	0.0834
November 2	300	30	0.1000
November 3	300	35	0.1167
November 4	300	40	0.1333
November 5	300	45	0.1500
November 6	300	35	0.1167
November 7	300	40	0.1333
November 8	300	30	0.1000
November 9	300	20	0.0666
November 10	300	50	0.1666
Total = 10	Total = 3000	Total = 350	

$$\text{Central line} = \bar{p} = \frac{350}{3000} = 0.1167$$

$$\text{UCL} = \bar{p} + 3\sqrt{\left[\frac{\bar{p}(1-\bar{p})}{n}\right]} = 0.1167 + 3\sqrt{\left[\frac{0.1167 \times (1 - 0.1167)}{300}\right]}$$

$$= 0.1167 + 3 \times (0.01852) \approx 0.1723$$

and $$\text{LCL} = \bar{p} - 3\sqrt{\left[\frac{\bar{p}(1-\bar{p})}{n}\right]} = 0.1167 - 3\sqrt{\left[\frac{0.1167 \times (1 - 0.1167)}{300}\right]}$$

$$= 0.1167 - 3 \times (0.01852) \approx 0.0611$$

The p-chart is shown in fig. (3).

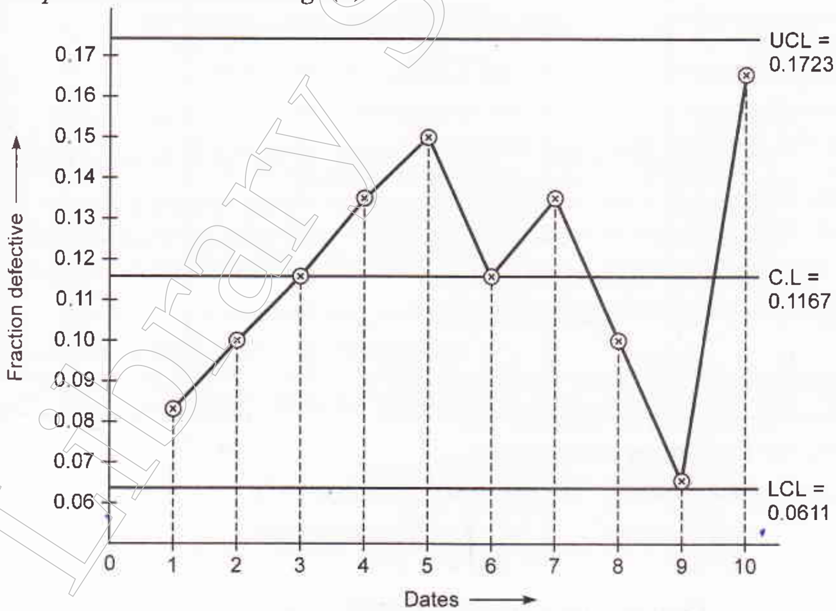

Fig. (3) *p*-Chart

Formulae used for p-chart

For central line, $\bar{p} = \dfrac{\text{Total number of pieces found defective}}{\text{Total number of pieces inspected}}$

The upper control limit is given by

$$UCL = \bar{p} + 3\sqrt{\left[\frac{\bar{p}(1-\bar{p})}{n}\right]}$$

where n = number of pieces inspected every day.

The lower control limit is given by

$$LCL = \bar{p} - 3\sqrt{\left[\frac{\bar{p}(1-\bar{p})}{n}\right]}$$

2. Control chart of defective items (*np*-chart) $n\bar{p}$

Central line (C.L.) $= n\bar{p}$

where $n\bar{p} = \dfrac{\text{Number of defective items in all samples}}{\text{Number of samples}}$

Upper control limit (UCL) $= n\bar{p} + 3\sqrt{[n\bar{p}(1-\bar{p})]}$

Lower control limit (LCL) $= n\bar{p} - 3\sqrt{[n\bar{p}(1-\bar{p})]}$

Calculations of np-chart

Let us consider the following example.

20 samples of size 20 each were inspected. Following are their results :

Sample No.	No. of defectives	Sample No.	No. of defectives
1	0	11	2
2	2	12	1
3	1	13	0
4	3	14	2
5	0	15	1
6	1	16	1
7	2	17	1
8	0	18	0
9	0	19	2
10	3	20	3
		$n = 20$	$\Sigma d = 25$

Now we shall draw the *np*-chart.

In the given problem, $n = 20$ and $K = 20$

$$\bar{p} = \left(\frac{\Sigma d}{nK}\right) = \frac{25}{20 \times 20} = 0.0625$$

Central line $= n\bar{p} = 20 \times 0.0625 = 1.25$

$$UCL = n\bar{p} + 3\sqrt{[n\bar{p}(1-\bar{p})]} = 1.25 + 3\sqrt{[1.25 \times (1-0.0625)]}$$

$$= 1.25 + 3\sqrt{(1.25 \times 0.9375)} = 1.25 + 3.25 = 4.50$$

$$LCL = n\bar{p} - 3\sqrt{[n\bar{p}(1-\bar{p})]} = 1.25 - 3\sqrt{[1.25 \times (1-0.0625)]}$$

$$= 1.25 - 3.25 = -2 \quad = 0 \text{ (being negative)}$$

The *np*-chart is shown in fig. (4).

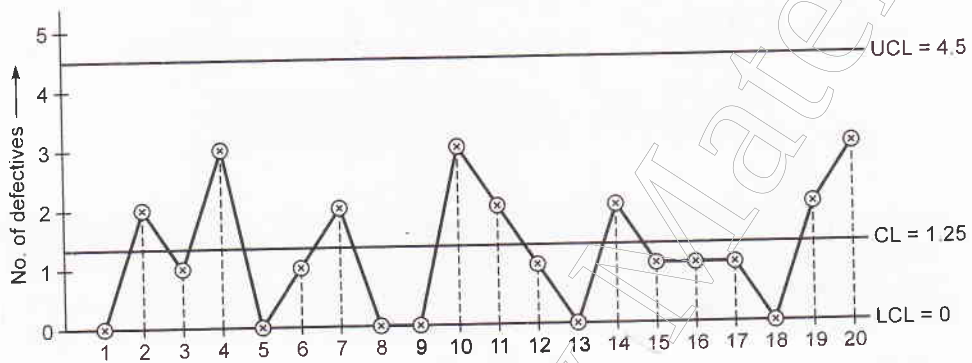

Fig. (4) *n-p* chart

It is observed from this chart that *np* of every sample lies inside of the LCL and UCL. Therefore, the process is under ***control.***

Formulae used in np-chart

$$\bar{p} = \frac{\text{No. of defectives}}{\text{Number of samples} \times \text{Number of size}} = \frac{\Sigma d}{nK}$$

Central line $= n\bar{p}$

$$UCL = n\bar{p} + 3\sqrt{[n\bar{p}(1-\bar{p})]}$$

$$LCL = n\bar{p} - 3\sqrt{[n\bar{p}(1-\bar{p})]}$$

$\boxed{3}$. Control chart of number of defects per unit (*C*-chart)

In this control chart number of defects in a place or a sample are plotted. It controls number of defects observed per unit or per sample. In *C*-chart, sample size is constant.

This chart is used where average number of defects are much less than the number of defects which would occur.

$$\text{Central line (CL)} = \bar{C} = \frac{\text{Total defects in all the items inspected}}{\text{Total number of items inspected}}$$

$$\text{Uper control limit (UCL)} = \bar{C} + 3\sqrt{\bar{C}}$$

$$\text{Lower control limit (LCL)} = \bar{C} - 3\sqrt{\bar{C}}$$

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Calculations of C-chart

Let us consider the C-chart of the following example :

Casting	No. of defects found on inspection C
1	2
2	4
3	1
4	5
5	5
6	6
7	3
8	4
9	0
10	7
Total = 10	Total = 37

Now $$\bar{C} = \frac{37}{10} = 3.7$$

Upper control limit (UCL) $= \bar{C} + 3\sqrt{\bar{C}} = 3.7 + 3\sqrt{(3.7)}$

$= 9.472$

Lower control limit (LCL) $= \bar{C} - 3\sqrt{\bar{C}} = 3.7 - 3\sqrt{(3.7)}$

$= -2.072 = \text{zero}$

Fig. (5) shows the C-chart

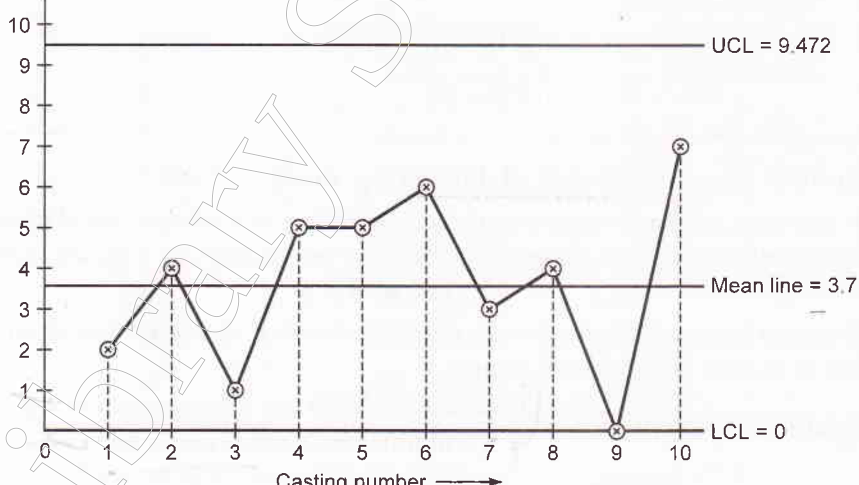

Fig. (5) *C*-chart

All values of C lies within the control limits. Therefore, the process is under ***control***.

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Formulae used in C-chart

$$\text{Central line (CL)} = \overline{C} = \frac{\text{Total defects in all the items inspected}}{\text{Total number of items inspected}}$$

Upper control limit is given by

$$\text{UCL} = \overline{C} + 3\sqrt{\overline{C}}$$

Lower control limit is given by

$$\text{LCL} = \overline{C} - 3\sqrt{\overline{C}}$$

Numerical Examples

Example 1 *25 samples of 4 units each were taken and their critical dimentions were measured. $\Sigma \overline{X}$ was 475 cm and ΣR was 150 cm. Determine the central line and both the control limits for $\overline{X}$ chart and R chart. Control factors $A_2 = 0.73, D_3 = 0$ and $D_4 = 2.282$.*

Solution Given $n = 25$, $K = 4$, $\Sigma \overline{X} = 475$ and $\Sigma R = 150$

$\overline{X}$ Chart

Central line $\overline{\overline{X}} = \frac{\Sigma \overline{X}}{n} = \frac{475}{25} = \mathbf{19}$

$$\overline{R} = \frac{\Sigma R}{n} = \frac{150}{25} = 6$$

$$\text{Upper control limit (UCL)} = \overline{\overline{X}} + A_2 \overline{R}$$
$$= 19 + (0.73)(6)$$
$$= 19 + 4.38 = \mathbf{23.38}$$

$$\text{Lower control limit (LCL)} = \overline{\overline{X}} - A_2 \overline{R}$$
$$= 19 - 4.38 = \mathbf{14.62}$$

R chart

$$\text{Central line (CL)} = \overline{R} = \frac{150}{25} = \mathbf{6}$$

$$\text{Upper control limit (UCL)} = D_4 \overline{R}$$
$$= 2.282 \times 6 = \mathbf{13.692}$$

$$\text{Lower control limit (LCL)} = D_3 \overline{R}$$
$$= 0 \times 6 = \mathbf{0}$$

Example 2 *Determine UCL and LCL for $\overline{X}$ chart and R chart for a sample size 4. The control factors are :*

$$A_2 = 0.729, \quad D_3 = 0 \quad \text{and} \quad D_4 = 2.282.$$

The values of $\overline{X}$ and R are given below is tabular form.

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Sample No.	$\overline{X}$	R
1	22.75	27
2	45.00	16
3	38.75	48
4	28.00	12
5	29.25	04
6	26.50	18
7	31.75	06
8	17.00	10
9	23.00	20
10	31.75	10
11	28.25	21
12	41.75	26
13	30.00	21
14	45.50	61
15	16.25	18

Solution $n = 15, \quad \Sigma \overline{X} = 455.50, \quad \Sigma R = 318$

$\overline{X}$ chart

$$\text{Central line (CL)} = \overline{\overline{X}} = \frac{\Sigma \overline{X}}{n} = \frac{455.50}{15}$$

$$= 30.37$$

$$\overline{R} = \frac{\Sigma R}{n} = \frac{318}{15} = 21.20$$

$$\text{Upper control limit (UCL)} = \overline{\overline{X}} + A_2\overline{R}$$

$$= 30.37 + (0.729 \times 21.20) = \mathbf{45.82}$$

$$\text{Lower control limit (LCL)} = \overline{\overline{X}} - A_2\overline{R}$$

$$= 30.37 - (0.729 \times 21.20) = \mathbf{14.92}$$

R chart

$$\text{Central line (C.L.)} = \overline{R} = \mathbf{21.20}$$

$$\text{Upper control limit (UCL)} = D_4\,\overline{R} = 2.282 \times 21.20$$

$$= \mathbf{48.38}$$

$$\text{Lower control limit (LCL)} = D_3\,\overline{R} = 0 \times 21.20$$

$$= \mathbf{0}$$

imp

Example 3 *The following table gives the mean ($\overline{X}$) of 20 samples. Size of each sample is 25. The population standard deviation is 13. Draw the control chart for the mean :*

$$\overline{X}\begin{cases} 31 & 25 & 31 & 33 & 20 & 27 & 18 & 20 & 17 & 27 \\ 30 & 32 & 29 & 31 & 25 & 37 & 23 & 19 & 28 & 27 \end{cases}$$

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Solution Given $n = 20$, $k = 25$ and $\sigma_P = 13$

$$\text{Central line (CL)} = \overline{\overline{X}} = \frac{\Sigma X}{n} = \frac{530}{20} = \mathbf{26.50}$$

$$\text{Upper control limit (UCL)} = \overline{\overline{X}} + \frac{3\,\sigma_P}{\sqrt{K}}$$

$$= 26.50 + \frac{3 \times 13}{\sqrt{25}}$$

$$= 26.50 + 7.80 = \mathbf{34.30}$$

$$\text{Lower control limit} = \overline{\overline{X}} - \frac{3\,\sigma_P}{\sqrt{K}} = 26.50 - \frac{3 \times 13}{\sqrt{25}}$$

$$= 26.50 - 7.80 = \mathbf{18.70}$$

The $\overline{X}$ chart is shown in fig. (6).

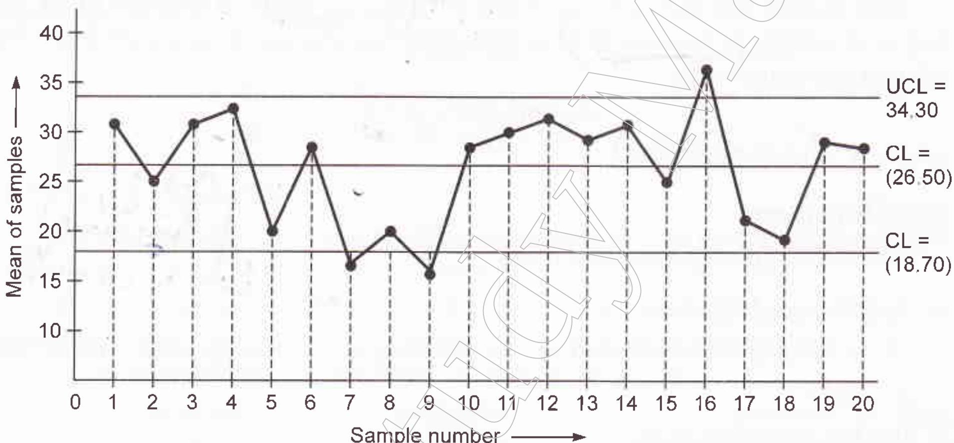

Fig. (6) $\overline{X}$ chart

It is observed that sample no. 7, 9 and 16 lie outside the control limits but sample no. 16 lies outside to UCL. Therefore, the process of this sample appears to be ***out of control***.

Example 4 *The total number of defects in 30 large size samples at a work station was 480. Apply the position distribution to determine the central line and the upper and lower control limits for the number of defects in the sample.*

Solution
$$\text{Central line (CL)} = \frac{\text{Total number of defects}}{\text{Total number of units observed}}$$

$$\overline{C} = \frac{480}{30} = \mathbf{16}$$

$$\text{Upper control limit (UCL)} = \overline{C} + 3\sqrt{\overline{C}}$$

$$= 16 + 3\sqrt{(16)} = 16 + 3 \times 4 = \mathbf{28}$$

$$\text{Lower control limit (LCL)} = \overline{C} - 3\sqrt{\overline{C}}$$

$$= 16 - 3\sqrt{16} = 16 - 12 = \mathbf{4}$$

7.12 SAMPLING AND SAMPLING PLANS

Sampling

Sampling is an act of drawing samples from a batch on random basis.

Consider that a box contains a lot or batch (of component parts). It is important to mention here that in the sampling process, the samples must be collected from all sides and different depths of the box so that every part has an equal probability or chance of being selected.

For a sample to represent truly a lot, the samples should be collected at regular intervals (say every hour, every six hour, every day, etc.) from the entire production run.

The sample size normally increases with the lot size and depends upon the degree of quality to be assured. The following relation serves as a good guide for calculating sample size :

$$\text{Sample size} = \sqrt{(2N)}$$

where N = batch or lot size.

C → C
K → Def
n → No.
K < C → Ac

Sampling plans

Following are the sampling plans :

1. ***Single sampling plans***

A lot is accepted or rejected on the basis of a *single sample* drawn from that lot.

2. ***Double sampling plans***

In case, it is not possible to decide the fate of the lot on the basis of single sample, then a second sample is drawn from that lot. The final decision is taken on the basis of combined results obtained with both the samples.

3. ***Multiple sampling plans***

In this plan, a lot is accepted or rejected on the basis of results obtained from several samples.

4. ***Sequential sampling plans***

This is also known as *item by item analysis.* This sampling involves increasing the sample size by one part at a time till the sample becomes large enough and contains sufficient number of defectives. On the basis of results obtained, it is decided whether the lost should be accepted or rejected.

7.13 SINGLE SAMPLING PLAN

In single sampling plan, a lot is accepted or rejected on the basis of single sample drawn from that lot.

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Method

Following steps are used :

1. A single sample of size n (*i.e.*, n component parts) is selected from the lot. The sample size may either be calculated with the formula $\sqrt{2N}$ (N = batch or lot size) or found from the table.
2. The sample is inspected and the defected components from the lot are selected and taken out.
3. If the number of defective pieces exceed the acceptance number C, then the lot is rejected.
4. If the lot is rejected then each and every piece of the lot is inspected. The defective parts are replaced.

Let, x be the number of defective pieces. If acceptance and rejection number for a sampling plan be C and R, respectively then there can be three outcomes of the inspection :

(i) If $x \leq C \rightarrow$ accepted

(ii) If $x \geq R \rightarrow$ rejected

(iii) If $C < x < R \rightarrow$ take the next sample

Calculation of sample size

For the calculation of sample size, let us explain the meaning of *acceptable quality level* (A.Q.L.) and *lot tolerance percent defective* (L.T.P.D.).

Acceptable quality level (A.Q.L.). It indicates a small proportion of bad components in a lot such that the lots having less than this proportion of bad components have a high probability of getting accepted.

Lot tolerance percent defective (L.T.P.D.). It indicates a small proportion of bad components somewhat larger than acceptable quality level in a lot such that the lots having more than this proportion of defective components have a small probability of getting accepted.

Given that AQL or $p_1 = 2\%$

$$\text{LTPD} = 9.2\%$$

$\therefore$ Operating ratio, $$R_0 = \frac{\text{LTPD}}{\text{AQL}} = \frac{9.2}{2} = 4.6$$

Table given below shows the producer's risk = Consumer's risk

TABLE

R_0	C	np_1
4.6	4	1.97
4.0	5	2.61
3.6	6	3.29

It is obvious from this table that for $R_0 = 4.6$, the values of C and np_1 are 4 and 1.97 respectively.

Therefore, Size of the sample $= \dfrac{np_1}{p} = \dfrac{1.97}{2\%} = \mathbf{99}$

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The sample size can also be determined with the help of standard table. Consider the following example :

Example *Using the table given below, for a lot size of 1200 and allowable percent defective 4% determine the sample size.*

TABLE

Lot size	Sample size	Allowable percent defective				
		1	2	3	4	5
		C	C	C	C	C
upto 499	75	1	2	3	4	5
500–799	115	2	3	4	6	8
800–1299	150	3	4	5	8	10
1300–3199	225	4	5	8	11	14
3200–7999	300	5	7	10	14	18

Solution Table gives a sample size 150 and acceptable number C as 8.

This means that a lot containing 1200 parts, at random pick up 150 parts. Inspect these parts and find out the number of defective pieces. If defective pieces are upto 8, the lot is ***accepted*** otherwise ***rejected***.

7.14 DOUBLE SAMPLING PLAN

When it is not possible to decide the fate of the lot on the basis of first sample. then a second sample is drawn out of the same lot. Now the decision whether to accept or reject the lot is taken on the basis of the combined results of first and second samples.

Double sampling plane procedure

Given that C_1 and C_2 as acceptance numbers and $C_2 > C_1$.

Procedure

1. Inspect a sample for size n_1 and count defective parts K_1.
2. We have the following three possibilities.
   (i) $K_1 \leq C_1$ (Result : ***accept the lot***).
   (ii) $K_1 > C_2$ (Result : ***reject the lot***)
   (iii) $C_1 < K_1 \leq C_2$ (***no decision***)

For (iii) condition, the following procedure is adopted

(a) Draw another sample of size n_2. Now the total sample size is $(n_1 + n_2)$.

(b) Inspect the sample and count defective parts. The defective parts are now $(K_1 + K_2)$.

(c) We have the following possibilities

(i) $(K_1 + K_2) \leq C_2$ (Result : ***accept the lot***)

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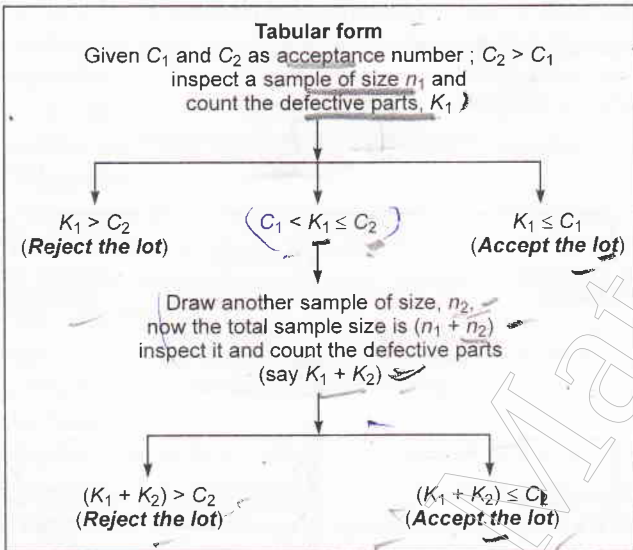
(ii) $(K_1 + K_2) > C_2$ (Result : ***reject the lot***)



7.15 SEQUENTIAL SAMPLING PLAN

The sequential sampling plan is of the following two types :
1. *Multiple sampling plan* and **2. *Item by item analysis***

1. Multiple sampling plan

A multiple sampling plan accepts or rejects a lot upon the results obtained from several samples.

The procedure is as follows :

1. Inspect the first sample and count the number of defects.
2. There are three possibilities
   (i) The number of defects is very small (Result : ***accept the lot***)
   (ii) The number of defects is very large (Result : ***reject the lot***)
   (iii) Borderline and undecisive (***No decision***)

For the third condition, we proceed as follows :

(a) Draw a second sample and inspect it. Combined the number of defects in the first and second samples.

(b) There are three possibilities
   (i) The number of defects is very small (Result : ***accept the lot***)
   (ii) The number of defects is very large (Result : ***reject the lot***)
   (iii) Borderline and undecisive (***No decision***)

For the third probability, we proceed as follows :

(c) Draw a third sample and inspect it. Count the number of defective pieces in all the three samples.

(d) There are three possibilities.
   (i) The number of defects is very small (Result : ***accept the lot***)

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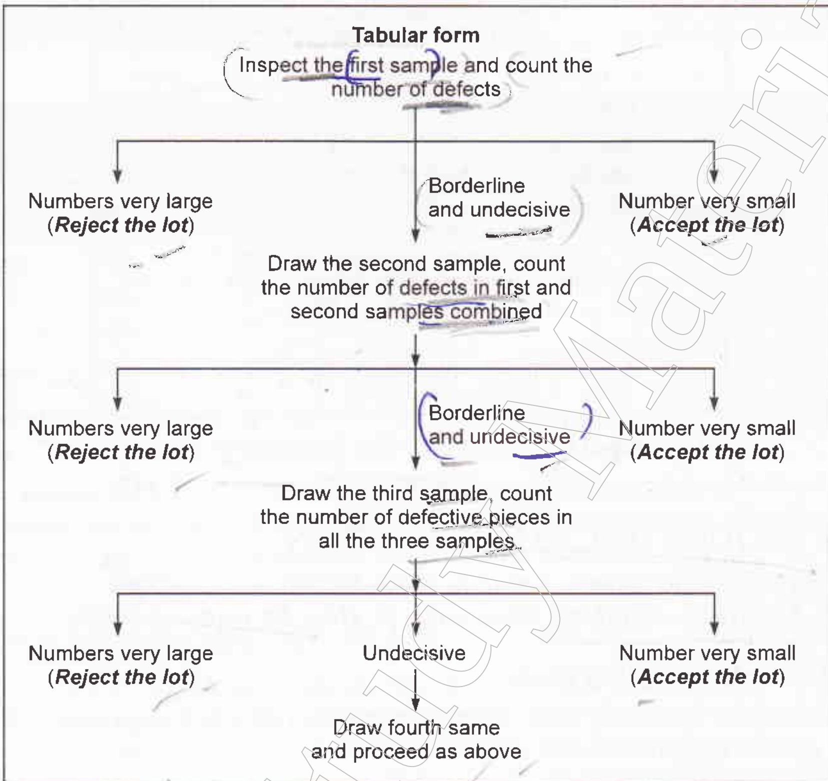
(ii) The number of defects is very large (Result : ***reject the lot***)

(iii) Borderline and undecisive (***No decision***)

For third probability proceed as above.



2. Sequential sampling plan (Item by item analysis)

It is a plan in which size is increased by one piece at a time till the sample becomes large enough and contain a large number of defective pieces to decide whether the lot should be accepted or rejected.

Although this plan is easy to design but more expensive because more steps are needed to take a decision. Since, sample size is increased by one at a time. sample results are analysed much faster than a single or double sampling plan.

This plan is seldom used in lot acceptance control. On the other hand, it is important because multiple sampling is based on it.

REVIEW QUestions

1. Give the meaning and definition of quality control.
2. Define quality. What are the objectives of quality control?
3. What is quality? What are the factors affecting quality?
4. What do you mean by quality control? What are the objectives and benefits of quality control?
5. Discuss the different steps taken in quality control.

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6. What is meant by statistical quality control? Give the fundamental basis of statistical quality control.
7. What is statistical quality control? Describe the significance of statistical quality control.
8. What is a control chart? State the puspose and advantages of control chart.
9. What are different control charts for variables? Describe any one of them.
10. Discuss $\overline{X}$ chart or mean chart.
11. What do you mean by central line, upper control limit and lower control limit. Discuss the range chart or R-chart.
12. Name the control charts for attributes. Discuss one of them.
13. Discuss the following charts :
    (i) p-chart (ii) np-chart (iii) C-chart
14. What do you mean by sampling and sampling plans?
15. Define the following
    (i) Acceptable quality level (AQL) (ii) Rejectable quality level (RQL)
    (iii) Indifference quality level (IQL) (iv) Average outgoing quality (AOQ)
16. Give the industrial applications of acceptance sampling.
17. Describe a single sampling plan. How will you calculate the sample size.
18. What is double sampling plan? Describe the double sampling plan procedure.
19. Discuss multiple sampling plan. Describe its procedure.
20. What do you mean by a sampling plan? Describe the sequential sampling plan.

PROBLEMS

1. Determine the control limits for $\overline{X}$ and R charts of $\Sigma\,\overline{X} = 357.50, \Sigma\,R = 9.90$. Number of groups = 25. It is given that $A_2 = 0.18, D_3 = 0.41$ and $D_4 = 1.59$.
   [**Ans.** $\overline{X}$-chart 14.372, 14.228, R-chart 0.629, 0.162]
2. Using the data given in table 4, calculate the control limits for n-p chart.
   [**Hint.** Central line $\overline{p} = \dfrac{350}{3000} = 0.1167$

$$n\overline{p} = 300 \times 0.1167 = 35.01$$
$$\text{UCL} = n\overline{p} + 3\sqrt{n\overline{p}\,(1-\overline{p})}$$
$$= 35.01 + 3\sqrt{35.01 \times (1 - 0.1167)} = 51.69$$
$$\text{LCL} = n\overline{p} - 3\sqrt{n\overline{p}\,(1-\overline{p})}$$
$$= 35.01 - 3\sqrt{35.01 \times (1 - 0.1167)} = 18.33$$

3. 20 samples each of size 5 were taken whose $\Sigma\,\overline{X} = 585$ and $\Sigma\,R = 410$. Control factor d_2 for a size of 5 is 2.326. Draw control limits for $\overline{X}$ chart.
   [**Hint.** $\overline{\overline{X}} = \dfrac{\Sigma\,\overline{X}}{n} = \dfrac{585}{20} = 29.25;$ $\overline{R} = \dfrac{\Sigma\,R}{n} = \dfrac{410}{20} = 20.50$

$$\sigma_P = \frac{\overline{R}}{d_2} = \frac{20.50}{2.326} = 8.81$$

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$$\text{UCL} = \overline{\overline{X}} + \frac{3\sigma_P}{\sqrt{K}} = 29.25 + \frac{3 \times 8.81}{\sqrt{5}} = 41.05$$

$$\text{LCL} = \overline{\overline{X}} - \frac{3\sigma_P}{\sqrt{K}} = 29.25 - \frac{3 \times 8.81}{\sqrt{5}} = 17.45$$

$\overline{X}$ chart is shown below.

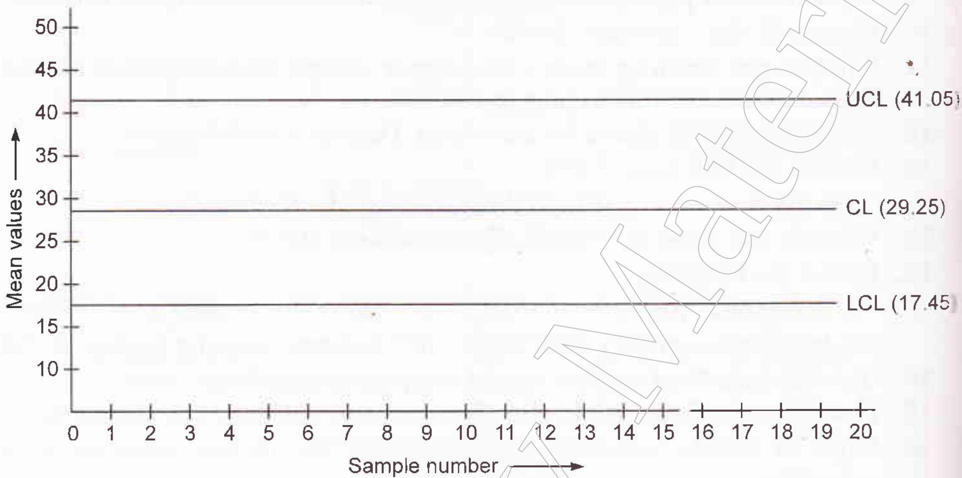

Fig. (7) $\overline{X}$ chart

4. Determine the central line and control limits for R-chart with the following specifications :

$\Sigma R = 60$, $n = 10$ and for a size of sample 4, $D_1 = 0, D_2 = 4.918$ and $d_2 = 2.059$

[**Hint.** Central line $\overline{R} = \frac{\Sigma R}{n} = \frac{60}{10} = 6$

$$\text{UCL} = D_2 \frac{\overline{R}}{d_2} = 4.918 \times \frac{6}{2.059} = 14.33\,; \quad \text{LCL} = D_1 \frac{\overline{R}}{d_2} = 0 \times \frac{6}{2.059} = 0]$$

5. A manufacturer finds that on an average 1 in 10 of the items produced by him is defective. A few days later, he finds that 20 items in a sample of 100 items are defective. Is the process in control?

[**Hint.** $\overline{p} = \frac{1}{10} = 0.1$

$$\text{UCL} = \overline{p} + 3\sqrt{\left[\frac{\overline{p}\,(1-\overline{p})}{n}\right]} = 0.1 + 3\sqrt{\left[\frac{0.1 \times 0.9}{100}\right]} = 0.19$$

$$\text{LCL} = \overline{p} - 3\sqrt{\left[\frac{\overline{p}\,(1-\overline{p})}{n}\right]} = 0.1 - 3\sqrt{\left[\frac{0.1 \times 0.9}{100}\right]} = 0.19$$

In the second case, $\overline{p} = \frac{20}{100} = 0.20$

This is higher than the UCL (0.19). Therefore, the process is ***out of control***.]

□□□

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8 TOTAL QUALITY MANAGEMENT (TQM)

Learning Objectives

After reading this chapter, you will understand :

- Introduction to TQM with definition
- Basic approach of TQM
- Essentials of TQM focus
- Characteristics of TQM
- Necessity for TQM
- Pillars of TQM
- TQM Framework
- Evolution of TQM
- Stages in TQM Implementation
- TQM models
- Failure of TQM programme
- ISO-9000 Series

INTRODUCTION

Let us first analyse the three words of total quality management (TQM), we have

Total—made up of the whole

Quality—Degree of excellence that a product provides

Management—Act, art or manner of handling, controlling, directing, etc.

The product which brings satisfaction is termed as ***quality product.*** The following factors are commonly expressed as need of a customer :

(i) Affordable cost
(ii) Longer life
(iii) Reliable performance
(iv) Look of the product
(v) Easy maintenance
(vi) Prompt after sales service
(vii) Its utility in the life

So, the quality is the ***customer satisfaction***, *i.e.*, delighting the customer. The quality is also defined as ***fitness for use.*** Total quality management is a philosophy which puts customer at the heart of production process and motivates workers to be concerned with quality at every stage of production process. In TQM the quality is ensured by workers and not inspectors.

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8.1 DEFINITION OF TQM

Total quality management (TQM) is defined as a philosophy designed to make an organisation ***faster, flexible, focussed*** and ***friendly***. It leads to a structured system that focusses each employee on customer. It creates an environment that allows organisation wide participation in planning and implementing a ***continuous improvement process*** to meet ***customer needs***.

TQM is an effective system for integrating the ***quality maintenance, quality development*** and ***quality improvement*** efforts of different functions of business to enable ***production*** and ***service*** at most ***economical levels*** to meet ***customers satisfaction.***

The total quality mangement can also be defined into a number of ways. Here, we present few standarded definitions.

- The total quality management is a total approach to put quality in every aspect of management.
- TQM is basically a business philosophy founded on customer satisfaction. That means low cost, high quality and speed drive all processes.
- This is defined as fitness for use or purpose.
- TQM is defined as a total organization working as a team to meet the customer needs and expectation by using systematic approach to continuous improvement.
- TQM is a cooperative form of doing business that relies on the talents and capabilities of both labour and management to continually improve quality and productivity using team.
- TQM is defined as developing, manufacturing, administering and distribution of low cost product and services that a customer wants or needs.
- TQM is a comprehensive and integrated way of managing any organization in order to meet the needs of customer consistently and to achieve continuous improvement in every aspect of the organization activities.
- TQM means that everyone in the organization is involved in the final product or service to the customer.

8.2 BASIC APPROACH OF TQM

Following are the six basic concepts that a TQM requires :

1. A committed and involved management to provide long term top-to-bottom organizational support.
2. Focus on the customer needs, both internally and externally.
3. Continuous improvement of the business and production process.
4. Proper utilization of entire work force.
5. Sympathetical behaviour to suppliers and partners.

6. Establish performance measure for the processes, *i.e.,* stepwise checkup for every part of the product.

The following chart shows the elements of TQM concept

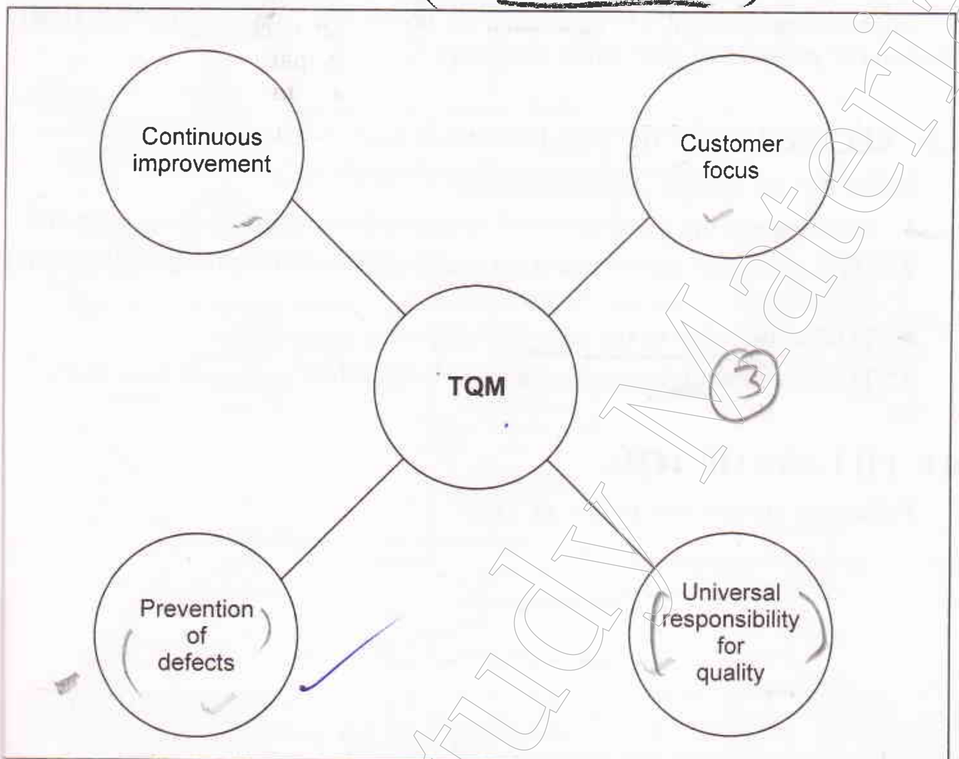

Fig. (1) Elements of TQM Concept

8.3 ESSENTIALS OF TQM FOCUS

Following are the essentials of TQM focus

1. Leadership
2. Quality policy and quality cost
3. Organisational structure
4. Employee involvement
5. Supplier selection and development
6. Use of continuous plan, checking, art (PDCA), etc.
7. Customer satisfaction
8. Recognition and reward

8.4 CHARACTERISTICS OF TQM

There are four major characteristics. They are :

1. **Totality.** It refers all areas and functions, all activities, and all employee for optimum quality at all times.

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2. **Improvements.** It specifies the ability which leads to development.

3. **Foundation.** This concerns with company's organisational structure and system. This ensures the scope of quality functions within organisation.

4. **Documentation.** It is integrated people-machine-information (PMI) relations to make the TQM effort happen.

8.5 NECESSITY FOR TQM

Following are the necessity for TQM :

1. All personnel are involved which improves motivation and commitment.
2. TQM provides assurance that performance and processes are well understood.
3. TQM adds value to the services offered to customers.
4. TQM is economic in the long term to both the company and customers.

8.6 PILLARS OF TQM

Following are the five pillars of TQM.

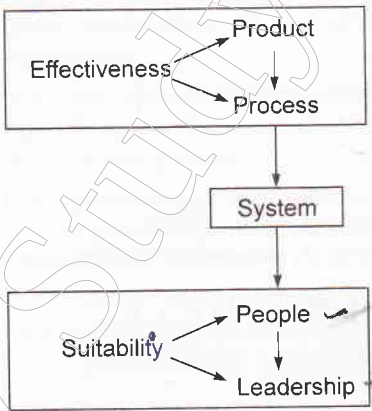


Fig. (2a) Pillars of TQM

Therefore, TQM focusses primarily on total satisfaction of both internal and external customers within a management environment that seeks continuous improvement of all systems and processes.

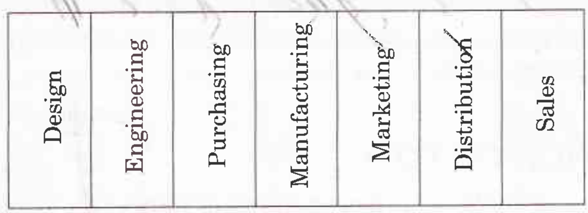
So, TQM is necessary. It is a journey that never ends, *i.e.*, a way to survive and succeed.

Organisation wide impact of TQM

A TQM requires a very committed and supportive management structure and system. This is resulted in shifting of management of such a new quality efforts from hands at functional managers to company's general management.

Fig. (2b) shows the different functional divisions

Functional Divisions



Total quality management

Fig. (2b) Showing different functional divisions

8.7 TQM FRAMEWORK

Fig. (3) shows the framework for the TQM system.

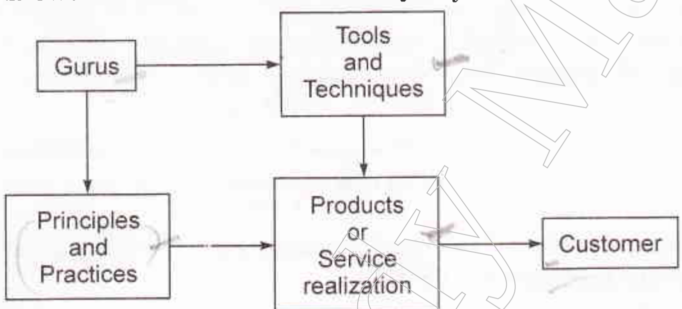


Fig. (3) TQM Framework

The framework starts with the knowledge provided by gurus of quality. They are : Shewhart, Deming, Juran, Figenbaum, Ishikawa, Crosby and Taguchi. They contributed to the development of principles and practices and/or tools and techniques.

The ***tools*** are :

Information technology
Quality management systems
Enviromental management systems
Quality by design
Failure models
Product and service liability
Total productive maintenance
Management tools
Experimental design

The ***principles*** and ***practices*** concerns the following

People and relationship
Customer satisfaction
Employee involvement
Supplier partnership

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Some tools and techniques are used in products or service realization.

Feedback from customers provides information to continuously improve the organization's system, product and service.

8.8 EVOLUTION OF TQM

The evolution of TQM, as it has emerged in industries is shown in fig. (4).

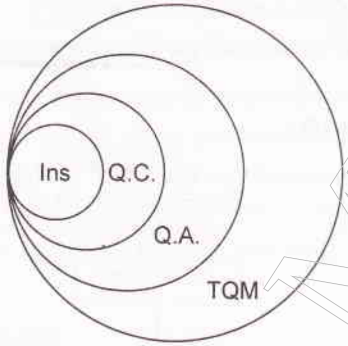

Fig. (4) TQM evolution

It includes, inspection (Ins), quality control (Q.C.), quality assurance (Q.A.) and total quality management (TQM).

The main focus on each of these stages are :

1. Inspection

Every industry has an inspection department. At the final stage of the process (manufacturing or service), it is inspected to check. In case, the inspection reveals the positive trend, the process is approved. On the other hand, if the inspection shows negative trend, the process is rejected. Inspection is essentially an ***end of pipe approach.*** So, ***inspection is a tool for checking quality.*** The underlying principle in this process of inspection is that ***"end justifies means".*** Therefore, in inspection, we have to focus on the following points :

(i) *Identifying non-conformities*
(ii) *Salvaging*
(iii) *End of pipe approach*
(iv) *End justifies means*

2. Quality Control

There are a number of lacunae in the process of inspection. Therefore, a quality control approach is used. In quality control, the process is given importance. In this process, ***performance data*** are collected and ***statistical techniques*** are used to keep the process under control. ***Instrumentation*** is also used to maintain quality. This made people inside to assess and know the

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quality of the process and product. However, people outside remained in dark. Quality control focusses on the following points :

(i) *Process performance data*

(ii) *Quality planning*

(iii) *Statistical tools*

(iv) *Control instrumentation*

3. Quality assurance

The next process is quality assurance. ***Documentation*** forms the most important part. The philosophy of "say what you do and do what you say" is adopted in every industry. ***Certification*** procedures are formulated and International bodies such as ISO (International Standards Organization) came out with ISO series certification. Such certifications assured about the quality of the product of the company. ***Quality manuals*** are also provided by the company. ***Quality cost*** is also another important factors. So, the company focusses on

(i) *Documentation*

(ii) *System certification*

(iii) *Quality manuals*

(iv) *Quality costs*

4. Total quality management (TQM)

This is essentially a management philosophy where every individual in the organization is motivated to work hard and contribute his power to improve quality of the product. The management provides an ideal environment for continuously improving their performance and resulting in better business opportunities. Therefore, total quality management includes ***teamwork, continuous improvement*** and ***performance measurement.*** The TQM also focusses on ***customers*** and considers the customers as king. Customers choice is given the most important consideration because ultimately the product has to go in the hand of customers for their use. For TQM, we have

(i) *Customer focus*

(ii) *Employer involvement*

(iii) *Continuous improvement*

(iv) *Performance measurement*

8.9 STAGES IN TQM IMPLEMENTATION

The various stages in an organization during TQM implementation are :

1. ***Unhealthy situation***
2. ***No relaxing situation***
3. ***Common goal or same vision situation***
4. ***Team work situation***

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All these situations are shown in fig. (5).

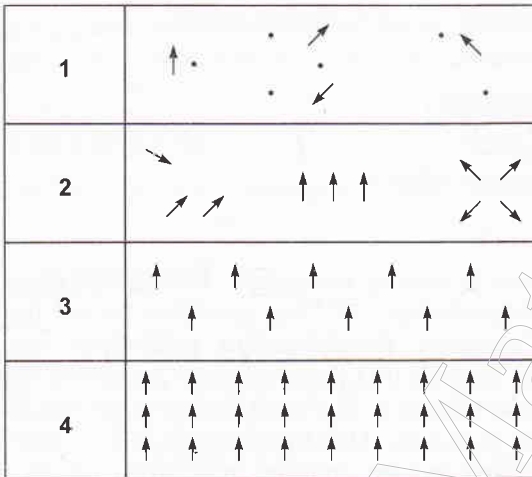

Fig. (5) Stages of development during TQM Implementation

Description of various stages

1. *Unhealthy situation*

This is the stage in which only few people (four) are constantly working as shown by arrows. The other people (six) shown by dots are doing very minimal work, *i.e.,* relaxing. This is unhealthy situation for an organization.

2. *No relaxing situation*

Under this situation, there is no dot in the fig. (5), *i.e.,* no people is relaxing. The peoples (ten) shown by arrows are focused in different directions. This shows that there is no single focus for the organization. Every people is working in his own way.

3. *Common goal or same vision situation*

As shown in the figure, all the arrows are pointing towards the same direction, *i.e.,* all people are working in the same direction. Therefore, all have a common goal or vision for the organization. This is a better situation in comparison to two previous situations.

4. *Team work situation*

It is obvious from the figure, that the number of arrows in the same direction is increased. This does not mean that the number of people (10) is increased but the increase is due to the fact that effect of ten people working towards a common goal has increased. This shows a *team work.* It is important to mention here that the people working as a team has an effect many times greater than when they are working as group. The team work situation shows a tremendous increase in productivity. In other words, we can say that with input remaining the same, the output is tremendously increased.

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Implementation of TQM strategies will be effective only when the organization is in a stage **4.** So, every organization should aim to reach stage 4 at the earliest.

The key factors for stagewise improvement is shown in fig. (6).

Stage 1 →	Stage 2	***Empowerment***
Stage 2 →	Stage 3	***Common Vision***
Stage 3 →	Stage 4	***Team Work***

Fig. (6) Key factors for stagewise Improvement

When the employees are empowered, it can be best assured that stage 2 is reached.

If the organization is in stage 2, then for movement to reach stage 3 requires a common vision.

In order to reach stage 4 from stage 3, one has to work towards teaming up the people.

8.10 TQM MODELS

There are various models adopted by different companies for implementing TQM. Here we shall consider the following different TQM models :

1. TQM ***transition model***
2. ***Integrated*** TQM ***model***
3. ***Operational*** TQM ***model***.

Considering the different conditions in the industries, it is recommended that in first step, TQM transition model should be adopted and as a second step, the integrated TQM model should be followed.

8.10-1 TQM TRANSITION MODEL

In this model, all initiatives are focused on *customers* and the customer is treated as a *key factor*. All the needs of customers are understood and fulfilled. To achieve this, the following three approaches are recommended :

(i) ***Vision***, (ii) ***Continuous improvement*** and (iii) ***Involvement of everyone.***

These are the three corner stones as shown in fig. (7). The three factors should be treated in the same order as shown in the figure.

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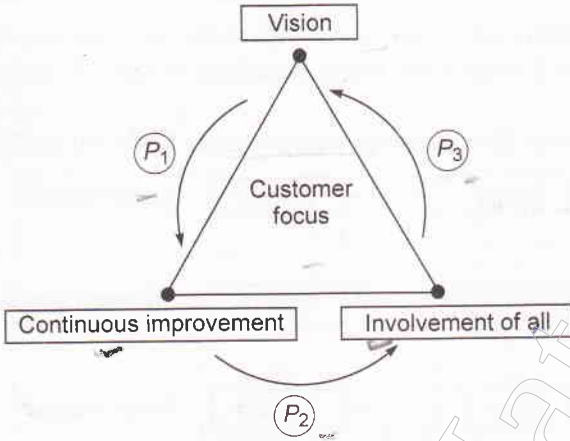

Fig. (7) TQM transition model

(i) *Vision*

The vision includes, *mission*, *objectives*, *goals*, *targets* and *action plans*. When the vision statement is formulated, then the next step is to concentrate on *system perfection*.

There are different views regarding the fact that whether the importance should be given first to *system component* or to *human component*. Considering all situations, it is said that irrespective of the type of company, it is always system first and human next.

(ii) *Continuous improvement*

The continuous improvement concerns with *system component*. The system component includes *technologies*, *procedures*, *resources* (such as machines), etc. Each system component should be given utmost care and importance. Continuous improvement is based on the current need in industries. The industries are required to produce better quality products at reduced costs in future. This is only possible when continuous improvement strategy is given greater importance.

(iii) *Involvement of everyone*

The involvement of everyone represents the *human* component. This includes *quality culture*, *training of personnel*, *attitude*, *relationship*, *cooperation*, etc. The main consideration is *team work*. This is a critical and difficult situation. Every effort should be made to include team spirit among employees to work whole-hearted for the implementation of TQM.

Involvement of everyone is only a single component which stands between the *success and failure* of TQM implementation in any industry.

In this model, following processes are used :

(a) ***Planning process*** (represented by P_1)

(b) ***Doing process*** (represented by P_2)

(c) ***Checking process*** (represented by P_3)

(a) ***Planning process*** **(P_1)**

This includes *benchmarking* and *long term planning*.

Benchmarking requires that an industry should select the strong areas of their competitors and take steps to improve themselves on these areas. Every industry should strive hard to benchmark their products against the best in the market and work for self improvement.

There is a failure in some companies due to their vision of short term gain. Quality management advocates *long term planning* with a clear vision.

(b) ***Doing process*** **(P_2)**

Doing process concerns with *quality and preventive mechanisms*.

The quality must be ensured in every activity of the industry. Scientific methods have to be introduced in every activity because it guarantees a foolproof analysis and solution.

It is recommended that preventive techniques are to be found out for every possible defect or failure in the organization and should be built in.

(c) ***Checking process*** **(P_3)**

The checking process includes *performance of employees, administrative audit of funds, implementation of* TQM and *progress of organization*. After checking process necessary improvement measures should be taken as and when required.

8.10-2 INTEGRATED TQM MODEL

In this model, preventive measures will ensure that without completing one's responsibility, he will not be able to take up the next responsibility. Therefore, in this model, evaluation of processes, auditing and performance appraisal do not find a place.

The integrated TQM model is shown in fig. (8). It has the following three approaches :

(i) ***Managment leadership,*** (ii) ***Product/process excellence*** and (iii) ***Human resource excellence.***

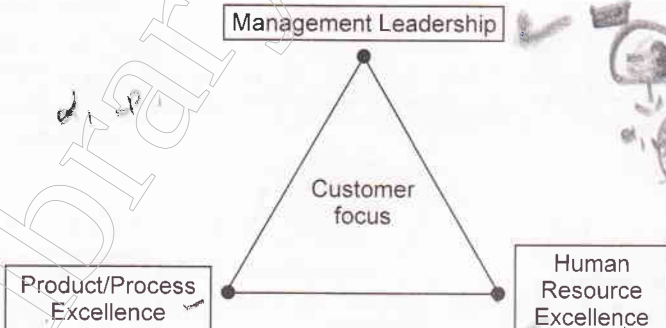

Fig. (8) Integrated TQM model

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(i) ***Management leadership***

It incorporates

(a) Proper vision

(b) 100% commitment from management

(iii) Motivation to employees

(iv) Strategic planning

(ii) ***Product/process excellence***

It reflects the system component of TQM

(a) Continuous improvement

(b) Preventive measures

(c) Documentation

(d) Data base approach

(iii) ***Human resource excellence***

It reflects the human component of TQM

(a) Training

(b) Team building

(c) Information communication

(d) Crossfunctional style

8.10-3 OPERATIONAL TQM MODEL

This model provides various point of view of management style. This model is based on participation and team work. This is focussed on the ***self-motivated*** and ***self-empowered teams*** consists of multi-skilled workers.

The another important point of this model is the judicious choice of various qualitative and quantitative tools to analyse quality problems situations.

The model is shown in fig. (9).

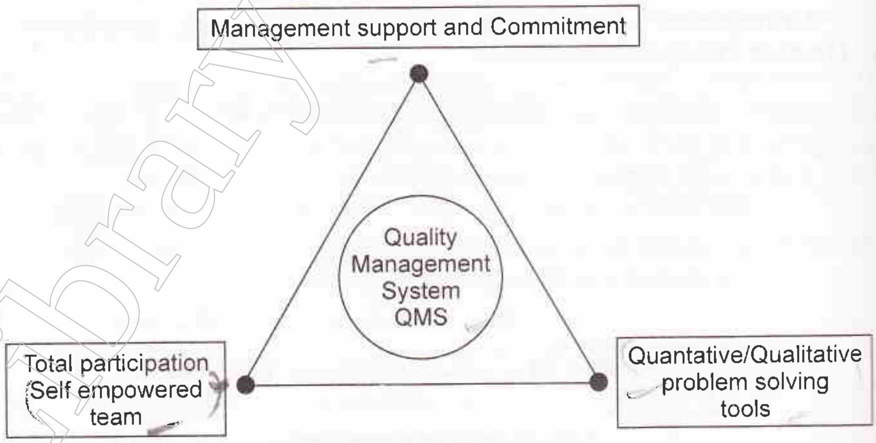

Fig. (9) Operational model of TQM

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8.11 FAILURE OF TQM PROGRAMS

The most common reasons for the failure of TQM programs are :

1. Lack of commitment from the top management.
2. Using some specific techniques rather than focussing on the system.
3. Program stops with training.
4. Expecting immediate results not a long term pay-off.
5. Not obtaining employee buy-in and participation.
6. No continuous improvement in the quality of product.
7. Not focussing on the requirement and demand of the customers, *i.e.*, customer satisfaction.
8. Not employing expert management of the field.
9. Not focussing on the reasonably cost of the product.
10. Not using quality equipment.

8.12 ISO-9000

The International Organisation for Standardisation (ISO) was founded in 1946 and adopted a series of ***written quality standards*** in 1987. These are called the ISO-9000 standards. These were revised in 1994. The standards are recognised by over 120 countries including India and Japan. Therefore, ISO-9000 refers to a ***set of quality management standards.***

Definition

The series of ISO-9000 tells manufacturers and suppliers, ***what is required of a quality-oriented system.*** It does not set out extra-ordinary requirements which only a very few firms can or need comply with, but it is a partial standard for quality system which can be utilised by all organisations. It defines the ***concepts*** and ***specifies the procedures*** and ***criteria*** to ensure that what leaves your organisation meets the customers requirements. So, ISO-9000 ***certifies the process or system used to manufacture a product or service.***

ISO-9000 and TQM

ISO-9000 is not TQM but it is a subcomponent of TQM. It is a good start on TQM path. ISO is only the minimum required quality standard that a supplier must demonstrate to receive ISO-9000 accrediation. TQM links quality to customer satisfaction.

8.13 OBJECTIVES OF ISO-9000

The basic objectives of ISO-9000 are :

(a) To facilitate International trade of goods and services.

(b) To obtain competitiveness by obtaining required quality in a cost effective way.

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These above objectives are achieved by the following means :

1. To achieve, maintain and seek to continuously improve product quality.
2. Improve the quality of operations to continually meet 'customers' and 'stakeholders' stated and implied needs.
3. Provide confidence to internal management and other employee that quality requirements are being fulfilled.
4. Provide confidence that quality system requirements are fulfilled.
5. Provide confidence to customers and other stakeholders that quality requirements are being achieved in the delivered product.
6. Becoming part of national/regional/international quality standard.
7. Encouraging bilateral and multinational agreements in trade, technology and manufacture.

8.14 ISO-9000 CERTIFICATION

There are eight steps to go through ISO certification. These are :

1. Evaluation of existing quality procedure against the needs of ISO 9001-03 standards.
2. Identification of corrective action needed to confirm with ISO-9000 series standards.
3. Preparation of a certificate quality management system.
4. Definition, documentation and implementation of new procedure.
5. Preparation of quality manual.
6. Pre-assessment meeting with registrar to evaluate quality manual.
7. Actual assessment visit.
8. Certification/Registration.

8.15 ISO-9000 SERIES

The ISO-9000 series comprises the following standards :

ISO-9000	:	Quality Management and Quality Assurance Standards-Guidelines for selection.
ISO-9001	:	Quality Systems-Model for Quality Assurance in design/development, production, installation and servicing.
ISO-9002	:	Quality Systems-Model for Quality Assurance in production and installation.
ISO-9003	:	Quality Systems-Model of Quality Assurance in final inspection and test.
ISO-9004	:	Quality Measurement and Quality system elements guidelines.

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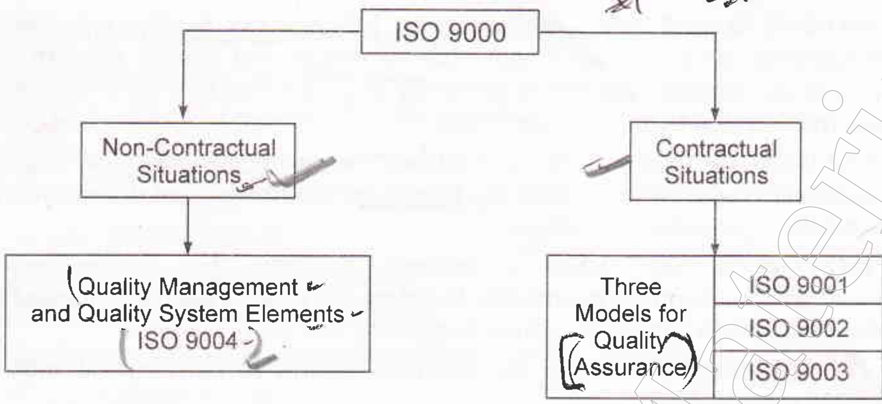
These series are shown below in tabular form.



8.16 ISO-9000 ASPECTS

ISO-9000 applies to all types of organisations. It does not matter what size they are or what they do. It can help both product and service oriented organisation achieve standards of quality that are recognized and respected throughout the world. Therefore, ISO purpose is to facilitate International trade by providing a single set of standards that people everywhere would recognise and respect.

The different aspects relating to ISO-9000 are :

1. Selection of model for quality assurance
2. Selection procedure
3. Selection factors

The selection factors are subdivided into six parts. They are :

(i) Design process complexity
(ii) Design maturity
(iii) Production process complexity
(iv) Product or service characteristics
(v) Product or service safety
(vi) Economics

1) select —
2) —

4. Demonstration and Documentation
5. Pre-control assessment
6. Control preparation aspect

This includes the following four points :

(i) Tailoring
(ii) Review of contractual quality system
(iii) Supplementary quality assurance or quality system requirements
(iv) Technical requirements.

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8.17 ISO-9001, 9002, 9003

ISO-9001 is used where an agreement between two parties requires the demonstration or a supplier's capability to design and supply product. The requirements specified are aimed primarily at presenting non-confirmity at all stages from design through to servicing.

ISO-9002 is used when a contract between two parties requires demonstration of supplier's capability to control the process that determines the acceptability of product specified.

ISO-9003 is used when a contract between two parties require demonstration of supplier's capability to detect and control the disposition of any product non-confirmity during final inspection and test.

The following table shows the different clauses to be complied with for ISO-9000 certification :

Table : ISO Series requirements

S. No.	Requirements	ISO-9001	ISO-9002	ISO-9003
1.	Management responsibility	✓	✓	×
2.	Quality system	✓	✓	×
3.	Contract review	✓	✓	✓
4.	Design control	✓	*	*
5.	Document and data control	✓	✓	✓
6.	Purchasing	✓	✓	*
7.	Customer supplied product	✓	✓	✓
8.	Product Identification and traceability	✓	✓	×
9.	Process control	✓	✓	*
10.	Inspection and testing	✓	✓	×
11.	Control of inspection, measuring and test equipment	✓	✓	✓
12.	Inspection and test status	✓	✓	✓
13.	Control of non-conforming product	✓	✓	×
14.	Corrective and preventive action	✓	✓	×
15.	Handling, storage, packaging, preservation and delivery	✓	✓	✓
16.	Control of quality record	✓	✓	×
17.	Internal quality audit	✓	✓	×
18.	Training	✓	✓	×
19.	Servicing	✓	✓	*
20.	Statistical techniques	✓	✓	×

✓—Mandatory, ×—Requirement stated butnot comprehensive,
*—not required

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8.18 ISO-9004

ISO-9004 lists out the different aspects relating to :

1. Terminology
2. Management responsibility for quality :
   (i) Quality policy
   (ii) Quality objectives
   (iii) Quality system
   (iv) Quality system principles
3. Economics
4. Quality related cost considerations :
   (i) Quality in marketing
   (ii) Quality in design and specification
   (iii) Quality in procurement
   (iv) Quality in production
   (v) Control of production
   (vi) Product verification
5. Control of measuring and test requirement
   (i) Non-conformity
   (ii) Corrective action
   (iii) Handling and post production functions
6. Personnel
7. Quality documentation and records
8. Product safety and liability
9. Use of statistical methods
10. System of handling of customer complaints
11. Quality reporting and view

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8.19 QUALITY CIRCLES (Q.C.)

A quality circle or ***quality control circle*** (Q.C. Circle) ***is a small group of employees*** (average number of nine) ***working at one place, who voluntarily meet once in a week (say) for one hour to discuss their work related problems.*** The circle members *identify, investiage* and *solve work-related problems.* The members utilise their ability to think for themselves for identifying the constraints being faced by them and final solutions that would improve their work life in general. The circle presents the solutions to the management and implements them approval. The circle is also responsible for the review and follow-up of the implementation of the solutions.

Characteristics of quality circles

Following are the characteristics of quality circles :

1. Quality circle is a small group of employees/workers.
2. The members are from the same work area or doing similar type of work.
3. The membership of the quality circle is voluntary.
4. Members meet regularly for about an hour every week.
5. Members are specially trained in problem-solving and analysis techniques in order to play their role effectively.
6. It is not a forum to discuss demands or grievances.
7. It has management support.
8. Members meet to identify, analyse and resolve work-related problems.
9. Members resolve work related problem leading to improvement in their total performance.
10. It is not a substitute for joint-plant councils or work committees.
11. Quality circles enrich the work life of the employees.
12. Quality circle activity contributes members a self confidence when management accept their recommendations.
13. The work also contributes to job satisfaction of members by creating a feeling of accomplishment from identifying and solving challenging problems.
14. Members also receive recognition in the form of momentos, certificates and privileges. In some cases, they also share in productivity gains that might be result of their work.

Objectives of quality circles

1. To improve mutual trust between management and employees/unions.
2. To identify and solve work-related problems that interfere with production.
3. To tap the creative intelligence of people working in the organisation and make full use of human resources.
4. To improve communication within organisation.
5. To increase employees loyalty and commitment to the organisation and its goals.
6. To improve quality of the organisation.
7. To reduce the cost of production or services by waste reduction, safety and effective utilisation of resources.
8. To respect humanity and build a happy, bright and meaningful environment.

The concept and philosophy of quality circle

Concept

The concept of quality circle is based on the fact that suggestions affecting the workplace come from those who perform the work and have a better

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knowledge of the job. The concept assumes that people closest to the problem understand it better and also what is or is not a feasible solution.

The concept of quality circle has following three major attributes :

1. Quality circle is a form of participative management.
2. Quality circle is a human resource development technique.
3. Quality circle is a problem solving technique.

Philosophical foundation of quality circle

1. It helps to develop in the employee a sense of belongingness towards a particular organisation.
2. A belief that people will take pride and interest in their work if they experience autonomy and concept over the decisions that affect them.
3. A willingness to allow people to volunter their time and effort for any work of the organisation.
4. Recognition of the importance of human resource development.
5. The importance of each and every member's role and function in meeting organisational goals.
6. An involved and respected employee is a productive employee whose work is of highest quality.

Potential benefits of quality circles

Quality circles pursue two types of problems : those concerned with the personal well being of the workers and those concern with the well-being of the company.

Worker's problems are concerned with the work itself, manufacturing processes, machines, equipments handled, working condition, working environment and life.

The potential benefits of quality circles may be examined under the following three categories :

(1) *Effect of quality circles on individual employee's characteristics*

- Enable the individual to improve personal capabilities
- Improve the individual's self-respect
- Help employees change certain personality characteristics.

(2) *Effect of quality circles on individual employee's relationship with other employees and managerial personnel*

- Increase the respect of supervisor for employees
- Increase employee's understanding of the difficulties faced by supervisors
- Increase management's respect for employees.

(3) *Effect of quality circles on the employees and their attitudes towards the company*

- Change some employees' negative attitude

- Reduce conflict stemming from the working environment
- Help employees to understand better the reasons that why many problems cannot be solved quickly
- Instill in the employees a better understanding of the importance of quality.

Starting a quality cycle

For starting a quality cycle, the following steps are performed :

Step 1. Explain to employees—what is quality circle and what possibly can be achieved by it.

Step 2. Form a quality circle.

(i) A circle, usually consisting of six to eight members.

(ii) The members should be working at the same area.

(iii) They should be interested to join the quality circle voluntarily.

(iv) Fix a day, time and venu for their weekly meeting.

Step 3. The circle formed begins work.

(a) *First meeting*

(i) choose team leader and deputy leader

(ii) remove all the doubts of employees in this meeting

(b) *Second meeting*

(i) List all the problems

(ii) Identify the problem to be taken first

(iii) Conduct brain-storming session

(iv) Leader keeps on recording the minutes.

(c) *Third meeting and onwards*

(i) Problem analysis by members

(ii) Study the cause and effect relations (For example, if two machines are looked after by one worker, what would be its impact and what good or bad will happen)

(iii) Solutions recommended.

Step 4. Management contribution

(i) The management must ensure that solutions are implemented quickly once they have been accepted.

(ii) The management must give appropriate and proper recognition to the solution.

QCC operation cycle of each problem

Each problem passes through various stages during the QCC operation cycle.

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The steps include
1. Problem identification
2. Problem selection
3. Problem analysis
4. Generate alternative solutions
5. Select best solution
6. Prepare plan of action
7. Present solution to management
8. Implementation
9. Review and follow-up.

Fig. (10) shows the QCC operation cycle

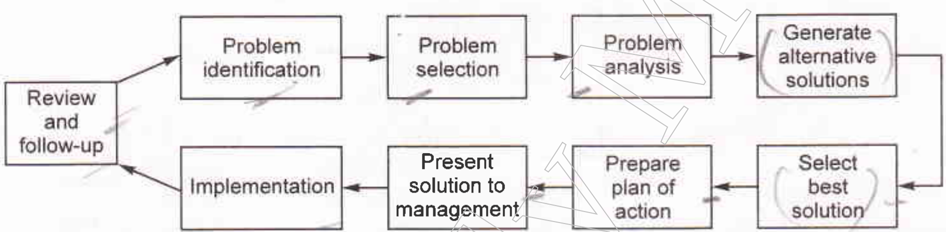

Fig. (10) QCC operation

How QC cycle works

The working of a quality circle is shown in fig. (11).

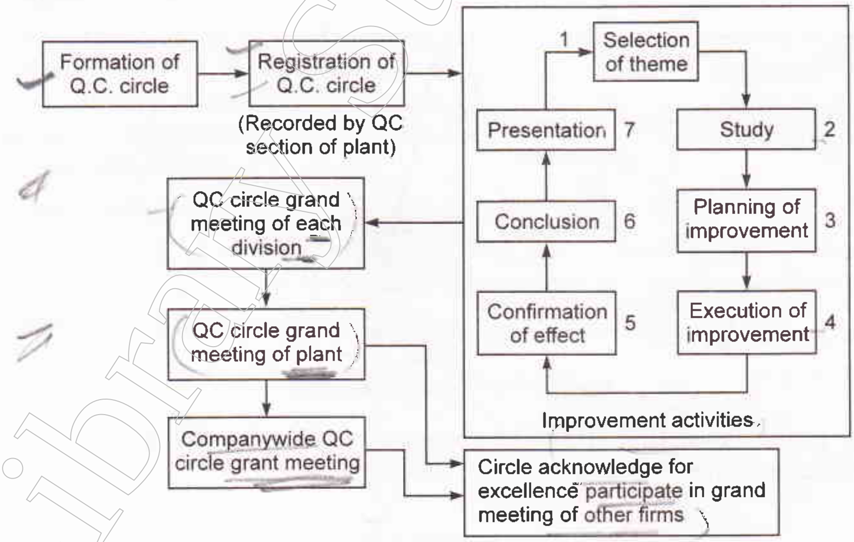

Fig. (11) Working of a quality circle

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8.20 SIX-SIGMA

Process Capability

A process capability is the variation in process output due to random causes.

We are often required to compare the output of a stable process with the process specifications. After this, we make a statement about how well the process meets the specifications. For this purpose, we compare the natural variability of a stable process with the process specification limits.

The process-capability graph is shown in fig. (12).

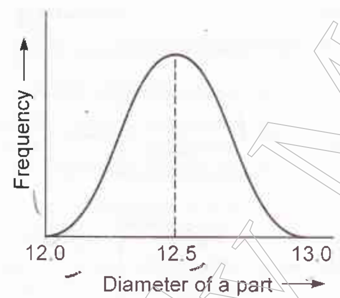

Fig. (12) Process Capability

A capable process is one where almost all the measurements fall inside the specification.

Fig. (13) shows the graph of ***high process capability***

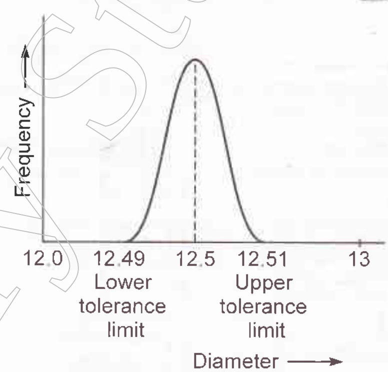

Fig. (13) High process capability

The graph shows that all the measurements fall within the lower tolerance limit (LTL) and upper tolerance limit (UTL).

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Fig. (14) shows the graph of low process capability

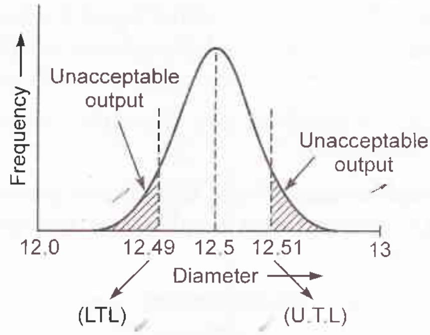

Fig. (14) Low process capability

The ***process capability index*** C_p is defined as

$$C_p = \frac{UTL - LTL}{6\sigma}$$

where C_p = process capability
UTL = upper tolerance limit
LTL = lower tolerance limit
σ = standard deviation process output

Let us consider the process capability index with the following specifications :

$$UTL = 50, \quad LTL = 40 \quad \text{and} \quad \sigma = 1$$

Process capability index $C_p = \frac{50-40}{6 \times 1} = \frac{10}{6} = \mathbf{1.66}$

Sigma

σ is a Greek alphabet used to represent the distribution on spread (variation) about the mean of a process. ***In manufacturing process σ is used to evaluate the capability of the process to produce defect free output leading to customer's satisfaction.*** σ is called standard deviation in a stable process, *i.e.*, a process under statistical control.

Normal distribution

The pattern of variation of measurable characteristics such as diameter, length, etc., will conform to the statistical method known as normal distribution.

Fig. (15) shows the normal distribution variation of $\pm 3\sigma$

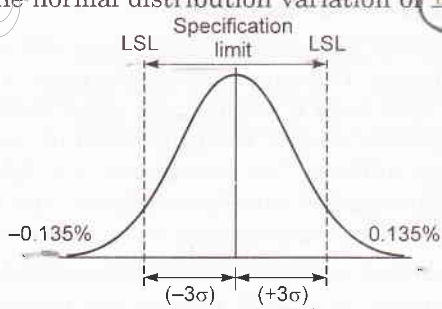

Fig. (15) Normal distribution showing variation spread between $\pm$ 3σ

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The property of normal distribution is that 99.73% of the entire output will be within $\pm 3\sigma$. The only 0.27% output remains beyond $\pm 3\sigma$. This means if output specification is $\pm 3\sigma$, then the products which are out of specifications will be 27 out of 10000.

This sort of result can be expected only if middle value of the specification is set at mean level or at the centre.

When we have started taken efforts, the chance cause of variations slowly start disappearing and improvements result. Now the spread of $\pm 3\sigma$ becomes lesser as shown in fig. (16).

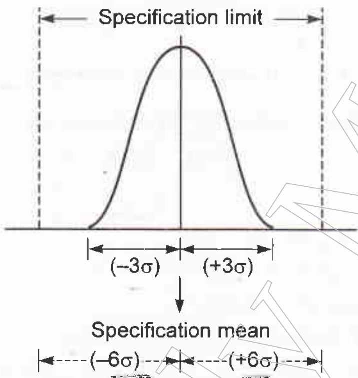

Fig. (16) Showing improvement in process and variation spread reduced to lesser than $\pm$ 3σ

Six Sigma

The Six Sigma concept was developed by Bill Smith, a famous reliability engineer of American Company—Motorola. It is a statistical measurement of quality product provided by the company. Today, it is synonymous with world class. The Six-Sigma strategy is applicable to any product, process, transaction or service.

To make a product defect free, it is essential to target zero-variation and minimise the variation of a process. For the product to be built virtually defect free, it must be designed to tolerance limits that are significantly more than $\pm 3\sigma$ from the mean. In other words, the process spread is measured by $\pm 3\sigma$ has to be significantly less than the spread between the upper and lower specification limits (USL and LSL). Motorola's answer to this problem in Six-Sigma quality. *i.e., **process variability must be so small that specification limits are 6 standard deviations from the mean.***

In real world situations, the process distribution will not always be centred between the specified limits. This may shifts to the right or to the left of centred line. It can be shown that even if the process mean shifts by as much as 1.5 standard deviation from the centre, the proportion of non-conforming will be about 3.4 ppm (part per million). Let us compare this figure with three sigma figure 2700 ppm, it is observed this demonstrates the improvement in the expected level of quality from the process.

If we consider a product containing 1000 parts and design it for six sigma capability, then an average of 0.0034 defects per product unit (3.4 ppm) is expected, instead of the 2.7 defects expected with three sigma capability. The cumulative yield from the process will thus be about 99.66%—a vast improvement over the 6.72% yield in three sigma case.

Fig. (17) shows Six-Sigma capability.

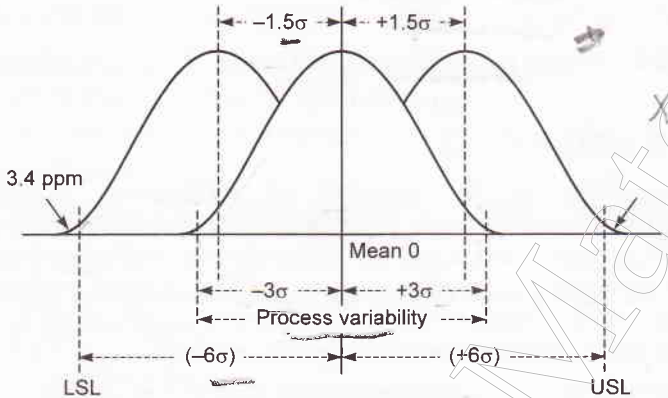

Fig. (17) Six-Sigma capability

Motorola assumed that the process mean would experience a 1.5 σ shift before a 3σ change. Thus, six-sigma corresponds to a ± 4.5 σ deviation on either side of the mean resulting in 3.4 ppm defects.

Today, world-class companies has also improved their business process to a level of excellence, where they are able to have a few as 3.4 defects in a million opportunities to make defects. This is called as ***Six-Sigma quality.***

Relationship between quality and cost

Motorola's six-sigma process changed the relationship between quality and cost. Actual quality cost relationship is shown in fig. (18).

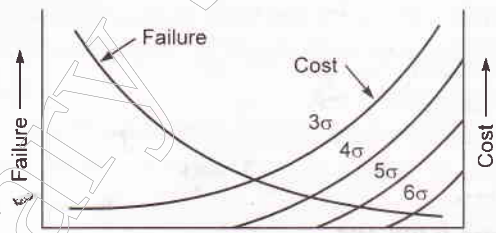

Fig. (18) Actual quality-cost relationship

It is observed from the fig. (18) that as the quality increases, the cost goes down. Thus, using 6σ, the quality of the process increases and thereby the cost of the product decreases.

Six-sigma projects have eight essential phases recognise, define, measure, analyse, improve, control, standardize and intergrate. The cycle is sometimes expressed as DMAIC (define, measure, analyse, improve and control).

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- **Units used to measure defects**

DPU → Defects per unit

DPM → Defects per million

DPMO → Defects per million opportunities

PPM → Parts per million

PPMO → Parts per million opportunities

DPU
DPM

8.21 BENCHMARKING

Benchmarking is the process of gathering, analysing and evaluating the world outside your organisation and comparing it to your own. It is dependent upon the determinations of your organisation to discover and continuously monitor your competitors or other companies that are recognized as industry leaders. So benchmarking is the search for best industrial practices that lead to superior performance. Benchmarking can be defined as :

- Measuring your performance against that of best in-class companies
- Analysing how (methods) the best achieve their performance level
- Using the information as the basis for evaluating your own targets, strategy and applications.
- Benchmarking is a tool to help you for improving your business processes.
- *Benchmarking is the process of identifying, understanding and adapting outstanding practices from organizations anywhere in the world to help your organization improve its performance.*

Therefore, ***the goal of benchmarking is to make your organisation the best it can be, based on the information from both internal and external sources.***

Reasons for benchmarking

The key reasons for taking up the task of benchmarking are :

1. Becoming competitive
2. Industry best practices
3. Establishing effective goals and objectives
4. Meeting customer requirements
5. Developing true measures of productivity

Advantages of Benchmarking

Following are the benefits of benchmarking :

1. It identifies the current position of the business of the company and determining priorities for improving environmental performance.
2. This allows the comparisons with previous benchmarking profiles and against recognised best partices and competitors.

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3. Encouraging regular monitoring of progress and a programme of continuous improvement.
4. This provides environmental improvements to customers and shareholders.

8.21-1 TYPES OF BENCHMARKING

Benchmarking is a very versatile tool that can be applied in a variety of ways to meet a range of requirements for improvements.

Standard benchmarking terms include

1. Strategic benchmarking
2. Performance benchmarking or competitive benchmarking
3. Process benchmarking
4. Functional benchmarking or generic benchmarking
5. Internal benchmarking
6. External benchmarking
7. International benchmarking

1. *Strategic benchmarking.* This is used where organisations seek to improve their overall performance by examining the long-term strategies and general approaches.

2. *Performance benchmarking.* This is used where organisations consider their positions in relation to performance characteristics of key products and services.

3. *Process benchmarking.* This is used when the focus is on improving specific critical processes and operations.

4. *Functional benchmarking.* This is used when organisations look to benchmark with partners drawn from different business sectors to find ways of improving similar functions.

5. *Internal benchmarking.* This involves seeking partners from within the same organisation.

6. *External benchmarking.* This involves seeking outside organisations that are known to be the best in class.

7. *International benchmarking.* This is used where partners are sought from other countries. The reason is that best practitioners are located elsewhere in the world and/or there are very few benchmarking partners within the same country to produce valid results.

8.21-2 BENCHMARKING PROCESS

The benchmarking process involves the following activities :

1. *Plan.* Planning involves determining the critical success factors, secting process for benchmarking, forming teams documenting processes and developing performance measures.

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2. *Search.* Searching involves identifying benchmarking partners

(i) Identify who will be on the benchmarking team

(ii) Ensure that there are adequate resources (people, time, funding, etc.) for the team to achieve its goal

(iii) Providing effective projet planning tools and techniques.

3. *Observe.* It involves assimilating and understanding the partners processes, performance and practices.

4. *Analyse.* This includes the determination of gaps in performance and also determining the main cause of gap.

5. *Adopt.* This includes the selection and adoption of best practices to the companies conditions and implement changes.

The benchmarking process cycle is shown in fig. (19)

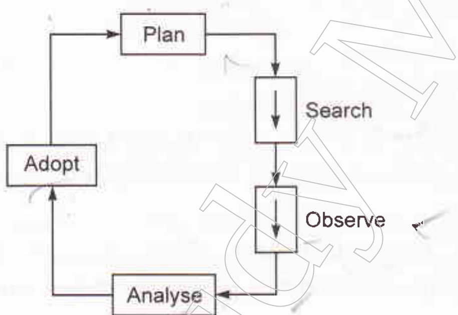

Fig. (19) Benchmaking process cycle

The main steps involved in the benchmarking are :

1. Identify what to be benchmarked
2. Identify comparative companies
3. Collect the relevant data
4. Determine current performance gap
5. Project (forecast) future performance levels
6. Communication of benchmark results (finding and gains)
7. Establish functional goals
8. Develop action plan
9. Implement specific actions and monitor progress
10. Recalibrate benchmarkers
11. Practices fully integrated into process.

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Fig. (20) shows a flowchart of a specific benchmarking process

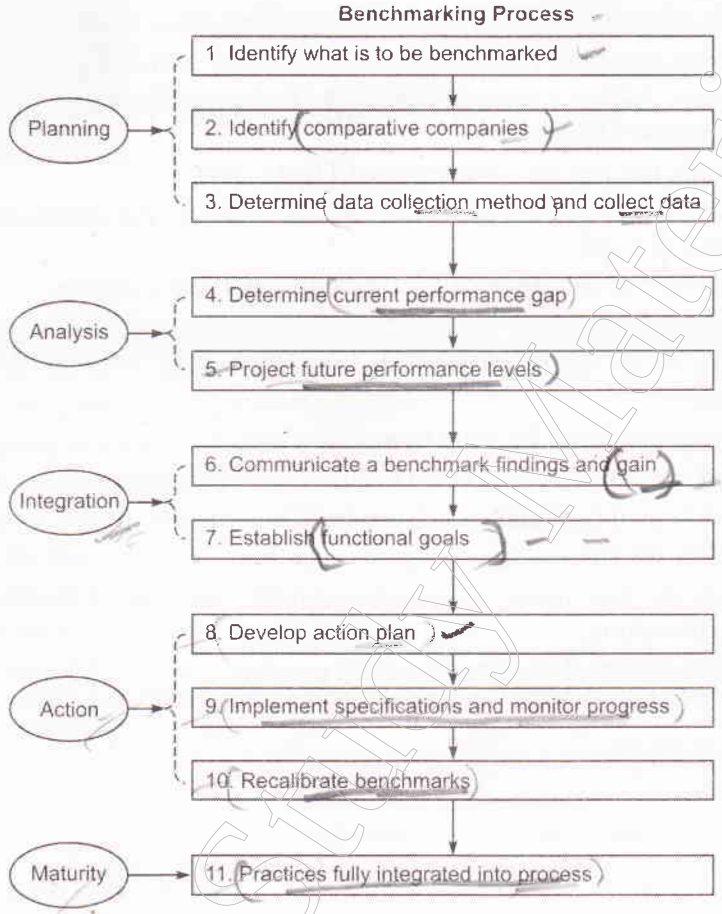

Fig. (20) Flowchart showing benchmarking process

REVIEW QUestions

1. What do you mean by TQM? Define it.
2. Explain the basic approach of TQM.
3. Give the essentials of TQM focus.
4. Describe the characteristics of TQM.
5. What is the necessity of TQM?
6. Give the different pillars of TQM.
7. Describe TQM framework.
8. Explain the evolution of TQM.
9. Describe the different stages used in TQM implementation.

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10. Name the different TQM models. Which one is more suitable for an organisation?
11. With schmeatic representation, explain Transition TQM model.
12. Why do you think Transition model is essential in the present day context?
13. Explain giving examples why the checking process is essential in Transition TQM model?
14. Explain the features of Integrated TQM model.
15. Describe an operational TQM model. Discuss the organisation wide impact of TQM.
16. Give the common reasons for the failure of TQM programs.
17. What is ISO-9000? Define it.
18. What is ISO-9000 series? What are the steps required to get ISO certificate?
19. Discuss briefly all ISO-9000 standards.
20. What are the objectives of ISO-9000? Explain the structure of ISO-9000.
21. Discuss quality circle.
22. What is 6σ. Discuss the six sigma capability.
23. What do you mean by benchmarking? Give the different types of benchmarking.
24. Discuss in detail the benchmarking process.

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9 ENVIRONMENTAL ISSUES

Learning Objectives

After reading this chapter, you will understand :

- Meaning of terms like environment, earth science and environmentalism
- Bio-geo-chemical cycles
- Climate change, Green house effect and Global warming
- Ozone layer depletion
- Acid Rain
- Deforestation
- Conservation of resources, Energy issues, Overpopulation, intensive farming and agriculture, Land degradation, Environmental degradation, Ocean deoxygenation, Sustainable development.

9.1 INTRODUCTION

The word *"environment"* is derived from a French word *"Environ"* which means encircle on surrounding. However, environment is commonly used for describing "natural" environment. It means the sum of all living and non-living things that surround an organism, or a group of organisms. Environment includes all elements, factors and conditions that have some impact on growth and development of certain organism. Environment includes both biotic (with life) and abiotic (without life) factors that have influence on observed organism. Abiotic factors such as light, temperature, water, atmospheric gases combine with biotic factors (all surrounding living species like man, animals, plants, etc.). There are two other terms which are important for understanding environment—*flora* (relating to plants, flowers, trees, etc.) and *fauna* (relating to animals).

Earth science (also known as geoscience or the earth sciences), is a term for the sciences related to the planet Earth. There are four major disciplines in earth sciences, namely geography, geology, geophysics and geodesy. These major disciplines use physics, chemistry, biology and mathematics to build a qualitative and quantitative understanding of the principal areas or *spheres* of the Earth system. Earth science generally recognizes 4 spheres, the lithosphere, the

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hydrosphere, the atmosphere, and the biosphere. These correspond to rocks, water, air, and life respectively. Sometimes practitioners also include, as part of the spheres of the Earth, the cryosphere (corresponding to ice) as a distinct portion of the hydrosphere, as well as the pedosphere (corresponding to soil) as an active and intermixed sphere.

Natural resources and physical phenomena, such as air, water and climate, as well as energy, radiation, electric charge and magnetism are limited. These resources are depreciating (reducing) due to human interaction and excessive exploitation. Protection of the environment is needed because of various human activities. The need of protecting the environment for the benefit of the natural environment and humans, has been well recognized in the late 20th century. This has also been realized and recognized that due to the pressures of population and technology, the biophysical environment is being degraded, sometimes permanently. Governments began placing restraints on activities that caused environmental degradation. Since, the 1960s activism by the environmental movement has created awareness of the various environmental issues.

An important term associated with environmental issues is *environmentalism*. Environmentalism is a political and social movement. It has a goal to protect natural environment by various actions and policies oriented to nature preservation. Environmentalism is a movement connected with environmental scientists and many of their goals. Some of these goals are :

(i) *To reduce world consumption of fossil fuel (coal) :* The first goal of reducing the world consumption of fossil fuels is very important to fight against climate change and global warming phenomenon which will be discussed in detail later on in this chapter. Fossil (non renewable) fuels like coal, etc. are mainly responsible for global warming. During the combustion of fossil fuels, carbon dioxide (one of the greenhouse gases) gets released into the atmosphere. Reducing the emission of carbon dioxide is the most important challenge to successfully fight global warming.

(ii) *To reduce and clean up all sorts of pollution (air, sea, river, etc.) with future goal of zero pollution :* Reducing and cleaning up pollution is also a very important task. Every day we hear that air, seas, rivers are greatly polluted. Pollution creates unhealthy environment, and often causes many health problems and different diseases.

(iii) *Emphasis on clean, alternative energy sources that have low carbon emissions :* Third goal is very obvious. World needs lot of energy. If we want to reduce the use of fossil fuels, then we should have some other alternative energy sources to satisfy world energy needs. These alternative energy sources such as wind energy and solar power have all great potential. They are also ecologically acceptable. However, their use is still negligible on global scale and fossil fuels are still dominant energy sources.

(iv) *Sustainable use of water, land and other scarce resources :* Water is precious but also scarce resource that needs to be preserved for future generations. Sustainable use of water, land and other natural resources is therefore vital to enable future life on the planet.

(v) *Preservation of existing endangered species :* The number of endangered species is lately increasing rapidly and many species have become extinct in the last 50 years or so. Preservation of endangered species is important to save number of ecosystems and to protect biodiversity of the planet.

(vi) *Protection of biodiversity :* Biodiversity is important in enabling the life on earth since, all species are connected in perfectly balanced circle. Each have their own role. It is a fact that humans are not the only owners of this circle. They are a small part. However this is often forgotten.

As already mentioned, the human interaction with environment and its excessive exploitation has given rise to many environmental issues. The aim of this chapter is to discuss these issues. Before, we actually discuss the various environmental issues, a brief outline of various bio-geo-chemical cycles is presented which will help us to understand these issues.

9.2 BIO-GEO-CHEMICAL CYCLES

Bio-geo-chemical cycles are global in nature. They are critical to life. Some of the important cycles are :

(1) The *nitrogen cycle* is the biogeochemical cycle that describes the transformations of nitrogen and nitrogen-containing compounds in nature. It is a cycle which includes gaseous components.

(2) The *water cycle,* also known as the hydrologic cycle, describes the continuous movement of water on, above, and below the surface of the Earth. Since, the water cycle is truely a "cycle", there is no beginning or end. Water can change states among liquid, vapour, and ice at various places in the water cycle. Although the balance of water on Earth remains fairly constant over time, individual water molecules can come and go.

(3) The *carbon cycle* is the biogeochemical cycle by which carbon is exchanged among the biosphere, pedosphere, geosphere, hydrosphere, and atmosphere of the Earth.

(4) The *oxygen cycle* is the biogeochemical cycle that describes the movement of oxygen within and between its three main reservoirs : the atmosphere (air), the biosphere (living things), and the lithosphere (Earth's crust). The main driving factor of the oxygen cycle is photosynthesis, which is responsible for the modern Earth's atmosphere and life.

9.3 GREENHOUSE EFFECT AND GLOBAL WARMING (CLIMATE CHANGE)

Climate Change

Climate is inherently variable. Climate differs from place to place. It also varies with time. Climate change is a change in the statistical distribution of weather over periods of time that range from decades to millions of years. It can be a change in the average weather or a change in the distribution of weather events around an average (for example, greater or fewer extreme weather

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events). Climate change may be limited to a specific region, or may occur across the whole Earth. The climate variations occur as a result of interaction amongst many external and internal processes of the Earth-atmosphere system. The internal processes include air-ice interaction, heat exchange, wind stress, precipitation and evaporation. The external processes include changes in atmospheric compositions, changes of land features, topography, vegetation, solar radiation and changes of ocean basin shape and salinity.

In the context of environmental policy, climate change usually refers to changes in modern climate. It may be qualified as anthropogenic (by population) climate change, more generally known as "global warming" or "anthropogenic global warming" (AGW). Today, the most crucial environmental related issue is *climate change* or *global warming*. In the recent past, global observations have provided a clear evidence of climatic changes resulting from anthropogenic activities. The Earth's temperature has risen by 0.5°C over the past century and recent years have been among the hottest on record.

Human activity has influenced the climate in at least three ways :

(1) By changing the radiational properties of the Earth's surface.

(2) By venting waste heat into the atmosphere.

(3) By changing the concentration of key gaseous components of the atmosphere. Trace gases or greenhouse gases like CO_2, ClO_x, CH_4, N_2O, HO_x, O_3, CFCs, etc. are minor gaseous constituents of the atmosphere. However, they play a surprisingly dominant role in regulating the entire earth's atmosphere.

Greenhouse Effect

The Sun heats the Earth. Solar radiation pass through the atmosphere and is mostly absorbed at the Earth's surface. Only a small portion is reflected back into the space. The absorbed heat is emitted from the surface as infra-red radiation. Fortunately, this radiated heat (in the form of IR radiation) cannot escape from the atmosphere of the earth. Some of this radiated energy is "trapped" by a number of gases present in the atmosphere. This phenomenon of "heat allowed in but cannot get out" is known as the *greenhouse effect*. The greenhouse effect is shown in fig. (1).

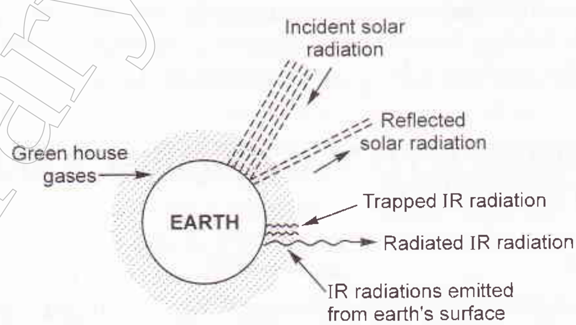

Fig. (1) The Greenhouse effect

Sources and sinks of Greenhouse gases : A sink is a reservoir that uptakes a chemical element or compound from another part of its cycle. For example, soil and trees act as a natural sink for carbon. Similarly, the atmosphere of the earth acts as a sink of greenhouse gases.

The three main sources of greenhouse gases are :

(i) *Solar sources :* Changes in solar constant, XUV region, solar proton events and changes in ozone content generate the greenhouse gases.

(ii) *Volcanic sources :* Cl_x and a number of molecular species like CO_2, H_2, CH_4, COs are generated when a volcano errupts.

(iii) *Biospheric or industrial sources :* CO_2, N_2O, CH_4 and CFCs are derived from biospheric or industrial sources.

Global Warming

Recent human activities are enhancing the natural greenhouse effect. The concentrations of certain greenhouse gases in the atmosphere are increasing. Therefore, more of the infrared radiation emitted by the earth's surface is being trapped. The planet is losing less heat. As a result we are beginning to experience *global warming*.

Global warming is caused by a thick blanket of gasses (carbon dioxide, methane, chlorofluorocarbon, nitrous oxide, etc.) and other air pollutants that is building up in the atmosphere because of which the earth gets warmer. This blanket of hot-house gases permits the entry of sun rays on to the earth but does not permit the return of reflected energy of sun to go back to upper atmosphere. Hence, the earth gets warmer.

Coal burning in power plants is the largest source of carbon dioxide pollution. Automobiles are the second largest source. Application of excess fertilizers causes emission of nitrous oxide. Garbage dumps produce methane. Looking at the source of emission, it can be easily concluded that developed countries are the largest sources of these gases. In fact, the United States emits more carbon dioxide than China, India and Japan put together.

Effects of Global Warming : Global warming would make large areas of the world uninhabitable and cause massive food and water shortage. This can spark widespread migration and possibly wars. Many of global warming effects are already being observed and felt. Some of the possible effects of global warming are :

(1) *Extreme weather conditions :* The temperature of earth had been rising at the rate of 1°C per century until the mid-1970s. This is the upper limit to which most ecosystems are able to adapt. After 1970s, a rate of 4°C rise per century is being observed. This has lead to extreme weather conditions in most parts of the world. For example, in 2003 extreme heat waves caused more than 20,000 deaths in Europe and more than 1,500 deaths in India.

Researchers have investigated the possibility of abrupt climate change in which gradual global warming triggers a sudden shift in the earth's climate. This may cause parts of the world to dramatically heat up or cool down in the span of few years.

Rainfall and monsoon patterns could shift as the planet warms. Some of the regions of the world could dry out while others could receive excessive rainfall—leading to floods and increasing soil erosion.

The increase in temperature can also cause more frequent storms in many parts of the world, including regions that have not experienced such activity in the past.

(2) *Sea level :* Melting glaciers and ice caps will lead to rising sea level. This would lead to coastal flooding all around the globe. Also, the marine ecosystems would also be disrupted. Flooding of coastal wetlands would mean the loss of breeding grounds of fish, shrimps and birds. Disruption of habitats such as coral reefs and alpine meadows could drive many plants and animal species to extinction.

An increase in temperature will cause the oceans to expand. This can further accelerate in rising sea level.

Warmer sea surface temperatures will fuel more intense hurricanes.

(3) *Water resources :* Global rainfall patterns will change and the water management strategies of different regions will have to adapt to these changes.

Droughts and floods will become more common. There are chances of groundwater supplies to be contaminated with sea water in several parts of the world. Rising temperatures will increase the domestic water demand.

(4) *Agriculture and forestry :* There will be more chances for crop failure and famine even in productive regions of the world. Forestry would also be affected. Broadleaf trees could suffer as a result of drought whereas conifer plantations are likely to become more productive. This would have serious implications for the biodiversity of our woodlands.

(5) *Terrestrial ecosystems :* Many species, particularly plants, would be unable to migrate to new and suitable habitats. This could lead to rapid loss of biological diversity and natural resources of economic importance.

(6) *Human health :* Over the long term, there are chances for increase in certain diseases. Humans could face troublesome new pests and more mosquito-borne diseases. Urban air-pollution is likely to get worse and its associated ill-health effects increased.

(7) *Economic consequences :* The disaster relief costs to governments will rise including the insurance claims to the insurance companies.

Measures to curb global warming : The most important contributor to global warming is the increase in atmospheric CO_2 levels due to human activity. It can be reduced by :

(1) *Reducing use of fossil fuels :* CO_2 emissions can be cut by reducing the use of fossil fuels and utilising renewable resources such as wind, solar and hydro power. Reducing fossil fuel use will also reduce emissions of methane, nitrous oxide and ozone.

(2) *Forestation :* CO_2 is consumed by plants and trees. Hence, by reversing deforestation and implementing reforestation programmes, CO_2 levels may be reduced in the atmosphere.

(3) *Individual efforts :* There are many simple steps an individual can take to check global warming. We should make conserving energy a part of our daily routine. For example, switch from a standard incandescent light bulb to a CFL (compact fluorescent bulb). Also, each time we choose a compact fluorescent light bulb over an incandescent bulb, we will lower our energy bill and keep a large amount of carbon dioxide out of the air over the bulb's lifetime. Trees also help in reducing carbon dioxide. Hence, we can help by taking pledge to plant and protect trees. Remember, using CNG vehicles can also be greatly helpful in reducing emissions.

9.4 OZONE LAYER DEPLETION

Ozone is a gas found throughout the atmosphere. It is highly concentrated in the stratosphere (between 10 to 50 km above sea level) where it is known as the "*ozone layer*". Life on the Earth's surface would not be possible without the ozone layer. It works like an umbrella and protects us from the damaging ultra-violet radiation of the sun. In particular, it filters out UV-B radiations (radiations below 3000 Å) which are biologically harmful and controls the heat budget of the earth.

Basically ozone is the simple combination of three oxygen molecules (O_3). Being a natural constituent of the stratosphere, O_3 is regularly formed and destroyed in a cyclic manner with solar radiations as the driving force. In the absence of any other disturbances, O_3 settles into a dynamic steady state in which the rate of its formation is equal to the rate of its destruction.

Ozone depletion refers to the chemically induced breakup of those molecules in the stratosphere. During the 1970s, scientists began expressing concerns about the effects that man-made chemicals such as Chlorofluorocarbons (CFCs) had on the ozone layer. They showed that these chemicals interact with O_3 and break off one of the oxygen molecules. The replacement of O_3 with O_2 and free O molecules meant an increase in the sun's ultraviolet radiation (UV-B) reaching the earth. Recent evidence has shown that certain parts of the ozone layer are becoming thinner and ozone "holes" have developed. The consequence is that more UV-B ratiation reaches the earth surface. Consequently, it leads to increasing the possibility of skin cancer and other dangers to human health.

Effects of Ozone Layer Depletion

The effects of an increase in the amount of UV-B radiation reaching the Earth's surface are :

(1) *Human health :* It causes skin cancer, leads to eye disease and is a general immunological suppressant.

(2) *Agriculture and plant life :* Crop yields can suffer. Exposure to high concentrations of UV radiation has shown to reduce the growth and leaf development of most plant varieties.

(3) *Marine environment :* UV-B causes direct damage to young fish, shrimp and crab larvae and other small animals. This means a reduction in fish stocks, marine animals and seabirds.

(4) *Material degradation :* Many plastics suffer when exposed to UV radiation. Photochemical reactions cause the properties of such materials to change. Thus, it shortens their useful life.

Saving the Ozone Layer

By the middle of the 1980s some countries of the world agreed to regulate the use of ozone depleting chemicals and codified that agreement in the form of multilateral treaties. The Ozone Secretariat is the formal body for coordinating state activity. While the Ozone treaties have been celebrated as models of international environmental cooperation, they have also shown the limits of international cooperation. Because CFCs and other ozone depleting substances are used for popular consumer items such as refrigeration and air conditioners, underground or illegal trade in ozone depleting substances picked up where the legal trade left off.

The result is that after twenty plus years of multilateral activity, ozone depletion is still a problem. Assuming that the illegal trade in ozone depleting chemicals can be effectively dealt with and states maintain their current reductions in the legal use of these chemicals, scientists predict that it will take fifty years or more for the problem to be resolved.

Saving the ozone layer requires :

(i) Planet-wide phase out of CFCs.

(ii) Developing alternative products without using CFCs.

9.5 ACID RAIN

"Acid rain" is a broad term that is used to describe various ways by which acids fall out of the atmosphere. Now-a-days, it is common to use this term to describe all forms of pollution associated with the burning of fossil fuels. However, a more precise term is "acid deposition" which has two parts :

(i) Wet deposition (ii) Dry deposition

(1) *Wet deposition :* Snow, sleet and mist are collectively known as "wet deposition". Therefore, wet deposition refers to acidic rain, fog and snow. As this acidic water flows over and through the ground, it affects a variety of plants and animals.

(2) *Dry deposition :* Acidic gases, dust and smog are collectively known as "dry deposition". About half of the acidity in the atmosphere falls back to Earth through dry deposition. The wind blows these acidic particles and gases onto buildings, cars, homes and trees. Dry deposited gases and particles can also be washed from trees and other surfaces by rain storms. In such a case these acids are added to the acid rain water—making the combination more acidic than the falling rain alone.

The two most important pollutants that contribute to the formation of acid rain are nitrogen oxides (NO_x gases) and sulphur dioxide (SO_2). Industrial plants and motor vehicles exhausts contains oxides of sulphur and nitrogen. When they interact with water vapour in atmosphere, sulphur acid and nitric

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acid are formed which fall on the earth as acid rain. Sunlight increases the rate of most of these reactions.

Pure water has a pH of 7.0. Normal rainfall is slightly acidic having a pH of 5.6. This is because carbon dioxide dissolves in water to form carbonic acid. Rainfall with a pH of less than 5.6 is called acid rain. So far the worst acid rain has been recorded in the United States (pH 2.4). The pH of acid rain in Western Europe can be between 4.0 and 4.5. In Mumbai, an acidity level of 5 has been recorded in rain water.

A strange aspect of the acid rain is that it may occur at a different place from the source responsible for causing it. This is because the pollutants are carried away by prevailing winds to some other place where precipitation takes place causing rain.

Effects of Acid Rain

The various effects of acid rain are :

(1) *Effects on human health :* Recent studies have shown a strong link between high levels of SO_2 in the air and increased occurrence of heart and breathing problems. These pollutants can be deposited through rain, snow, fog, dew or sleet. Many scientific studies have identified a relationship between elevated levels of fine particles, increased illness and premature death from heart and lung disorders such as asthma and bronchitis. In short, we can say that acid rain has decremental effect on human health.

(2) *Effects on lakes, streams and aquatic life :* Acid rain has an acidifying effect on lakes, rivers and streams. Most aquatic life is affected below a pH of 4.5.

Toxic metals, such as aluminium, leached by the acid in the soil are introduced in the ground water. The presence of toxic metals in water supplies (from ground or lakes/rivers) presents a health problem to all animal life, including humans.

(3) *Effect on ecosystems :* Together, biological organisms and the environment in which they live are called an *ecosystem*. The plants and animals living within an ecosystem are highly interdependent. Thus, as lakes and streams become more acidic, the numbers and types of fish and other aquatic plants and animals that live in these waters decrease. This disturbs the equilibrium of ecosystems.

(4) *Effects on agriculture and forests :* Acidification changes the biology and chemistry of the soil. It can have adverse effects on crop yields. Acid rain is also known to cause slower growth, injury or even death of forests.

(5) *Effect on materials :* Acid rain and the dry deposition of acidic particles contribute to the corrosion of metals (such as bronze). It also leads to deterioration of paint and stone (such as marble and limestone). These effects reduce the value of buildings, bridges, cultural objects (such as statues, monuments and tombstones) and cars. Dry deposition of acidic compounds can also dirty buildings and other structures. This leads to increased maintenance costs.

Control Measures

It is clear from the above discussion that two main sources of acid rain are the fossil-fuel based power-houses and the emissions from the transport vehicles. The control measures for acid rain are related with the two as under :

(i) ***Curbing acid emissions :*** Serious efforts are required to reduce acid gas emissions. This can be done by fitting desulphurisation plants to power stations and making catalytic converters compulsory on new motor vehicles.

(ii) ***Cleaning up smokestacks and exhaust pipes :*** Power plants can use technologies that do not burn fossil fuels. Other options for reducing SO_2 emissions are using coal containing less sulphur, washing the coal (a chemical process) and using scrubbers. *Scrubbers* are devices which remove the SO_2 chemically from the gases leaving the smokestack.

Similarly, catalytic converters reduce NO_x emissions from cars.

(iii) ***Using alternative energy sources :*** There are other sources of electricity beside fossil fuels. For example, nuclear power, hydropower, wind energy, geothermal energy and solar energy.

Similarly, there are alternative energies available to power automobiles. These are natural gas powered vehicles, battery powered cars, fuel cells and combinations of alternative and gasoline powered vehicles.

9.6 DEFORESTATION

Importance of Forests

- Forests play an integral support role in the planet. History is the witness that forests have acted as a centre of evolutionary activity.
- Forests are the world's ecosystems and reservoirs of biodiversity.
- Forests influence wind, rain-fall, humidity and temperature patterns.
- They are a crucial link in the ecological chain of life-recycling water, oxygen and carbon dioxide.
- They reduce soil erosion, flooding and air-contamination on a global scale.
- Half of the world's plants, animals and insects live in forests.
- Forests play an important role in our daily lives. Food, medicine and other products of our industrialised world are derived from them.
- Forests are an economic resource of a nation. They play an important economic role in total economy of many countries. For example, forest products provide the foundation of many local and national economies.

Deforestation and it's effects

Forests are fast disappearing than any other natural community on Earth. Forest land is deforested for :

- Farming
- Accelerated urbanisation and industrialisation

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- Mining
- Large scale oil exploration
- Paper manufacture
- Creation of dams
- Cattle grazing and use of wood as fuel for cooking

Deforestation is a short-term benefit in exchange for irreversible loss. If the vegetation cover is removed, the area is exposed to erosion. It leaves a poor soil due to washing out of minerals and nutrients. Without shade from the trees, the Earth is left dry. The surrounding land floods from silt and eroded wasteland is emptied of diversity of life.

On a regional basis, deforestation results in fertile soil loss, floods, drought, severe climatic changes and the loss of rich habitat. On a broader basis, the burning of the forests have been linked to increased carbon dioxide levels in our atmosphere. It is second to that produced by the burning of fossil fuels.

Therefore, we need to protect our forests. Efforts in this direction have been made through *afforestation* and *reforestation*.

Afforestation and Reforestation

Afforestation is planting seeds or trees to make a forest on land which has not been a forest recently, or which has never been a forest. *Reforestation* is the reestablishment of a forest after removal, for example, from a timber harvest. Many countries have experienced centuries of deforestation. Some governments and non-governmental organizations directly engage in programs of afforestation to restore forests and assist in preservation of biodiversity.

9.7 OTHER ENVIRONMENTAL ISSUES

The environmental issues discussed uptil now—Global warming, ozone layer depletion, acid rain and deforestation are all global environmental issues. This is because their effects and impact are world wide. There are some other environmental issues whose impacts are regional in character. We will now discuss some of these issues.

[I] Conservation of resources

Conservation is the usage of the resources in a manner so that they are not depleted and the future generations are also able to get its benefit. Conservation depend on resource use, allocation, and protection. Its primary focus is upon maintaining the health of the natural world : its fisheries, habitats and biological diversity. Secondary focus is on materials conservation and energy conservation, which are important to protect the natural world. Those who advocate or work toward conservation goals are termed *conservationists*. Different types of conservations in respect of environment are :

(1) ***Habitat Conservation :*** The protection of the natural habitats of the endangered areas and keeping them as natural as possible, even though allowing

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access for visitors. To conserve habitat in terrestrial eco regions and stop deforestation is a goal widely shared by many groups with a wide variety of motivations.

(2) *Checking Poaching* : The illegal killing of animals is known as *poaching*. The poachers kill the animals as their parts like the furs, skin, teeth, horns, nails, etc., are used for making clothing, minks, decorative pieces as well as for their medicinal values. These parts can earn large sum of money.

(3) *Trading of Endangered Species* : Endangered species are the species which, if further reduced (by any action of nature or man) would become extinct, *i.e.,* will not be available on the earth or in a part of the earth. Various governments are also taking harsh actions against traders of endangered species.

[II] Energy issues

There are many environmental issues relating to energy with the largest being climate change due to the burning of fossil fuels and the direct impact of greenhouse gases on the Earth's environment. In recent years there has been a trend towards the use of various renewable energy sources. Global warming and climate change due to human activity is generally accepted as being caused by gas emissions. The majority of these emissions are due to burning of fossil fuels with most of the rest due to deforestation.

(a) *Fossil fuel use* : The three fossil fuel types are coal, petroleum and natural gas. It was estimated by the Energy Information Administration that in 2006 primary sources of energy consisted of—petroleum 36.8%, coal 26.6%, natural gas 22.9%, amounting to an 86% share for fossil fuels in primary energy production in the world.

The burning of fossil fuels produces around 21.3 billion tonnes of carbon dioxide per year. It is estimated that natural processes can only absorb about half of this amount. So there is a net increase of 10.65 billion tonnes of atmospheric carbon dioxide per year (one tonne of atmospheric carbon is equivalent to 3.7 tonnes of carbon). Carbon dioxide is one of the greenhouse gases that enhances radiative forcing and contributes to global warming. This causes the average surface temperature of the Earth to rise in response, which causes major adverse effects. On the other hand, natural gas is the cleanest fossil duel. It produces far fewer pollutants than other fossil fuels. But, natural gas itself is a greenhouse gas far more potent than carbon dioxide when released into the atmosphere. However, it is generally released in smaller amounts.

(b) *Firewood* : Direct burning of wood as an energy resource is known as *firewood*. This is probably the most ancient energy suppliant. Unsustainable firewood harvesting can lead to loss of biodiversity and erosion due to loss of forest cover. The graveness of the situation can be understood by the example of Africa, the continent with the largest forest area. Earlier Africa boasted seven million square kilometers of forest but now a third of that has been lost, most of it as firewood.

The solution to energy problem lies in searching and developing alternative energy sources, for example, biofuel. Biofuel is defined as solid, liquid or gaseous fuel obtained from relatively lifeless or living biological material. It is different from fossil fuels, which are derived from long dead biological material. Also, various plants and plant-derived materials are used for biofuel manufacturing. Biofuels are a renewable energy. They are sustainable (carbon neutral) in terms of greenhouse gas emissions since, they are in the carbon cycle for a short term.

[III] Over-population

The term over-population refers to the relationship between the human population and its environment and the Earth. Overpopulation is a condition where an organism's numbers exceed the carrying capacity of its habitat.

Overpopulation does not depend only on the size or density of the population, but on the ratio of population to available sustainable resources. It also depends on the way resources are used and distributed throughout the population. Overpopulation can result from an increase in births, a decline in mortality rates due to medical advances, from an increase in immigration, or from an unsustainable biome and depletion of resources. It is possible for very sparsely populated areas to be overpopulated, as the area in question may have a meager or non-existent capability to sustain human life (*e.g.*, a desert).

The resources to be considered when evaluating whether an ecological niche is overpopulated include clean water, clean air, food, shelter, warmth, and other resources necessary to sustain life. If the quality of human life is addressed, there may be additional resources considered, such as medical care, education, proper sewage treatment and waste disposal. Overpopulation places competitive stress on the basic life sustaining resources leading to a diminished quality of life.

Methods to overcome overpopulation

(i) *Birth regulation policies :* Overpopulation is related to the issue of birth control. There are government regulations or laws which enforces people regarding birth control. Some nations, like China, use strict measures to reduce birth rates. Religious and ideological opposition to birth control has been cited as a factor contributing to overpopulation and poverty. Some leaders and environmentalists have suggested that there is an urgent need to strictly implement a China-like one-child policy globally because this would help control and reduce population gradually.

(ii) *Education and empowerment :* One of the options is to focus on education about overpopulation, family planning, and birth control methods, and to make birth-control devices easily available.

[IV] Intensive farming and intensive agriculture

Intensive agriculture is an agricultural production system characterized by the high inputs of capital, labour, or heavy usage of technologies such as pesticides and chemical fertilizers relative to land area. Modern day forms of intensive crop based agriculture involve the use of mechanical ploughing, chemical fertilizers, plant growth regulators and/or pesticides. It is associated with the increasing use of agricultural mechanization, which has enabled a substantial increase in production. However, it has also dramatically increased environmental pollution by increasing erosion and poisoning water with agricultural chemicals.

Intensive animal farming practices can involve a very large number of animals raised on limited land which requires large amounts of food, water and medical inputs (required to keep the animals healthy in cramped conditions). Very large or confined indoor intensive livestock operations are often referred to as Factory farming and are criticized due to the low level of animal welfare standards and associated pollution and health issues.

Disadvantages of Intensive agriculture and intensive farming

- It alters the environment in many ways.
- Limits or destroys the natural habitat of most wild creatures, and leads to soil erosion.
- Use of fertilizers can alter the biology of rivers and lakes.
- Pesticides generally kill useful insects as well as those that destroy crops.
- Is often not sustainable if not properly managed. This may result in desertification, or land that is so poisonous and eroded that nothing else will grow there.
- Requires large amounts of energy input to produce, transport and apply chemical fertilizers/pesticides.
- The chemicals used may leave the field as runoff eventually ending up in rivers and lakes or may drain into groundwater aquifers.
- Use of pesticides have numerous negative health effects in workers who apply them, people that live nearby the area of application or downstream/downwind from it, and consumers who eat the pesticides which remain on their food.

Preventive Methods

(a) *Crop rotation :* Crop rotation or crop sequencing is the practice of growing a series of dissimilar types of crops in the same space in sequential seasons. This results is various benefits such as to avoid the build up of pathogens and pests that often occurs when one species is continuously cropped. Crop rotation also seeks to balance the fertility demands of various crops by avoiding excessive depletion of soil nutrients. A traditional component of crop rotation is the replenishment of nitrogen through the use of green manure in sequence with cereals and other crops. It is one component of polyculture. Crop rotation can also improve soil structure and fertility by alternating deep-rooted and shallow-rooted plants.

(b) *Water use efficiency :* Optimal water efficiency means minimizing losses due to evaporation, runoff or subsurface drainage. An evaporation pan can be used to determine how much water is required to irrigate the land. Flood irrigation, the oldest and most common type, is often very uneven in distribution, as parts of a field may receive excess water in order to deliver sufficient quantities to other parts. Overhead irrigation, using centre-pivot or lateral-moving sprinklers, gives a much more equal and controlled distribution pattern. The inadequacy of water affects negatively but even the excess running water causes soil erosion.

(c) *Nutrient audits :* Better nutrient audits allow farmers to spend less money on nutrients and to create less pollution. As less nutrient is added to the soil, there is less run off to pollute.

(d) *Weed control :* In agriculture, large scale and systematic weeding is usually required. This is often performed by machines such as cultivators or liquid herbicide sprayers. Selective herbicides kill specific targets while leaving the desired crop relatively unharmed. These chemicals directly affect the plant hormone and the environment. Solutions include :

- using cover crops that out-complete weeds and/or inhibit their regeneration.
- using a different herbicide.
- using genetically altered crop to be herbicide resistant through horizontal gene transfer.
- using locally adapted seeds that resists, tolerates or even out-competes weeds
- ploughing
- ground cover such as mulch or plastic
- manual removal

(e) *Terrace farming :* In agriculture, a terrace is a leveled section of a hilly cultivated area, designed as a method of soil conservation. It is done to slow or prevent the rapid surface runoff of irrigation water. Often such land is formed into multiple terraces, giving a stepped appearance. This method is very effective in rice plantation.

(f) *Rice paddy :* A paddy field is a flooded parcel of arable land used for growing rice and other semi aquatic crops. They can occur naturally along rivers or marshes, or can be constructed, even on hillsides, often with much labour and materials. They require large quantities of water for irrigation, which can be quite complex for a highly developed system of paddy fields. Flooding provides water essential to the growth of the crop. It also gives an environment favourable to the strain of rice being grown, and is hostile to many species of weeds.

This is in contrast to many forms of sustainable agriculture such as organic farming or extensive agriculture. They involve a relatively low input of materials and labour, relative to the area of land farmed. They also focus on maintaining long-term ecological health of farmland, so that it can be farmed indefinitely.

[V] Land degradation

Land degradation is a concept in which the value of the biophysical environment is affected by one or more combination of human-induced processes acting upon the land. It is viewed as any change or disturbance to the land perceived to be undesirable. Natural hazards are excluded as a cause. However,

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human activities can indirectly affect phenomena such as floods and bushfires. It is estimated that up to 40% of the world's agricultural land is seriously degraded.

Causes and effects of land degradation

- Land clearance, such as clear cutting and deforestation
- Overgrazing by livestock can lead to land degradation
- Agricultural depletion of soil nutrients through poor farming practices
- Inappropriate Irrigation and over drafting
- Urban sprawl and commercial development
- Land pollution including industrial waste
- Vehicle off-roading
- Quarrying of stone, sand, ore and minerals

The main outcome of land degradation is a substantial reduction in the productivity of the land. The major stresses on vulnerable land include :

- Accelerated soil erosion by wind and water
- Soil acidification and the formation of acid sulfate soil resulting in barren soil
- Soil alkalinisation owing to irrigation with water containing sodium bicarbonate leading to poor soil structure and reduced crop yields
- Soil salination in irrigated land requiring soil salinity control to reclaim the land
- Soil water logging in irrigated land which calls for some form of subsurface land drainage to remediate the negative effects.
- Destruction of soil structure including loss of organic matter

[VI] Environmental degradation

Environmental degradation is the deterioration of the environment through depletion of resources such as air, water and soil. This may lead to the destruction of ecosystems and the extinction of wildlife. It is defined as any change or disturbance to the environment perceived to be undesirable. When natural habitats are destroyed or natural resources are depleted, environment is degraded.

The degradation of environment causes illnesses and premature deaths. If vast improvements are made in human health, millions of people will be living longer. In the poorest regions of the world, an estimated 11 million children (1.10 crores), or about one in five, will not live to see their fifth birthday, primarily because of environment-related diseases like malaria, acute respiratory infections or diarrhea—illnesses that are largely preventable.

Causes of environmental degradation

- Rapid population increase
- Unsustainable resource use

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- Poverty due to which people destroy the forests, wildlife, soil, grasslands and water supplies to meet their daily requirements
- Environmental management with inadequate knowledge
- Non-inclusion of environmental cost in market price of goods

[VII] Ocean deoxygenation

Ocean deoxygenating is a term that has been suggested to describe the expansion of oxygen minimum zones in the world's oceans as a consequence of anthropogenic emissions of carbon dioxide. In a more generic terminology it may be referred as 'ocean suffocation', 'ocean oxygen deprivation', 'decline in ocean oxygen', 'marine deoxygenating', 'ocean oxygen depletion' and 'ocean hypoxia'. Anoxic waters are a natural phenomenon. They are areas of sea water or fresh water that are depleted of dissolved oxygen. This condition is generally found in areas that have restricted water exchange. In most cases, oxygen is prevented from reaching the deeper levels by a physical barrier (sill) as well as by a pronounced density stratification, in which, for instance, heavier hyper saline waters rest at the bottom of a basin. Anoxic conditions will occur if the rate of oxidation of organic matter by bacteria is greater than the supply of dissolved oxygen.

Anoxic conditions result from several factors. For example, stagnation conditions, density stratification, inputs of organic material, and strong thermo clines. The bacterial production of sulfide starts in the sediments, where the bacteria find suitable substrates, and then expands into the water column.

When oxygen is depleted in a basin, bacteria first turn to the second-best electron acceptor, which, in sea water, is nitrate. Denitrification occurs, and the nitrate will be consumed rather rapidly. After reducing some other minor elements, the bacteria will turn to reducing sulfate. If anoxic sea water becomes deoxygenized, sulfide will be oxidized to sulfate.

[VIII] Sustainable Development

The term "development" is generally used to describe a set of activities initiated by humans to enhance the quality of life. These activities have an impact on environment, economy and the society's structure. Any major change in one or more of these components backfires and often the goals of activities initiated for human welfare become unachieved.

Sustainable development is a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but also for future generations to come. Sustainable development is development that "meets the needs of the present without compromising the ability of future generations to meet their own needs." The field of sustainable development can be conceptually broken into three constituent parts : environmental sustainability, economic sustainability and sociopolitical sustainability.

[IX] Environmental Pollution

This is one of the most important environmental issues. We will discuss it in detail in next chapter.

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REVIEW QUestions

1. What are the various bio-geo-chemical cycles? Discuss their importance in brief.
2. Explain the greenhouse effect. What are greenhouse gases?
3. Discuss the causes, effects and measures used to curb global warming.
4. Distinguish between greenhouse effect and global warming.
5. What are the causes and effects of climate change?
6. Explain the phenomenon of ozone layer depletion.
7. List some measures to protect/save the ozone layer.
8. How is acid rain formed? What are its effects and how it can be prevented?
9. What are the effects of deforestation?
10. What is the difference between afforestation and reforestation?
11. Narrate the causes of environmental degradation.
12. Discuss the principles of sustainable development.
13. Discuss the various emerging energy issues in detail.
14. Define environment and discuss major environmental issues.
15. What are the threats to the environment?
16. Write short notes on :
    (a) Conservation of resources
    (b) Energy issues with respect to environment
    (c) Effects of overpopulation on environment
    (d) Intensive farming and intensive agriculture
    (e) Land degradation
    (f) Environmental degradation
    (g) Ocean deoxygenation

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10 ENVIRONMENTAL POLLUTION

Learning Objectives

After reading this chapter, you will understand :

- Contributors and major forms of environmental pollution
- Air pollution—its sources, effects and control
- Water pollution
- Chemical and Biological treatment of waste water
- Solid waste management
- Noise pollution and its control
- Land or soil pollution—its causes and effects

10.1 INTRODUCTION

Pollution is the introduction of contaminants into a natural environment. This causes instability, disorder, harm or discomfort to the ecosystem, *i.e.*, physical systems or living organisms. Pollution can take the form of chemical substances or energy, such as noise, heat, or light. Pollutants are the elements of pollution. They can be foreign substances or energies, or naturally occurring. When they are naturally occurring, they are considered contaminants, *i.e.*, they exceed natural levels.

Pollution is the introduction of a waste into the atmosphere making it impossible for the life on earth possible to sustain. It is created mostly by human actions, but can also be a result of natural disasters. Pollution has a detrimental effect on any living organism in an environment, making it virtually impossible to sustain life. The dangerous effects of pollution are a result of undesirable changes in the physical, chemical and biological characteristics of air, land and water. Pollution can be natural or man-made.

Pollution may be classified in three major categories :

- Physical
- Chemical
- Biological

Besides the above, there are some minor categories like radiological, etc., but they are site specific.

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The agents or substances that cause pollution are known as pollutants. Pollutants can be broken down into simpler compounds by the action of microbes. These are known as *biodegradable* pollutants, *e.g.*, agricultural and kitchen waste. Pollutants that do not break down from the action of microbes into simpler compounds are known as *non-biodegradable* pollutants, *e.g.*, pesticides, DDT, plastics, aluminium foils, etc.

Contributors to Pollution

Some of the main contributors to pollution are :

- Chemical and nuclear plants
- Industrial factories
- Oil refineries
- Human sewage
- Oil and antifreeze leaking from cars
- Mining
- Littering
- Overcrowded landfills
- Deforestation
- Construction debris
- High population density
- Increased standard of living

The importance and magnitude of the causes of pollution varies from situation to situation and place to place.

Major forms of Environmental Pollution

The major forms of pollution are :

- ***Air pollution :*** This is caused by the release of chemicals and particulates into the atmosphere. Common gaseous air pollutants include carbon monoxide, sulfur dioxide, chlorofluorocarbons (CFCs) and nitrogen oxides produced by industry and motor vehicles. Photochemical ozone and smog are created as nitrogen oxides and hydrocarbons react to sunlight.
- ***Water pollution :*** Pollution by the release of waste products and contaminants into surface runoff into river, drainage systems, leaching into groundwater, liquid spills, wastewater discharges, eutrophication (increase in quantity of nutrients) and littering.
- ***Noise pollution :*** which encompasses roadway noise, aircraft noise, industrial noise as well as high-intensity sonar.
- ***Soil pollution*** occurs when chemicals are released by spill or underground leakage. Among the most significant soil contaminants are hydrocarbons, heavy metals, herbicides, pesticides and chlorinated hydrocarbons.
- ***Light pollution*** includes light trespass, over-illumination and astronomical interference.

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- ***Littering :*** spreading of unwanted waste articles.
- ***Radioactive pollution,*** resulting from 20th century activities in atomic physics, such as nuclear power generation and nuclear weapons research, manufacture and deployment.
- ***Thermal pollution*** is a temperature change in natural water bodies caused by human influence, such as use of water as coolant in a power plant.
- ***Visual pollution*** refers to the presence of overhead power lines, motorway billboards, scarred landforms (as from strip mining), open storage of trash or municipal solid waste.

The aims of the chapter is to discuss the major forms of environmental pollutions and their control in detail.

10.2 AIR POLLUTION

Our earth is surrounded by air on all sides. It is invisible and the area covered by air is called atmosphere. When the air gets dirty and is unhealthy to breathe it is called as Air pollution. Air pollution is a term used to describe the presence of contaminant/s in the atmosphere which are injurious to human health and other natural environmental processes.

The occurrence of wastes in the atmosphere of one or additional contaminants in excess and for long period is harmful to human health, animals and plant life. Air pollution can cause health problems and it can also smash up the atmosphere and material goods.

Nature of Air Pollutants

There are two types of air pollutants :

(i) Particulate matter (ii) Gaseous

Particulates are small solid or liquid substances in the air resulting mostly from fuel combustion and industrial processes. The gaseous air pollutants result from combustion processes in industries. Examples of gaseous air pollutants are carbon dioxide, carbon monoxide, sulphur compounds, chlorine, oxides of nitrogen, etc.

Sources of Air Pollution

Air pollution results from a multiplicity of causes. Modernization has led to air getting more and more contaminated over the years. Industries, vehicles, increase in the population, and urbanization are some of the most important factors for increase in air pollution. The industries like thermal power plants, cement, steel, refineries, petrol chemicals, and mines, etc. give off a great deal of pollutants into the air. Natural sources can also cause air pollution. Dust storms in desert areas and smoke from forest fires and grass fires have a say to chemical and particulate pollution of the air. The source of pollution may be in one place and its effects may be felt in another place.

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Hence, it can be concluded that the main causes of air pollution are Industries, automobiles, power production, burning of fossil fuels and insecticides.

Major air pollutants, their sources and their effects are summarized in table I.

Table I : Major Air Pollutants

Pollutants	Sources	Effects
Ozone A colorless gas that is the major constituent of photochemical smog at the Earth's surface. In the upper atmosphere (stratosphere), however, ozone is beneficial, protecting us from the sun's harmful rays.	Ozone is formed in the lower atmosphere as a result of chemical reactions between oxygen, volatile organic compounds, and nitrogen oxides in the presence of sunlight, especially during hot weather. Sources of such harmful pollutants include vehicles, factories, landfills, industrial solvents, and numerous small sources such as gas stations and farm and lawn equipment.	Ozone causes significant health and environmental problems at the Earth's surface. It can irritate the respiratory tract, produce impaired lung function and cause throat irritation, chest pain, cough and lung inflammation. It can also reduce the yield of agricultural crops and injure forests and other vegetation. Ozone is the most injurious pollutant to plant life.
Carbon Monoxide Odourless and colourless gas emitted in the exhaust of motor vehicles and other kinds of engines where there is incomplete fossilfuel combustion.	Automobiles, buses, trucks, small engines and some industrial processes. High concentrations can be found in confined spaces like parking garages, poorly ventilated tunnels, or along roadsides during periods of heavy traffic.	Reduces the ability of blood to deliver oxygen to vital tissues, affecting primarily the cardiovascular and nervous systems. Lower concentrations have been shown to adversely affect individuals with heart disease; higher concentrations can cause dizziness, headaches and fatigue.
Nitrogen Dioxide Light brown gas at lower concentrations; in higher concentrations becomes an important component of unpleasant-looking brown, urban haze.	Result of burning fuels in utilities, industrial boilers, cars and trucks.	One of the major pollutants that causes smog and acid rain. Can harm humans and vegetation when concentrations are sufficiently high.
Particulate Matter Solid matter or liquid droplets from smoke, dust, fly ash and condensing vapours that can be suspended in the air for long periods of time.	Industrial processes, smelters, automobiles, burning industrial fuels, wood smoke, dust from paved and unpaved roads, construction and agricultural ground breaking.	These microscopic particles can affect breathing and respiratory health, causing increased respiratory disease and lung damage and possibly premature death.

Sulfur Dioxide Colourless gas, odourless at low concentration but pungent at very high concentrations.	Emitted largely from industrial, institutional, utility and apartment-house furnaces and boilers, as well as petroleum refineries, smelters, paper mills and chemical plants.	One of the major pollutants that cause smog. At high concentrations, can also affect human health, especially among asthmatics and acidify lakes and streams.
Lead Lead and lead compounds can adversely affect human health through either ingestion of lead-contaminated soil, dust, paint or direct inhalation.	Transportation sources using lead in their fuels, coal combustion, smelters, car battery plants and combustion of garbage containing lead products.	Elevated lead levels can adversely affect mental development, kidney function and blood chemistry. Young children are particularly at risk.
Toxic Air Pollutants Includes pollutants such as arsenic, asbestos and benzenes.	Chemical plants, industrial processes, motor vehicle emissions and fuels and building materials.	Known or suspected to cause cancer, respiratory effects, birth defects and reproductive and other serious health effects.
Stratospheric Ozone Depleters Chemicals such as chlorofluorocarbons (CFCs), halons, carbon tetrachloride, and methyl chloroform. These chemicals rise to the upper atmosphere where they destroy the protective ozone layer.	Industrial household refrigeration, cooling and cleaning processes, car and home air conditioners, some fire extinguishers and plastic foam products.	Increased exposure to UV radiation could potentially cause an increase in skin cancer, cataracts, suppression of the human immune response system and environmental damage.
Greenhouse gases Gases that build up in the atmosphere that may induce global climate change or the "greenhouse effect". They include carbon dioxide, methane and nitrous oxide.	The main man-made source of carbon dioxide emissions is fossil fuel combustion for energy-use and transportation. Methane comes from landfills, cud-chewing livestock, coal mines and rice paddies. Nitrous oxide results from industrial processes, such as nylon fabrication.	The extent of the effects of climate change on human health and the environment is still uncertain, but could include increased global temperature, increased severity and frequency of storms and other "weather extremes," melting of the polar ice cap and sea-level rise.

10.2-1 EFFECTS OF AIR POLLUTION

Air pollution has both severe and never-ending effects on human health. Health effects range from minor irritation of eyes and the upper respiratory system to persistent respiratory ailment, heart disease, lung cancer and death.

Specific effects of air pollution are :

(i) *Tobacco smoke :* contains carbon monoxide; tar and nicotine which increases the risk of life threatening diseases such as heart attacks and can cause cancer.

(ii) *Decomposing garbage and open sewers :* Decomposing garbage gives out methane and open sewers emit hydrogen sulphide. Open garbage and sewers are breeding ground for mosquitoes, flies, germs and other harmful bacteria.

(iii) *Piosonous gases :* from factories and chemical plants cause respiratory diseases.

(iv) *Acid Rain :* When acidic gases dissolve in the moisture in the air, acids are formed. The acids fall on the earth as 'acid rain' and pollute the fresh water resources.

(v) *Mining activities :* Rock particles, smelters, coal and mineral dust cause lung and respiratory ailments.

(vi) *Carbon monoxide and lead :* from exhausts of motor vehicles affect the brain and organs like kidney.

(vii) *Ozone Depletion effect :* CFCs destroy the protective ozone layer and let in harmful ultraviolet rays, causing skin cancer and affecting plant life.

(viii) *Smoke from Burning fuels and oil rigs :* Smoke is a mixture of soot and acidic gases. It causes global warming and impure air. Smoke contains harmful substances which causes cancer.

(ix) *Green house effect :* Increasing carbon dioxide in the atmosphere due to industrial activity and burning of fossil fuels traps more heat, changes the climate, melts the polar ice caps and submerges coastal areas.

(x) *Automobile exhaust :* It is one of the major sources of air pollution in big cities. The exhaust contains carbon dioxide, carbon monoxide, sulphur dioxide, lead, particulate matter and polarity burned hydro carbons. They are called pollutants. All these pollutants are highly harmful to human health.

Asthma is caused by allergic reactions to pollutants in the air. Air pollution may show the way to several diseases in the human beings such as allergic reaction, asthma and lung diseases. Asbestosis is an allergic reaction to the occurrence of silica and asbestos in the air.

10.2-2 AIR POLLUTION CONTROL

Air pollution can be controlled by the following ways :

(1) Plants suck in carbon dioxide and breathe out oxygen. Air pollution can be reduced by planting more trees in our neighbourhood. More trees should be planted, so that people get fresh, clean and more oxygen. Cutting of tree should be completely banned.

(2) The vehicles such as cars, scooters, auto rickshaws, trucks, buses, etc., that ply on the road are increasing drastically on a day to day basis. All these vehicles run on fuel like diesel or petrol. When the fuel from these vehicles burns in the engine, a lot of harmful smoke is released in the air. In big cities the number of auto vehicles is very high. Thus, large amount of smoke which is

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hateful to the nose, harmful to the brain and dangerous to the lungs is released. Smoke contains many poisonous gases due which lot of people suffer from dangerous diseases like asthma. The emission level of all these auto vehicles should be checked regularly. Strict laws should be imposed to control air pollutions and the guilty should be fined. Old vehicles should be banned as the emission level is very high. Public vehicles like buses and auto rickshaws should be compulsorily made to use compressed natural gas. This fuel causes minimum pollution and has already been made compulsory in metro cities like New Delhi, Mumbai, etc.

(3) There are many factories in cities, which also cause air pollution and emit a lot of harmful gases like carbon dioxide and carbon monoxide from the chimneys. To avoid this, manufacturing units should be located in industrial estates far away from the cities. Moreover, tall chimneys should be used because it reduces the effect of air pollutions to the mankind. Due to the tall chimneys the harmful gases do not come in contact with people and get mixed in clouds.

(4) Waste accumulation also pollutes the air, when people drop filth in open. Many fly and insects breed on them and sit on uncovered food which causes diseases like Diarrhea and Malaria. Sometime people burn waste material, which can be re-used or re-cycled. This practice adds to the problem of air pollution.

(5) *Treatment of Air Pollution in Industries :* Airborne particles can be removed from a polluted airstream by a variety of physical processes. Common types of equipment for collecting fine particulates include cyclones, scrubbers, electrostatic precipitators, and baghouse filters. Once collected, particulates adhere to each other, forming agglomerates that can readily be removed from the equipment and disposed off, usually in a landfill.

In general, cyclone collectors should be used to control industrial dust emissions and as precleaners for other kinds of collection devices. Wet scrubbers should be applied in the control of flammable or explosive dusts or mists from such sources as industrial and chemical processing facilities and hazardous-waste incinerators. They can handle hot airstreams and sticky particles.

10.2-3 POLLUTION CONTROL DEVICES

[I] Electrostatic precipitator

Electrostatic precipitation is a commonly used method for removing fine particulates from airstreams. In an electrostatic precipitator, particles suspended in the airstream are given an electric charge as they enter the unit. They are then removed by the influence of an electric field. The precipitation unit comprises baffles for distributing airflow, discharge and collection electrodes, a dust clean-out system, and collection hoppers. A high DC voltage (as much as 100,000 volt) is applied to the discharge electrodes to charge the particles, which then are attracted to oppositely charged collection electrodes, on which they become trapped.

Advantages : Electrostatic precipitators are preferred over other particulate removal process because

- They are economical to operate.
- They provide high efficiency (near 99%).
- They are dependable and predictable.
- They do not produce a moisture plume.

Disadvantages :

- They cannot be used with moist flows, mists or sticky or hygroscopic particles.
- They must be heated during start up and shut down to avoid corrosion from acid gas condensation.
- Performance is inhibited since water droplets can insulate particles and reduce their resistivities.

[II] Wet scrubber

The objective of the scrubber is to entrain the particulate matter in water droplets. Wet scrubbers trap suspended particles by direct contact with a spray of water or other liquid. In effect a scrubber washes the particulates out of the dirty airstream as they collide and are entrained by the countless tiny droplets in the spray. The principle of a wet scrubber is shown in fig. (1). Subsequently, the water flows from the bottom of the scrubber. The particulate is allowed to settle and clarified water is re-circulated.

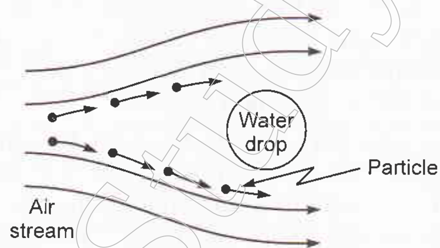

Fig. (1) Principle of scrubber

Advantage : Compared to dry particulate removal process, scrubbers provide advantages of reduced explosion risk and quenching of hot gases.

Disadvantage : They present the disadvantage of having to settle the particulate and manage a wet sludge.

Several configurations of wet scrubbers are in use. In a spray-tower scrubber, an upward-flowing airstream is washed by water sprayed downwards from a series of nozzles. The water is re-circulated after it is sufficiently cleaned to prevent clogging of the nozzles. Spray-tower scrubbers can remove 90 percent of particulates larger than about 0.0008 mm (0.0003 inch). The other types are cyclones and venturi scrubbers.

[III] Cyclone separator

A cyclone separator removes particulates by causing the dirty airstream to flow in a spiral path inside a cylindrical chamber. Dirty air enters the chamber from a tangential direction at the outer wall of the device, forming a vortex as it

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swirls within the chamber. The larger particulates, because of their greater inertia, move outward and are forced against the chamber wall. Slowed by friction with the wall surface, they then slide down the wall into a conical dust hopper at the bottom of the cyclone. The cleaned air swirls upward in a narrower spiral through an inner cylinder and emerges from an outlet at the top. Accumulated particulate dust is periodically removed from the hopper for disposal. Fig. (2) shows a cyclone separator.

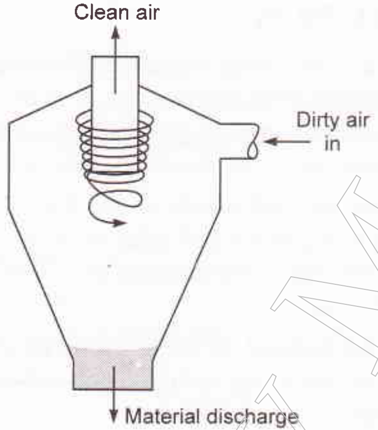

Fig. (2) Cyclone Separator

Cyclones are best at removing relatively coarse particulates. They can routinely achieve efficiencies of 90 percent for particles larger than about 20 μm (0.0008 inch). By themselves, however, cyclones are not sufficient to meet stringent air quality standards. They are typically used as precleaners and are followed by more efficient air-cleaning equipment such as electrostatic precipitators and baghouses.

[IV] Bag House

One of the most efficient devices for removing suspended particulates is an assembly of fabric filter bags, commonly called a *baghouse*. A typical baghouse comprises an array of long, narrow bags—each about 25 cm (10 inches) in diameter—that are suspended upside down in a large enclosure. Dust-laden air is blown upward through the bottom of the enclosure by fans. Particulates are trapped inside the filter bags, while the clean air passes through the fabric and exits at the top of the baghouse.

A fabric-filter dust collector can remove very nearly 100 percent of particles as small as 1 μm (0.00004 inch) and a significant fraction of particles as small as 0.01 μm (0.0000004 inch). Fabric filters, however, offer relatively high resistance to airflow and they are expensive to operate and maintain. Additionally, to prolong the useful life of the filter fabric, the air to be cleaned must be cooled (usually below 300°C [570°F]) before it is passed through the unit; cooling coils needed for this purpose add to the expense. (Certain filter fabrics—*e.g.*, those made of ceramic or mineral materials—can operate at higher temperatures.)

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Several compartments of filter bags are often used at a single baghouse installation. This arrangement allows individual compartments to be cleaned while others remain in service. The bags are cleaned by mechanical shakers or by reversing the flow of air, and the loosened particulates are collected and removed for disposal.

10.3 WATER POLLUTION

In addition to clean air, all living organisms, animals and plants call for a clean water supply in order to continue to exist. It is thought that earth contain lots of water but merely a small amount of it is fresh water that we can use. Day by day we are polluting our water in the same way we are polluting our air.

Surface waters are the natural assets of the Earth. They are found on the peripheral of the Earth's outer layer and take account of the oceans, rivers and lakes. These waters can become contaminated in a number of ways, and this is called surface water pollution.

Water pollution may be defined as the addition of any material to a natural body of water which diminishes the optimal economic use of the water by the population which it serves.

Water is polluted by four kinds of substances :

(i) traditional organic waste

(ii) waste generated from industrial processes

(iii) chemical agents of fertilizers and pesticides

(iv) silt from degraded catchments.

10.3-1 SOURCES OF WATER POLLUTION

The sources of water pollution are classified into two types :

(1) Point source pollution (2) Nonpoint source pollution

(1) *Point source pollution :* If the pollution is due to a single, well identified starting place like oil spill, drain, etc., it is called *point source pollution*. Point source pollution is discharged into the environment through pipes, sewers or ditches from specific sites such as factories or sewage treatment plants.

(2) *Nonpoint source pollution :* If the pollution comes from many sources which cannot be easily identified such as acid rain, farmer's field, it is called *nonpoint source pollution*. This type of pollution is caused by pollutants that enter bodies of water over large areas. Examples of such sources are contaminants that enter the water supply from soil/groundwater systems and from the atmosphere via rain water. Soil and groundwater contain the residue of fertilisers, pesticides and improperly disposed off industrial wastes. It also includes agricultural run-off, mining wastes, urban wastes and construction sediments. Soil erosion is a major source of non-point source pollution. Non-point source discharges are much more difficult to identify. Consequently, it is more difficult to regulate and control them. Therefore, non-point source

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discharge control strategies require improved management practices to reduce the potential for pollution from occurring.

10.3-2 MAJOR CONTRIBUTORS TO WATER POLLUTION

Some of the main contributors of water pollution are :

- Factories
- Refineries
- Waste treatment facilities
- Mining
- Pesticides, herbicides and fertilizers
- Human sewage
- Oil spills
- Failing septic systems
- Soap from washing cars
- Oil and antifreeze leaking from cars
- Household chemicals
- Animal waste

When harmful substances such as oil and chemical wastes come in the waterways either through accidents or through being deliberately dumped, they are soon carried away by the flow of the river. They are really not so easy to remove. As a river makes its way to the ocean, a number of different chemicals can enter its waters. Harmful chemicals can enter rivers and lakes from any number of sources. For example, they can dribble out of dumpsites or pesticides and fertilizers may draw off from farmlands or they may find their way into manure that is pumped from local towns and cities.

One of the most destructive forms of water pollution is from oil. Oil spills from ships and oil tankers at sea cause overwhelming water pollution and harm flora and fauna. These events receive lots of attention on television and from ecological groups that work towards shielding our mother earth. However, these spills only correspond to a small percentage of the total amount of oil that contaminates our water. Tankers dump oil into oceans as part of their custom cleaning, refineries pump oily wastewater into surface water and oil from city streets are washed into storm drains that sooner or later enter our waterways.

When people rinse materials down the drain, flush their toilets or do a load of wash, the wastewater usually goes to sewage treatment plants to be purified. These plants will then remove dirt, eco-friendly materials such as food waste and a number of other pollutants before the water reach our waterways. However, most treatment plants can't remove all the chemicals that are used in products such as paint thinners or phosphates that are used in many detergents. These substances end up passing right through the sewage treatment plant untreated.

Other sources of water pollution include the grime and garbage from the streets that are washed into storm drains. In most areas these storm drains

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vacant into underground pipes that will sonner or later dump directly into our lakes, rivers and oceans.

The condition in India is even more critical as large number of small cities, towns and villages do not have any treatment facilities and the disposal is totally disorganized which makes the treatment almost impossible. In house technology or appropriate technology is required to be developed.

10.3-3 CAUSES OF WATER POLLUTION

Some of the main causes of water pollution are :

(1) Farmers use quantities of chemicals, fertilizers and pesticides which are far more than what is actually required by the crops. This is because of false thinking or belief that more use of these will give better crops or will kill the harmful insects faster, etc. Farmers also make use of chemicals to smooth the progress of the growth of the crops. Either way these chemicals percolate into the ground water or run off into a lakes, rivers and creeks causing water pollution. The farmer's land which is irrigated are treated by means of chemicals in the form of fertilizers or pesticides becomes a most important contributor to water pollution.

(2) Industrial processes generate poisonous waste containing heavy chemicals. When heavy metals filter into the water, they are lethal to marine life. Human being are also effected by consuming the polluted fish, etc., leading to disease and sometimes death. The heavy metals in the water have also been associated to severe birth defects, a damaged or covered up immune system, cancer, fertility problems and developmental troubles in kids.

(3) The building industry also pollutes huge part of our water resources with cements, lubricants, plastics and metals. Rivers and lakes are also polluted from silts and remains than run off into the rivers and lakes from a range of building sites.

(4) Ground water pollution occurs when chemicals, debris, garbage, oil or other damaging contaminants enter the ground water supply. Major natural events such as storms, earthquakes, acid rains, floods and volcanic eruptions have been known to interrupt the ecological system and contaminate the earth.

(5) The growth of algae owing to food items, urea in the water source is also a cause of water pollution. When algae grow in water they use more oxygen, causing other living organisms in the body of water to suffer. The course of action of pollution begins with tiny organisms that pass through the food chain through birds, marine creatures and in due course through humans. These types of algae are known to be piosonous for the reason that they are measured to be causing fatalities in humans. Even over-growths of non-toxic type of algae can in actual fact block the sunlight from entering the water's surface, which makes it difficult for marine life to find food, sooner or later causing death.

(6) Littering on the land or on the water is an additional source of water pollution. Debris thrown on the land in due course makes its way into the storm drains and then returns to surface water. Ships and boats discharging human wastes and chemicals into the water directly are cleanly speeding up the procedure of water pollution.

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10.3-4 ADVERSE EFFECTS OF WATER POLLUTION

The environment and human beings feel the pinch of polluted water. Water pollution affects our rivers, lakes, oceans and drinking water. With the increase in population and industrial development, demand for water has also increased.

Water is said to be polluted when chemicals, harmful contaminants are detected. Human being have the most crucial impact on our water resources. Moreover, the need for water is far more in the society today than the quantity of water available. Some water pollution effects show up immediately whereas others do not show up for months or years.

The effects of water pollution are :

(1) The water pollution has damaged the food chain and is very important for the food preparation of plants through photosynthesis. When Filth is thrown in water the toxins travel into the water. When the animals drink that water they get contaminated and when humans tend to eat the meat of the animals infected by toxins it causes further damage to the humans.

(2) Infectious diseases such as cholera and typhoid can be contracted from drinking contaminated water. Our whole body system can have a lot of harm if polluted water is consumed regularly. Other health problems associated with polluted water are poor blood pressure, vomiting, skin lesions and damage to the nervous system. In fact the evil effects of water pollution are said to be the leading cause of death of humans across the globe.

(3) Pollutants in the water alter the overall chemistry of water, causing a lot of changes in temperature. These factors overall have had an adverse effect on marine life and pollutes and kills marine life. Marine life gets affected by the ecological balance in bodies of water, especially the rivers and the lakes.

Water pollution effects have a huge impact on the health of an individual and the environment as a whole. The balance between the nature and the humans can be protected and should be maintained. But it will take efforts on all fronts by each and every individual from the society to prevent and eliminate water pollution locally and globally.

10.4 WATER POLLUTION CONTROL

With a wide variety of types of water pollution, a single action will not be enough to ward off all pollutants. Prevention starts with awareness and continues with a dedicated effort to not only prevent further contamination but also clean up the present pollutants.

The various ways to control water pollution are :

(1) The problems linked with water pollution have the capabilities to disturb life at an individual level as well as on a greater level for the planet as a whole. Government bodies have approved laws in trying to combat water pollution. This acknowledges the fact that water pollution is without doubt a serious issue which needs to be addressed at the earliest. But the government single-handedly cannot get to the bottom of this problem. It is up to us to be well-versed and act.

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(2) We must become familiar with our local water resources and learn about ways for disposing household wastes efficiently, so that they do not end up in sewage treatment plants that cannot handle them or landfills not planned to accept the dangerous materials.

(3) We must take dynamic participation and straighten out on whether supplementary nutrients are needed before fertilizers are applied and look for alternatives where fertilizers may run off into surface waters.

(4) We should take care of existing trees and plant new shrubs and trees to put a stop to soil erosion and promote penetration of water into the soil. At an individual level around our houses we have got to keep waste, pet squander, leaves and grass clippings out of gutters and storm drains. These are just a small number of the many ways in which humans can take remedial action against the water pollution problem.

(5) By being conscious ourselves and educating our younger ones and siblings, we can help to battle water pollution.

(6) Various engineering and technical measures can be used for waste water treatment for controlling water pollution.

10.5 WASTE WATER TREATMENT

Natural water in contact with foreign matters during either industrial process or domestic use, becomes polluted. Such polluted water is termed as *waste water*. The used-up community water is called domestic waste water, whereas the effluent discharged from the industry is called industrial waste water. The removal of excessively accumulated matters from the waste water is known as treatment.

The matters incorporated into the waste water may be either organic or inorganic in nature depending upon the sources of the wastes. The effluents generated from industries like diaries, distilleries, tanneries, paper manufacturing units, oil refineries, vegetable and fruit processing units, sugar industries and fertilizer producing units are rich in organic contents. The wastes produced from municipalities and corporations are also rich in organic matters. The industries manufacturing cement, steel, alkali, generate effluents which contain relatively higher proportion of inorganic matters. The effluents with high organic matters are biodegradable and are usually accompanied by very high BOD (bio-chemical oxygen demand) values, causing environmental pollution. On the other hand, the inorganic wastes are poor in BOD but rich in valuesof COD (chemical oxygen demand). They do not produce colour, odour and other environmental nuisance.

Types of Treatments

There are two types of waste water treatments :

(1) *Chemical Treatment* : The chemical treatment includes coagulation, flocculation and sedimentation. Treatments through sand and pressure filters, iron removal, defluoridation and other such type of treatments are the examples of chemical treatment.

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(2) *Biological Treatment :* Biological treatment is of two types :

(i) *Aerobic Treatment :* A treatment is which purification is carried out by aerobes in presence of molecular oxygen. It is a natural biological degradation and purification process in which bacteria that thrive in oxygen-rich environments break down and digest the waste. Trickling filter, activated sludge process, oxidation pond, extended aerated lagoon are the examples of aerobic biological treatment.

(ii) *Anaerobic Treatment :* A treatment where purification of the waste is achieved by anaerobes in complete absence of molecular oxygen. The need of oxygen for anaerobic treatment is satisfied by the oxidation of the oxygenated compound, *e.g.*, SO_2, NO_4, etc., where the oxygen is locked in combined forms. Anaerobic treatment is a complex biochemical reaction carried out in a number of steps by a complex consortium of micro-organisms that require little or no oxygen to live.

The differences between aerobic and anaerobic treatment processes are shown in fig. (3).

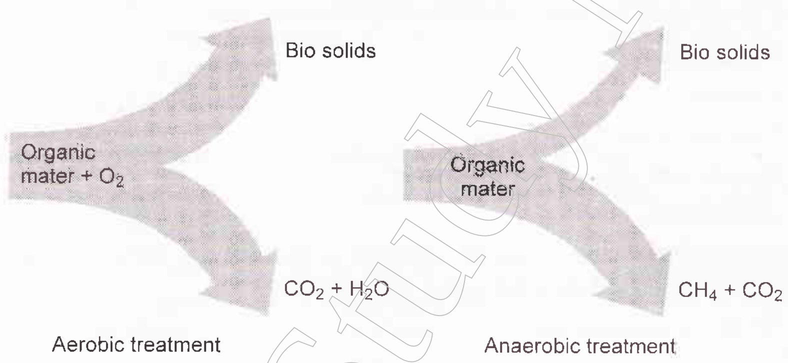

Fig. (3)

10.5-1 CHEMICAL TREATMENT OF WASTE WATER

As already mentioned, flocculation, sedimentation and filtration are different parts of a chemical treatment. Public water supply, especially from surface water, often involves the chemical treatment methods. Surface raw water is generally purified by slow sand or rapid sand filters.

Primary, Secondary and Tertiary Treatment

(1) *Primary treatment :* Primary treatment involves the screening out of the large suspended or floating matters, *e.g.*, wood, hairs, etc. Suspended matter of smaller size of non-biodegradable nature is removed by maintaining the optimum velocity of 12 m/sec in the screening channel. The suspended matters are allowed to settle in the primary sedimentation tank. Suspended solids present in the municipal sewage generally settle down without any aid of coagulants. Industrial wastes often need addition of some chemicals as coagulants. The most commonly used coagulants are alum and lime. The optimum dose for such coagulants is determined in jar test. Lower or higher concentrations of coagulants achieve coagulation and sedimentation to the

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desired level. Sometimes, additional chemical aid is added. The application of Fuller's earth as coagulant aid in case of the effluent produced from oil refinery industries is a well experimented examples. Besides, clay, bantonites, activated carbon and ploy-electrolytes are commonly used as coagulant aids. The sedimented water is further led to another joining chamber, which is technically known as secondary treatment unit.

(2) ***Secondary treatment :*** In secondary treatment the whole contents are thoroughly aerated in order to produce a settleable bio-mass. The settled bio-mass considerably brings down the BOD load from 400 parts per million (ppm) to less than 30 ppm, particularly in sewage treatment plants. The finally treated effluents by secondary treatment process are generally within the acceptable range of BOD (0 ppm) limit and fit to be discharged in any water course.

(3) ***Tertiary treatment :*** Further treatment is needed. If the effluent contains an objectionable proportion of phosphate and nitrogen, which ultimately stimulates the growth of the plankton in the receiving water bodies. Tertiary treatment consists of different processes like :

- Coagulation
- Filtration
- Coprecipitation
- Membrane separation processes
- Adsorption, etc.

Sooner or later this modified treatment facility, *i.e.*, tertiary treatment is likely to be introduced in larger part of the country.

Notes :

- The untreated sewage in general has SS (suspended solids) and BOD ratio 400 : 30.
- Efficiently treated sewage after primary treatment has SS : BOD ratio of 150 : 200.
- After secondary treatment, the same has SS : BOD ratio of 30 : 20.
- The effluent after tertiary treatment is expected to have the ratio of SS and BOD equal to 10 : 10.
- In terms of nutrients removal, 5 to 15% of nutrients are removed by primary treatment.
- 30 to 50% of nutrients are removed by secondary treatment process.
- The tertiary treatment takes further care of the remaining nutrients in the partially treated effluents.

10.5-2 BIOLOGICAL TREATMENT

Sewage and industrial wastes are purified mostly by biological treatment. In order to run the biological treatment plant efficiently and effectively knowledge about the principles involved in such treatment is essential. Some details of the various types of the biological treatment plants along with their basis principles are now discussed.

Criteria for the Application of Aerobic and Anaerobic Biological Treatment

The problem is to decide as to whether aerobic or anaerobic treatment would be applied for the waste which have BOD and COD ratio higher than 6. Before finding the final solution of the problem let us turn our attention towards the conditions for both types of the biological treatments :

(i) When the ratio of BOD : N : P being equal to 100 : 50 : 1, the waste is ideal for aerobic treatment. When the ratio of BOD : N : P is 100 : 2.5 : 0.5, then it is good for anaerobic treatment.

(ii) Wastes of relatively higher strength should go for anaerobic treatment. It becomes more significant in case of wastes associated with intensive odour. Furthermore, less sludge (digested and non-offensive matter) and less space with practically no environmental odour problems are required during anaerobic treatment process.

(iii) The localities with high ground water tables are not suitable for anaerobic treatment. Areas away from habitation with sufficient availability of land are suitable for aerobic treatment. For regions with frequent power failure, anaerobic treatment is preferable. The energy produced during the process of the anaerobic treatment may be utilized for domestic purpose. Bio-gas plants are popular examples of the utility of anaerobic treatment.

Monitoring the Efficiency of the Biological Treatment Plant

To run the anaerobic treatment plant efficiently, following parameters need to be regularly and carefully monitored :

(i) The concentration of volatile acid must vary in the range of 200-400 ppm for proper digestion. The concentration of propionic acid (a member of volatile acid with three carbon atoms) in no case should exceed 100 ppm.

(ii) The pH should be maintained around 7.0, otherwise methane producing bacteria will die out.

(iii) The ratio of volatile acid and bicarbonate alkalinity should be 0.4. A value above 0.8 indicates grave situation. In such cases, buffering capacity is required to be increased by adding lime in suitable proportion.

The efficiency of the aerobic treatment plant is judged on the values of food to microbes (F/M) ratio and sludge volume index (SVI). Mixed liquor suspended solid (MLSS), Mixed liquor volatile are determined in the laboratory to ascertain F/M ratio and SVI values. The mathematical formulae for F/M and SVI are given below :

(i) **F/M ratio**

$$= \frac{\text{BOD or COD of effluent } (g/m^3) \times \text{Flow rate of influent } (m^3/d)}{\text{Aeration tank volume } (m^3) \times \text{MLVSS } (g/m^3)}$$

The results obtained for F/M, generally ranges between 0.05 to 0.15 for extended aerated tank, 0.2 to 0.5 for conventional treatment plant and 1.5 to 5 for modified aeration tank which are considered satisfactory.

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(ii) **Sludge Volume Index (SVI)** $= \dfrac{\text{Settled sludge (ml)} \times 1000}{\text{MLSS (mg/l)}}$

The values for SVI equal to 50 are considered to be excellent, 50 to 100 good, 100 to 150 satisfactory and above 150 is an indication of severe bulking of the settled sludge. A process in which the settled sludge from the bottom comes over the surface of effluent is known as *bulking of the sludge*. The SVI values are brought to the lower side by increasing the recycling ratio (R) for which MLSS must be maintained between 0.25 and 1. Sometimes, bulking is controlled by maintaining 5 to 60 ppm of residual chlorine. Alternatively, the bulking is reported to be maintained at the minimum in the antibiotics producing industry by applying Bordeaux mixture at a concentration of 10 to 20 ppm. Bordeaux mixture is the mixture of copper sulphate and lime in equimolecular ratio.

Types of Biological Treatment

Trickling filter, activated sludge, oxidation ponds, etc., are the examples of biological treatment plants.

(1) *Trickling Filter* (TF) : The biology of TF is as under :

(i) The dominant aerobic bacteria present in TF are generally gram negative.

(ii) Fungi are normally outnumbered in 8 : 1 ratio by bacteria, most abundant at the top 15 cm. The heterotrophic bacteria and fungi are responsible for the primary oxidation of the effluent. The autotrophic bacteria tend to be dominant in the lower layers of the filter, *i.e.*, nitrosomonas oxidizes NH_4 to NO_2 and nitrobacter oxidizes NO_2 to NO_3.

(iii) Algae are commonly found but have very little role in the process of waste purification. When present in large numbers, they may reduce the efficiency of the filter bed.

(iv) Protozoa are present in similar proportion as fungi. Among them, the ciliates are usually the most numerous. The major role of the protozoa is to remove bacteria so as the clarify the effluent.

(v) A diverse grazing fauna is also present in percolating filter viz. rotifers, nematodes and lumbricid worms. These micro-invertebrates produce a much better effluent owing to its grazing activity by preventing the accumulation of too much of film and increase in the oxygen diffusion. It is shown that the respiration of the macro-invertebrate community may be responsible for between 3% (in water) and 10% (in summer) of the total CO_2 dissipated and this is a valuable contribution to the purification of waste in biological filter.

(vi) The development of community depends upon the depth of the bed, time to the year and the composition of the waste to be treated. For example, fungi perform better than bacteria at low temperature in acid media and in waste water with high organic content.

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(vii) Trickling filters have found to reduce salmonella, paratyphi by 84-99% and enteric virus by 40-60% and cysts of entamoeba histolytica by 88-89%, while waste stabilization ponds result in further loss of the pathogens.

(2) *Activated Sludge :* The ecological condition of activated sludge differs from that to trickling filter in the following manner :

Bacteria are gram-negative (similar as that of trickling filter). Fungi are not usually dominant, though they may grow profuesly if bacteria are inhibited often when industrial effluent is present. Fungi may cause 'bulking'. Protozoa are present in richer proportion than that of percolating filters. The protozoa are known to be available in activated sludge as high as 50,000 cells/ml.

Advantages of activated sludge process systems are :

- Flexible scale
- Effective removal of organics and about 97% of suspended solids
- Effective oxidation and nitrification
- Biological nitrification without the addition of chemicals
- Biological phosphorus removal
- Solids/liquids separation
- Stabilisation of sludge

Disadvantages of activated sludge process systems are :

- Does not remove colour from waste water
- Does not remove nutrients, tertiary treatment is necessary
- Problems in removal of well-settled sludge.

(3) *Oxidation pond*

- These ponds are shallow lagoons with an average depth of 1 m. The retention period for settled sewage varies from 2 to 3 weeks. Raw sewage of waste may be retained up to 6 months.
- This offers an excellent example for symbiosis process of bacteria and algae.
- The oxidation pond does not only purify the waste but also serves to provide energy. The algae have a solar conversion efficiency of 3-5%. 1 kg. of algae may produce 116 tons of energy. One unit of oxidation pond could fertilize 10-50 acres of agricultural land. As much as 50 to 60 tons/hec/yr of algae on dry basis can easily be obtained in an Indian oxidation pond. About 40% of nitrogen of the waste is recovered in the oxidation pond by algae.

Role of Microbes in Sludge Digestion and Disposal

The sludge produced by primary and secondary treatment processes is taken to the sludge digestion tank where it is decomposed an aerobically. The role of anaerobic bacteria is to convert the high putrescible raw sludge into a table and

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disposable product, which neither gives rise to offensive smells nor attracts harmful insects or rodents. There are three stages in the process of digestion.

(i) Hydrolysis which involves the formation of long chain fatty acids, amino acid and disaccharide.

(ii) Acid formation that results in the production of fatty acid, alcohol, aldehyde, ketone, together with ammonia, carbon dioxide. Hydrogen and water.

(iii) The third stage is known as *gasification stage* in which the formation of methane by methanoic bacteria under favourable conditions occurs. The digestion takes place in a close tank at 27-35°C for 7-30 days. Further, it is done in open tank for 20-60 days. For effective digestion, volatile acid (VA) propionic acid, bicarbonate alkalinity (BA), etc., should be properly maintained upto maximum desirable limits which have earlier been shown in the preceding column. The sludge produced in the process is good fertilizer and improves soil aggregation. However, the germination of barley and some other grasses were found to be inhabited in presence of sewage sludge. This may be due to the production of inhibitors, *i.e.*, ethylene or ammonia or both caused by lowering of oxygen in the soil, following intense microbic activity.

10.6 SOLID WASTE MANAGEMENT

Rapid and widespread industrial development, unplanned urbanization, regular flow of persons from rural to urban areas and improper and inadequate action of the authorities entrusted with the work of pollution control and environmental protection have largely contributed to unhealthy and degraded environment. This all, in turn, affected the quality of life of the large number of persons. Unplanned and alarming rate of urbanization has given rise to many environment related problems, such as problem of health and hygiene, sewage, disposal of solid waste, air, water and land pollution, slums, housing, basic amenities and others. Apart from air and water pollution problems, most gigantic problem which modern cities and industries are facing is the solid waste disposal problem.

The *'solid waste'* can be defined as—'Any garbage, refuse, sludge from a waste treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolids or contained gaseous material resulting from industrial, commercial, mining and agricultural operations and community activities.'

Waste management is the collection, transport, processing, recycling or disposal and monitoring of waste materials. The term usually relates to materials produced by human activity, and is generally undertaken to reduce their effect on health, the environment or aesthetics. Waste management is also carried out to recover resources from it. Waste management can involve solid, liquid, gaseous or radioactive substances, with different methods and fields of expertise for each.

It is important to ascertain the nature of waste whether it is biodegradable or combustible in handling and disposal. Combustion and landfill method of disposal further gives rise to problems like air, water and land pollution, affecting adversely the health of the man, and flora and fauna. Apart from household, office waste, the waste from industries within the cities have become a threatening problem now-a-days. Waste from industries using chemicals and synthetics, biomedical waste are dangerous too.

Waste management practices differ for developed and developing nations, for urban and rural areas and for residential and industrial producers. Management for non-hazardous residential and institutional waste in metropolitan areas is usually the responsibility of local government authorities, while management for non-hazardous commercial and industrial waste is usually the responsibility of the generator.

Elements of Waste management

Solid waste management typically involves at least six functional elements :

(1) *Generation rate :* Generation rates of wastes are used to evaluate reuse, recycling feasibility, processing and disposal requirements.

(2) *On-site handling, storage and processing :* This is simply the on-site preparation of the waste for reuse, recycling or disposal. For example, in our homes we may separate recyclables from other wastes.

(3) *Collection :* This is the physical gathering of waste. It may vary from the garbage collection from homes to collection of toxic chemical wastes from industry.

(4) *Transfer and transport :* This implies the consolidation of collected waste for bulk transport to a processing, recovery or disposal facility.

(5) *Processing and recovery :* These are the activities which are employed for recovery of waste as raw materials or energy or preparation of wastes for disposal.

(6) *Disposal :* This is the ultimate fate of non-reusable and non-recyclable wastes. Incineration and landfilling are the two common disposal alternatives.

Controlling pollution due to solid-wastes

As discussed above, there are a lot of wastes which are harmful for the environment like Industrial end product, household, e-waste, plastics, sewage, nuclear waste, fumes, etc. When these enter the enviroment and get in contact with the air, water or soil, they cause various pollutions. The best way to control this type of pollution is :

(1) Stop the usage of articles which cause such waste.

(2) Reduce the usage of non-biodegradable products.

(3) Research for biodegradable replacements.

(4) Recycling.

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10.6-1 METHODS OF DISPOSAL

[I] Recycling

'Recycling' refers to the widespread collection and reuse of everyday waste materials such as empty beverage containers. These are collected and sorted into common types so that the raw materials from which the items are made can be reprocessed into new products. Material for recycling may be collected separately from general waste using dedicated bins and collection vehicles, or sorted directly from mixed waste streams.

The most common consumer products recycled include aluminium beverage cans, steel food and aerosol cans, HDPE and PET bottles, glass bottles and jars. paperboard cartons, paper for newspapers, magazines, and corrugated fiberboard boxes. PVC, LDPE, PP and PS are also recyclable, although these are not commonly collected. These items are usually composed of a single type of material, making them relatively ease to recycle into new products. The recycling of complex products (such as computers and electronic equipment) is more difficult, due to the additional dismantling and separation required.

Waste materials that are organic in nature, such as plant material, food scraps and paper products can be recycled using biological composting and digestion processes to decompose the organic matter. The resulting organic material is then recycled as mulch or compost for agricultural or landscaping purposes. In addition, waste gas from the process (such as methane) can be captured and used for generating electricity and heat (CHP/cogenaration) maximizing efficiencies. The intention of biological processing in waste management is to control and accelerate the natural process of decomposition of organic matter.

There are large variety of composting and digestion methods and technologies varying in complexity from simple home compost helps, to small town scale batch digesters, industrial-scale enclosed-vessel digestion of mixed domestic waste (see Mechanical biological treatment). Methods of biological decomposition are differentiated as being aerobic or anaerobic methods, though hybrids of the two methods also exist.

Anaerobic digestion of the organic fraction of MSW Municipal Solid Waste has been found to be in a number of LCA analysis studies to be more environmentally effective, than landfill, incineration or pyrolisis. The resulting biogas (methane) though must be used for cogeneration (electricity and heat preferably on or close to the site of production) and can be used with a little upgrading in gas combustion engines or turbines. With further upgrading to synthetic natural gas it can be injected into the natural gas network or further refined to hydrogen for use in stationary, cogeneration fuel cells. Its use in fuel cells eliminates the pollution from products of combustion (SOx, NOx, particulates, dioxin, furans, PAHs...).

The energy content of waste products can be harnessed directly by using them as a direct combustion fuel, or indirectly by processing them into another type of fuel. Recycling through thermal treatment ranges from using waste as a fuel source for cooking or heating, to anaerobic digestion and the use of the gas fuel (see above), to fuel for boilers to generate steam and electricity in a turbine. Pyrolysis and gasification are two related forms of thermal treatment where waste materials are heated to high temperatures with limited oxygen availability. The process usually occurs in a sealed vessel under high pressure. Pyrolysis of solid waste converts the material into solid, liquid and gas products. The liquid and gas can be burnt to produce energy or refined into other chemical products (chemical refinery). The solid residue (char) can be further refined into products such as activated carbon. Gasification and advanced Plasma arc gasification are used to convert organic materials directly into a synthetic gas composed of carbon monoxide and hydrogen. The gas is then burnt to produce electricity and steam. An alternative to pyrolisis is high temperature and pressure supercritical water decomposition (hydrothermal monophasic oxidation).

Advantages of recycling are :

(1) ***Saving energy :*** It takes less energy to process second hand supplies than it does to use virgin materials. For example, it takes a lesser amount of energy to recycle paper from waste material than it does to make paper from new woodland. There is no longer a need to cut down a new tree, process the wood and craft it into paper.

Energy from non-renewable income is protected and saved for future generations, money is saved when less power is used and time and again pollution and emissions are reduced when less energy is used.

(2) ***Saving Money and Land Space :*** Recycling reduces litter in landfill sites, which cuts down on the cost of throw away disposal and the clearing of more land for new landfills when the up do date landfills turn out to be too full to store any more waste. Recycling is a simple option to clearing more land for new landfills. For example, composting, recycling kitchen waste and back garden waste into compost provides revenue of free nourishing soil for crop growing. Recycling would allow us to use again the materials over and over again.

(3) ***Air Pollution and Water Pollution :*** Decomposing waste over and over again releases noxious gases and chemicals as it decomposes at landfill sites. These gas and chemicals form air pollution. When the chemicals percolate into the groundwater this creates water pollution and our water is infected. Imagine how much toxic waste we could prevent if as an alternative of landfills we had recycling centres. We could take in cleaner air and drink cleaner water.

(4) ***Additional Benefits :*** Recycling also preserves wildlife. When smaller amount of trees are cut down to make new material or to put together space landfills, environment for wildlife remains. More habitats for animals stand for less animal extinction.

Despite what some may say, recycling is imperative and it can make a difference. We possibly will not be proficient to solve our landfill and pollution problems anytime almost immediately, but at least are capable to help to keep them from getting worse.

[II] Landfill

Disposing of waste in a landfill involves burying the waste and this remains a common practice in most countries. Landfills were often established in abandoned or unused quarries, mining voids or borrow pits. A properly designed and well-managed landfill can be a hygienic and relatively inexpensive method of disposing of waste materials. Older, poorly designed or poorly managed landfills can create a number of adverse environmental impacts such as wind-blown litter, attraction of vermin and generation of liquid leachate. Another common byproduct of landfills is gas (mostly composed of methane and carbon dioxide), which is produced as organic waste breaks down anaerobically. This gas can create odour problems, kill surface vegetation, and is a greenhouse gas.

Design characteristics of a modern landfill include methods to contain leachate such as clay or plastic lining material. Deposited waste is normally compacted to increase its density and stability, and covered to prevent attracting vermin (such as mice or rats). Many landfills also have landfill gas extraction systems installed to extract the landfill gas. Gas is pumped out of the landfill using perforated pipes and flared off or burnt in a gas engine to generate electricity.

[III] Incineration

Incineration is a disposal method in which solid organic wastes are subjected to combustion so as to convert them into residue and gaseous products. This method is useful for disposal of residue of both solid waste management and solid residue from waste water management. This process reduces the volumes of solid waste to 20 to 30 percent of the original volume. Incineration and other high temperature waste treatment systems are sometimes described as "thermal treatment". Incinerators convert waste materials into heat, gas, steam and ash.

Incineration is carried out both on a small scale by individuals and on a large scale by industry. It is used to dispose of solid, liquid and gaseous waste. It is recognized as a practical method of disposing of certain hazardous waste materials (such as biological medical waste). Incineration of a controversial method of waste disposal, due to issues such as emission of gaseous pollutants.

Incineration is common in countries such as Japan where land is more scarce, as these facilities generally do not require as much area as landfills. Waste-to-energy or energy-from-waste are broad terms for facilities that burn waste in a furnace or boiler to generate heat, steam and/or electricity. Combustion in an incinerator is not always perfect and there have been concerns about micro-pollutants in gaseous emissions from incinerator stacks. Particular concern has focused on some very persistent organics such as dioxins, furans, PAHs,... which may be created within the incinerator and afterwards in the incinerator plume which may have serious environmental consequences in the area immediately around the incinerator. On the other hand this method or the more benign anaerobic digestion produces heat that can be used as energy.

10.7 NOISE AND IT'S CONTROL

Noise is any undesirable sound. It is a disturbance to the environment. Sounds are well thought-out noise pollution if they unfavourably have an effect on natural world, human activity, or are competent of destructive physical structures on a customary, repeating starting point. In the broadcast sense of the expression, a sound may be painstaking noise pollution if it disturbs any ordinary course of action or causes human harm, even if the sound does not take place on a habitual basis. Prolonged introduction to noise levels higher than eighty-five decibels can damage inner ear cells and show the way to hearing loss.

The customary starting place of noise pollution is from transportation. In rural areas, train and airplane noise can upset natural world way of life. Thereby they affect the manner in which animals in areas around train tracks and airports live. In urban areas, automobile, motorcycle, and even amusement noise can cause sleep interference in humans and animals, hearing loss, heart disease as a result of stress and even mental flux. Even low levels of noise can be maddening or annoying. Sudden increases in volume can make sounds aggravating—this is why sirens are so disturbing. The quieter the environment, the sharper a noise can be.

Causes of Noise Pollution

Noise pollution is a silent cause of death and much community concern has not been created on the effect of noise on both workers in the industries in particular and the public in the community at large. Noise is a significant environmental contaminant that spoils our air, water and soil. It has the capability to destroy bridges and develop cracks in the buildings. The noise can also cause skin and mental diseases. It has been found that noise is a technology generated problem and on the whole noise doubles every 10 years keeping pace with our social and industrial progress.

- Environmental pollution has been largely affected due to noise pollution each day. The noise pollution in the different parts of the city increases in and around work places and homes. The noise levels reach a peak in the twilight areas when people are off to work hours as traffic too reaches at peak.
- In India the problems caused by noise pollution are further provoked in view of the fact that there are scarcely any celebrations, festivals, marriage or religious functions where there is no use of loud speakers at a very high pitch for long period of time.
- In offices too there is noise pollution owing to the clicking of typewriters, bells, telephones, clattering office machines and conversations.
- On the roads noise pollution occurs due to rising number of automobiles each day. Screeching of tyres, squealing breaks and sirens honking at

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highest decibels possible are all factors that add violently and at length to noise pollution.

- Blaring televisions and radios are another major factors contributing noise pollution in India.
- The other most important problem adding to the existing problem of noise pollution is that the profit-making and the industrial units are either not very far from the inhabited areas or from time to time they are setup in the residential areas itself.
- Machinery, motors and compressors used in the industries creates a lot of noise which adds up to the harmful state of noise pollution. Boilers, generators and conditioners add to the previously established noise pollution.
- To meet the demands of the basic requirements of living the structure of highways, buildings and city streets causes a lot of noise. Air compressors, bulldozers, loaders, dump trucks and concrete workers are the major sources of noise pollution in construction sites. Though, not a most important reason industrial noise adds to the noise pollution.

Effects of noise pollution on human health

Noise pollution can have disastrous effects on human life. Each and every one knows that noise can be very disturbing. Children who are out in the open to noise may have hearing and even reading impairment. Those working in loud office environments have been found to be less cognitively motivated, and tend to have higher stress levels. The most serious problem associated with noise pollution is the disastrous impact it has on our nervous system which perhaps reduces our response to fight back against the drastic pollution. One of the major health effects of noise pollution is chronic stress and the high levels of irritation.

As a result, noise pollution has also been linked with increasing health problems in the society with life threatening diseases such as heart diseases, high blood pressure and stroke Noise pollution disrupts the sleep pattern of an individual by preventing sleep and troublemaking sleep cycles. The ear-piercing noises in most high population cities must in no way be underestimated. The consequences cannot be gauged at an early stage, but its drastic effects can disrupt in the future for sure.

Noise Control

The solution to noise pollution may include one or a combination of the following measures :

(1) *Source control :* This may include source modification such as acoustic treatment to machine surfaces, design changes, limiting the operational timings and so on.

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(2) ***Transmission path intervention :*** This may include containing the source inside a sound insulating enclosure, construction of a noise barrier or provision of sound absorbing materials along the path.

(3) ***Receptor control :*** This includes protection of the receiver by altering the work schedule or provision of personal protectoin devices such as ear plugs while operating noisy machinery.

The above control measures can be implemented by damping, absorption, dissipation and deflection methods. Common techniques involve constructing sound enclosures, applying mufflers, mounting noise sources on isolators and by using materials with damping properties. We can trim down noise in our home considerably by installing dual-paned windows, weather stripping and even added padding. As an additional benefit, these changes can also trim down our heating and cooling bills and help the environment.

10.8 LAND OR SOIL POLLUTION

Soil pollution comprises of the toxic waste of soils with resources, mostly chemicals that are out of place or are present at concentrations more than normal which may have unpleasant effects on humans or other organisms. However, soil pollution is also caused by resources other than the undeviating addition of man-made chemicals such as undeveloped runoff waters, industrial waste materials, acidic precipitates, and radioactive clash.

Both organic and inorganic contaminants are imperative in soil. Soil pollution is caused by the presence of synthetic chemicals or other modification in the natural soil background. This type of contamination normally arises from the split of underground storage links, use of pesticides and percolation of polluted surface water to subsurface strata, oil and fuel dumping, leaching of wastes from landfills or direct discharge of industrial wastes to the soil. The most common chemicals involved are petroleum hydrocarbons, solvents, pesticides, lead and other heavy metals. This episode of this incident is linked with the degree of industrialization and intensities of chemical treatment.

Soil pollution can lead to water pollution if poisonous chemicals percolate into groundwater, or of contaminated overflow reaches streams, lakes or oceans. Soil also naturally contributes to air pollution by releasing likely to explode compounds into the atmosphere. The decay of untreated materials in soil can release sulfur dioxide and other sulfur compounds, causing acid rain. Heavy metals and other potentially toxic elements are the most grave soil pollutants in sewage. Sewage mud contains heavy metals and, if functional over and over again or in large amounts, the treated soil may build up heavy metals and as a result become not capable to even support plant life.

In accumulation, chemicals that are not water soluble contaminate plants that grow on polluted soils. The greater than ever polluton of the atmosphere has been one of the greatest concerns for science and the universal public in the last fifty years. The brisk industrialization of agriculture, spreading out of the chemical industry and the need to generate cheap forms of energy has caused the constant release of man-made organic chemicals into natural ecosystems. As a result, the atmosphere, bodies of water, and many soil environments have become contaminated by a large variety of toxic compounds. These include the hazard of acute toxicity, genetic changes, birth defects for humans and other organisms. Some of these artificial toxic compounds are also dead set against to substantial, chemical or biological dreadful conditions and thus be a symbol of an ecological burden of considerable amount.

Causes of Soil Pollution

Soil pollution is caused by the existence of man-made chemicals or additional variation in the usual soil environment. This type of infectivity characteristically arises from the rupture of alternative storage links, application of pesticides and percolation of contaminated surface water to subsurface strata, oil and fuel throwing away, leakage of wastes from landfills or nonstop discharge of industrial wastes to the soil.

A soil pollutant is any feature which deteriorates the excellence, stability and mineral substance of the soil or which disturbs the organic sense of balance of the organisms in the soil. Pollution in soil is coupled with factors such as :

(1) *Haphazard use of fertilizers :* Soil nutrients are vital for plant growth and development. Fertilizers pollute the soil with impurities. The over use of fertilizers reduce quantity of vegetables and crops grown on soil over the years. It also reduces the protein content of wheat, maize, etc., grown on that soil. The carbohydrate quality of such crops also gets tainted. Surplus potassium at ease in soil decrease Vitamin C in vegetables and fruits. The vegetables and fruits grown on over fertilized.

(2) *Use of pesticides, insecticides and herbicides :* To kill useless insects living on crops farmers use pesticides. Pesticides not only bring toxic effect on human and animals but also drop off the fertility of the soil.

(3) *Damping of solid wastes :* In broad-spectrum, solid wastes include trash, domestic refuse and not needed solid materials such as those from commercial, industrial and agricultural operations. Since a considerable amount of urban solid throw away tends to be paper and food waste, the majority is recyclable or biodegradable in landfills. In the same way, most agricultural waste is recycled and mining waste is left on site.

The segment of solid waste that is dangerous such as oils, battery metals, heavy metals from smelting industries and organic solvents are the ones we have to pay particular attention to.

(4) *Deforestation :* Soil Erosion occurs when the worn out particles are dislodged and passed away by wind or water. Deforestation, agricultural development, temperature extremes and human actions add to this erosion.

Humans speed up this process by construction, mining and overgrazing. It results in floods and cause soil erosion.

Forests hold up many habitats and ecosystems, which make available immeasurable freeding pathways or food chains to all species. During the past few years quite a lot of vast green land has been converted into deserts. Deforestation is slowly destroying the most dynamic flora and fauna areas in the human race.

Effects of Soil Pollution

Soil Pollution was in the beginning defined as the pollution of soil system where by noteworthy quantities of chemical or other substances, resulted in the turn down of its fertility or output with respect to the yield of crops. Soil pollution differs from water and air pollution, because the contaminants remain in direct contact with the soil for comparatively longer periods and hence change the chemical and genetic properties of soil. The harmful chemicals can also enter the human food chain from land or water plants.

The major sources of pollution of soil include mining, mud, fertilizers, pesticides, composted town refuse, etc. Fly ash generated from thermal power plants, industrial wastes dumped into surrounding land, mining wastes, non-biodegradable organic pollutants and industrial sludge's, etc. are the reasons which cause soil pollution. Commercial and domestic urban wastes consisting of dried sewage sludge as well as trash and debris materials such as plastics, metal cans, glasses, street sweepings, waste paper, fibers, rubber, etc. contribute to soil pollution.

Effects of Soil Pollutants

Different types of soil pollutants have different effect on the nature of soil. Now let's look into the effect caused by each of these pollutants.

(a) Synthetic fertilizers : Excess use of fertilizers destroys the microbial plant life in the soil, thus leading to disturbance of essential processes in soil such as nitrogen fixation.

(b) Pesticides are often used to keep away pests which damage the crops produced and often cause soil pollution as they are mostly non environmental. They take many years to degrade and remain as toxic remains in soil. They may also enter marine environment through run off after rain and enter the food chain.

(c) Industrial effluents : Solid, liquid and gaseous pollutants from thermal power plants, paper, fertilizer, iron and steel industry often end up in the soil and cause dreadful conditions of soil due to their toxicity.

(d) Urban wastes : Wastes generated in urban living areas such as sewage mud, garbage, hospital wastes, plastic bags, etc., also are a major cause of soil pollution. These wastes tend to build up in soil, support the growth of pathogenic

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life form and cause diseases. Waste material like plastic tends to remain non biodegradable in soil and affect soil yield.

Effective treatment of household wastes and modern methods of sewage throwing away if implemented, soil pollution can be taken care of. Formulation of rigorous pollution control legislation and its efficient realization is also essential and imparting public awareness programs to educate people regarding the health hazards of pollution is a must to control soil pollution.

Effects of Soil Erosion on the Environment

Loss of soil from land owing to the water and wind currents is called soil erosion. It is a natural process that transports soil from one location to another. In natural conditions, this progression takes place in a slow and continuing manner. Due to human being impact the rate of soil erosion is considerably accelerated. Some of the issues that speed up the process of soil erosion are deforestation, over grazing and improper or in excess amount of farming practices.

When soil erosion happens very slowly but surely it has negligible effect on the land as an adequate amount of time is on hand for to substitute with new soil. But accelerated erosion leads to unfavourable special effects and decreases soil fertility as it diminishes the amount of nutrients. Decrease in soil fertility due to wearing away leads to decrease in the output of crop and also excellence of crops grown.

Eroding land can show the way to accidents and when soil that shifts and gets accumulated on roads and streets can block the driving. These effects are common in sloppy and mountain regions. Soil erosion can reason great damage to environment as greater than before loss of soil can have an effect on the growth of natural vegetation and in turn this leads to transfer of fertile land into a desert.

Soil erosion leads to confirmation of remains by water currents in water bodies like ponds, which can hurt marine plant and animal life. The soil sediments can cover up fish eggs present in ponds and prevent their hatching. Due to erosion soil particles stay on the edge in water and prevent light from reaching marine plants and have an effect on the process of photosynthesis. Due to gigantic amount of suspended soil particles in water it retains the heat and raises the water temperature, which affects the living organisms.

Another major shock from the agricultural chemicals that often move with worn residue is that these chemicals move into and pollute, downstream watercourses and water bodies. Where inputs of agricultural chemicals are high—as in the more wealthy nations—costs of removing such pollutants from drinking water can be extensive.

The harmful effects of erosion, in terms of decreased agricultural yields, are well known in the developing countries. In erosion-prone areas of the more well-off countries, productivity may be maintained in the short to medium term by increased fertilizer input. The effects of erosion are thus rarely recognized by farmers in richer countries. This approach is however infeasible with regard to erosion in developing countries.

10.9 INDUSTRIAL POLLUTION

Industrialization is very crucial for development and for the improvement of life. But, it would be a huge price if we endanger future generations for this industrialization. Industries generate a lot of wastes which spil our eco-system. Industrial Pollution Control include steps to reduce present or future air pollution control, product or waste heat recovery application by :

- Adhering to the government regulations.
- Creating green zones (green belt) in factories.
- The processes like, flue gas desulphurization and denitrification, retrofitting, gas conditioning, system design, emission measurements, design of chimney, design of dust handling equipment, fan, handling explosive dusts are required in industries.
- Identify and select the right type device or system, it could be a stand alone or fully engineered complete packaged for pollution control.
- Various conventional and advanced gas absorption, particulate capture, pollutant and heat recovery technologies are available to reduce harmful effects of industrial pollution.
- Also air emission, air pollution control systems, odour control, gas scrubbing systems, particulate removal, fume scrubbing, ammonia recovery, acid recovery, acid gas removal, product recovery, aerosol removal, waste heat recovery, mist removal, NO_x removal, high efficiency cyclones, wet scrubbers consisting of packed absorption and waste heat recovery towers, horizontal cross flow scrubbers, fluidized bed scrubbers, multiple type tray scrubbers, high energy gas atomized venturi and jet ejector venturi scrubbers, mist or preformed spray scrubbers, dry and dry/wet scrubbers, forced condensation scrubber systems, wet electrostatic precipitators, specially adsorption and scrubbing systems, an advanced NO_x scrubbing reagent and full product recovery and by-product production systems are also used to curb the effects of pollution in industries.
- Energy saving by recovering heat from a multitude of hot gas sources.

These steps highly required in large number of industries including; chemical, pharmaceutical, medical products, fertilizer, plastics, petroleum, hazardous waste, biofuel, nanotech, pulp and paper, wood products, electronics, semiconductor, power, mineral products, mining, iron and steel, nonferrous metals, metal finishing, waste water, food and by-products and textile.

Industrial Waste Treatment

The best method for any type of waste treatment is to recycle or to recover the pollutants from the waste. The recovery and recycling the wastes ensures the conservation of the environmental resources, reduces the cost of production, creates opportunity for employment, besides considerable eliminating the load of pollution. In fact, nothing is waste rather the waste of today is the resource of tomorrow. Some of the industrially recovered products from the wastes are described below :

Furfural may be obtained as recovery product from the sugar wastes, containing molasses and bagasse. Oxalic acid is obtained by oxidation of molasses. Sugar press mud which is obtained during filtration process is a source of sugarcane wax. Potassium could be processed form spent wash of distillery waste; vitamin B-12 (cyanocobalamine) may also be recovered from municipal sewage waste. Many useful pharmaceutical ingredients, viz. tocopherol (vitamin E), phytin and lecithin are obtained from rice bran. Sodium silicate is obtained as by-product from paddy husk. Brome lain is prepared from pine-apple waste. Saw dust which is a waste product from timber industry can be utilized in manufacturing active carbon and moulding power. Fly-ash, a waste product, obtained in huge quantity from thermal power station, may be utilized for manufacture of fly-ash brick, clay fly-ash bricks, pozzolanic cement and can be incorporated as one of the ingredients of Portland cement. Mica waste could profitable be utilized for making insulating bricks and mica paints. Slaughter house waste could be utilized for making peptone which is used as media in bacteriological analysis. Pan creation is also obtained from slaughter house waste which is used in for processing industries. Commonly wastes consisting of night soils may be utilized for producing biogas. Community garbage containing cellulosic materials in significant proportion may be utilized for paper and alcohol production.

10.10 CHEMICAL POLLUTION

Chemical pollution is caused due to the contamination of the environment due to the chemicals byproducts. It may originate from industrial areas as well as anywhere where there are people. Its major influence is on marine or soil composition.

As the human population is fast increasing, the human race has become more developed and chemical wastes have increased dangerously growing each day at high levels in some areas. The ocean, can reduce the effect on some chemical wastes however, as the amounts of chemicals add to, toxins begin to mount up. Some marine organisms come in contact with these harmful toxins, and these toxins unfavourably affect the marine life and there is a slowdown in terms of their population.

The various chemical wastes are :

(1) *Industrial Chemical Waste :* With the industrialization started the industrial waste in the form of chemicals. This waste has long been dumped into the water bodies, air as well as the land. This waste then enters directly, in the form of air in the human beings; or indirectly, from the water, vegetables, poultry or fisheries into the human beings.

(2) *Oil* is a major component of chemical pollution and causes environmental harm to the ocean. The thick, sticky oil coats the fine hair on birds, inhibiting flight and the capability of those feathers to protect the bird. The gills of fish become blocked with oil and the fish choke. Marine mammals' bodies become coated in oil, and they cannot maintain their body temperatures. Oil coated marine plants cannot get hold of energy from the sun for photosynthesis. Oil may also become attentive in sediments for existence and may become on the brink again in storms.

(3) ***Water Disposal :*** To further complex this situation, humans in broad-spectrum desire to live near the water. Water provides recreation, a means of transportation, a source of food and other wealth. Groundwater aquifers, rivers and streams provide the world with drinking water. These water bodies are too often used for sewage disposal. Access to the water has always been a significant consideration. However, as more people make their home in coastal areas, the problems of water pollution enhance.

(4) ***Chemicals from Vehicles :*** Commercial and recreational vehicles try to win for space and property on and in the water. Gas and oil from these vessels may by industrial accident trickle into the water. People swarm beaches and many leave waste behind. Increased structure along the coast leads to greater than before erosion, loss of habitat and more smash up to the coast during storms as the natural shock absorber zone is ruined.

To keep away from chemical pollution man needs to take charge in person of the community environment. Man is the most evolved human being on the planet and by desirable quality of his brainpower and aptitude to revolutionize the natural surroundings; man can produce an environment of his choice and need.

10.11 GOVERNMENT INITIATIVES FOR ENVIRONMENT

The central and the state governments own, control and develop the forests, dams, major irrigation systems, power stations, industries, means of transportation, railways, roads, ports, etc. The government is not just the protector of the environment of the country but also has a major responsibility for sustaining environmental conscience.

In India the ***Ministry of Environment and Forests*** is the main nodal agency for generating environment consciousness and making and implementing schemes for environmental protection. The government's environmental policy focuses to check degradation of land and water through wasteland management and restoration of river water quality programs.

The policy also focuses to provide for conservation of natural resources by direct action such as declaration of reserved forests, biosphere reserves, wetlands, mangroves and protection of endangered species. It ***makes laws*** and acts for environment protection and initiates penal measures against those who violate the laws.

The government's initiatives are to plan and execute a nationwide program for the prevention, control of environmental pollution. It emphasizes to lay down standards for the quality of the environment in various aspects and for emission or discharge of environmental pollutants from different sources.

To protect wildlife the government of India has set up national parks, sanctuaries and tiger and biosphere reserves.

Indian satellite to monitor green house emission : In March 2010, Union Minister of Environment and Forests Mr. Jairam Ramesh announced that by 2012, a dedicated satellite would be launched with the support of Indian Space Research Organization (ISRO) to monitor India's greenhouse gas emission. Currently, Japan and European countries have this satellite.

As such the environment has a major role in environmental protection. It is the government's duty to find out ways and means of improving efficiency of existing technologies and introduce new eco-friendly technologies.

Eco-friendly technologies are based on renewable sources as raw material as well as energy to produce environment friendly products. For example, to reduce vehicular Pollution in Delhi, the government initiated the development and use of CNG kits in automobiles instead of petroluem. This step has reduced air pollution in Delhi to a considerable extent.

In order to minimize the adverse impact of a number of development projects on the environments, the government ensures that an environmental impact assessment is carried out before such a project is started. These plans are also strictly monitored for compliance.

Number of laws, committees have been formulated and created. These laws are discussed in a fiarly good details later.

The government has set up various committees to evaluate the impact of various development projects on environment. Some of the issues which have been hotly debated in recent decades include the importance of constructing big dams, affect of pollution on monuments like Taj Mahal, protection of wildlife, especially endangered species like lions, tigers, etc. The government also seeks public opinion on certain matters related to the environment.

10.12 SOCIAL AND INDIVIDUAL INITIATIVES FOR ENVIRONMENTAL PROTECTION

Environment protection is not the responsibility of the government alone. All sections of the society have to participate in this endeavour. The role of every individual in environmental protection is of great importance because if every individual contributes substantially the effect will be visible only at the commuity, city state or national level but also at the global level. It is ultimately the society that suffers due to environmental degradation.

Therefore the society has to play an important role in maintaining environmental standards. It is the responsibility of each individual to protect the earth and provide conducive environment for itself and innumerable other species which evolved on the earth. Each individual should change his or her lifestyle in such a way as to reduce environmental pollution.

If air and water resources in the area are unfit and do not meet the acceptable standards, the people of the area can organize themselves and force the responsible agencies to take necessary action. If suitable action is not forthcoming they can under the laws of the land, file a public interest litigation (PIL) and can get their problems solved.

Society is made of individuals together. So it is the duty of each individual to see that his/her actions do not pollute the environment. Each individual must use paper or cloth bags instead of polythene. Use of eco-friendly products and CFC free refrigerators can help control pollution.

Groups of individuals together can make a huge difference in maintaining environmental standards. For example, group housing societies can initiate steps for waste management by making provisions for segregating wastes, taking measures for recycling wastes like making compost pits, etc. They can also take measures for reducing the use of electricity and finding alternative sources of energy.

Saving electricity by not wasting it when it is not required because electricity saved is electricity generated. For example, put on warm clothes rather than switching on a heater.

Air pollution especially vehicular pollution can be minimized by adopting car pool method. This will also save large amounts of money spend on importing petroleum from other countries. Adopting and popularizing renewable energy sources and promoting reuse and recycling wherever possible will help reduce the production of waste.

Societies can play a significant role in environmental protection by creating awareness and educating people about the need to conserve and manage natural resources. Social and individual consciousness if carefully encouraged is a step to transformation.

Day to Day Habits

There are certain habits which, if cultivated, will make tremendous difference in the pollution levels. These are :

- Reuse any items that you can
- Buy biodegradable products
- Store all liquid chemicals and waste in spill-proof containers
- Eat organic foods that are grown without pesticides
- Do not use pesticides

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- Use a drip tray to collect engine oil and do not dump motor oil on the ground
- Buy products that have little packaging
- Ways to control air pollution :
  - Carpool or join a ride share with friends and coworkers
  - Do not smoke
  - Keep your car maintenance up-to-date
  - Drive as less as possible
  - When you drive accelerate slowly
  - Always replace your car's air filter
  - Use a push or electric lawnmower rather than a gas-powered one
  - Do not use harsh chemical cleaners that can emit fumes
  - Inspect your gas appliances and heaters regularly
  - The best way to prevent water pollution is to not throw trash and other harmful chemicals into our water supplies.
  - Wash your car far away from any storm water drains
  - Do not throw trash, chemicals or solvents into sewer drains
  - Inspect your septic system every 3-5 years
  - Avoid using pesticides and fertilizers that can run off into water systems.
  - Sweep your driveway instead of hosing it down.
  - Use non-toxic cleaning materials.
  - Do not wash paint brushes in the sink.
- Suggestions which may help in maintaining the ecological balance :
  - Afforestation should be encouraged by planting additional trees.
  - To stop the over-exploitation of the wooded area by government contractors for resin, medicinal herbs, timber, etc., there should be an overall ban on cutting of trees on mountain slopes and in catchment's areas.
  - Instead of big dams, small dams and hydro-electric power stations can be constructed. For a very small village a hydro-electric generator can be installed in the water mill.
  - Promote horticulture and small-scale industry in the region, which will make available job opportunities to the local people.
  - Promote *sulabh sauchalaya* and bio-gas plants for recycling eco-friendly material. To reduce the pressure of the growing population on natural wealth, they should be provided with LPG gas, kerosene oil and solar cookers.
  - Precuationary measures have to be taken to keep away from the chances of forest fires.

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Promotion of Renewable Resources and their benefits

As the conventional resources are fast depleting, we must look out for alternative power resources. Among these is the sun, wind, biogas and tides which are sources of renewable energy. They score over the conventional sources of energy and are inexhaustible and pollution free. The renewable resources can be generated continuously in nature and are inexhaustible, *e.g.*, wind, water, sun, etc.

Wind and running water, as sources of energy, were in use long before the conventional sources of energy like coal, oil, mineral and natural gas came to be used by the masses. Wind and running water were being used for navigation. Wind mills were used for pumping water and for grinding grains. The alternatives sources of energy are always very environment friendly and are not at all highly polluting. This turns out to be an important factor for sustained economic growth. The benefits of renewable resources are :

- Petroleum and gas are an added source of pollution for our environment. Coal produced by mining also produces dust particles in the air and moreover mining and handling is a hazardous job.
- Fossil fuels such as petroleum and coal damage and ozone layer and also danger to human settlements.
- The prime advantage of using energy from renewable resources is that they are easily available and these have a never ending supply.
- Renewable energy can be locally produced.
- The cost of distribution involved is very low.
- They do not cause any harm to the environment.
- They are reusable and recyclable.
- Solar power is the most 'green' energy source in the world. It does not harm the atmosphere around it in any way.
- There are no residues, waste or byproducts of any kind.
- The process of capturing the energy does not bring into being any noise pollution.
- No one will charge you any money for harvesting the sun's power. Once you have setup the solar panels, you can start converting solar energy into electrical energy for free. Thus ,one has no doubts of spending a large portion of your earnings on electrical energy bills.
- Solar technology is very suitable. You can unplug the panel and take it with you on a trip. Tiny solar panels are also obtainable, which you can use to charge your electronic gadgets while you're on the move.

By altering to renewable energy sources such as solar energy and wind power, you can save manually a lot of money and leave a superior planet behind than the one you found for your future generation. A voyage in the right direction to control the air pollution will also reduce its catastrophic impact on the future generations.

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Creating Awareness

The role of learning environment is as important as understanding the geographical location where the person is growing. The learning-teaching seems necessary to understand and develop a love for ecology. The natural surroundings are vital to sensitized observation making environment awareness a natural learning from indigenous experiences.

This has to be achieved through frequent visits to the park, zoo supplemented with good literature. A rich exposure to the wealth of nature and innovative teaching learning modes enables all to be environmentally sensitive. In the absence of abundance of nature, the familiarity with the flora and fauna and cycles of nature has to be created through awareness of books and other forms of simulated experiences.

With the wide range of living habitats and need for conservation and protection of the environment . an exhaustive curriculum is required. The environment education has to be in relatoin with the local flora and fauna along with child-friendly methods. The relationship between classroom learning and the experiences the children encounter has to be meaningful. A child has a different agenda as for him pollution and congestion has no real meaning. Generating a love for his essence of nature by concrete exercises such as group visits with an excitement for identifying stars would provide a child stimulating encounters with nature. Discoveries of a few of nature's secrets would be enough to initiate a child-environment relation.

When people live in close proximity with of nature, the free time and the space and the flexibility in interactions across ages facilitates children's natural adventures with the many phenomena in nature. Humanity is not alone and the earth is one of the issues of the environment movement. Scientific breakthrough with the power of being able to control and create, giving a short lived vision for success. Technology and scientific knowledge are not a replacement for the wonder of nature; this progress is a mode to unravel the wonder of nature and not to tamper with the rhythms and cycles.

Above all by learning about the environment meaningfully it would be half the battle won for laying the foundation for continued ecological sensitivity. It is the oneness with the earth that would harness people to appreciate and protect the beauty of nature.

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REVIEW QUestions

1. What are the major forms of environmental pollution?
2. Discuss the major air pollutants alongwith their sources and effects.
3. List the potential health impacts of air pollution.
4. State the principle on which the following air pollution control devices operate :
   (i) Wet scrubber (ii) Cyclone separator (iii) Bag house
5. What are the global environmental problems resulting from air pollution?
6. What do you understand by water pollution? Suggest various remedial and control measures to minimize water pollution.
7. What are the non-point sources of water pollution?
8. What are the possible adverse impacts of water pollution?
9. Enumerate various types of pollutants that cause pollution of water bodies. Also discuss how water bodies can be saved from ill-effects of uncontrolled discharge to waste water into them.
10. What are the ecological consequences of domestic and industrial sewage disposal into surface water bodies?
11. Explain the primary, secondary and tertiary treatment of waste water.
12. Distinguish between aerobic and anaerobic digestion.
13. What are the advantages and disadvantages of activated sludge process?
14. What do you understand by the term "solid waste"? Discuss in brief the various types of solid wastes alongwith their sources.
15. What is solid waste management? Discuss the various sources of solid wastes.
16. What are the elements of integrated waste management?
17. List the problems involved in the disposal of solid wastes.
18. How do we manage waste and what are various methods for its disposal?
19. Discuss the various methods of disposal of solid wastes.
20. What is recycling? What are its advantages?
21. Describe "landfill" and "incineration" as solid waste management techniques.
22. Write a detailed note on solid waste management highlighting various steps involved in the process.
23. Discuss some important issues relating to municipal solid waste management in India. What are your recommendation for improving the situation?
24. How are the characteristics of Indian solid wastes different from that of developed countries?
25. How does noise affect human life?

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26. What are the causes and adverse impacts of noise pollution?
27. List the sources of noise pollution and the different approaches for its control.
28. Define land pollution. Discuss the causes of land pollution and their control.
29. Discuss the harmful effects of industrial wastes.
30. Describe the various methods of control of industrial pollution.
31. Describe the various chemical waste treatment methods.
32. What are the various day to day habits which an individual can follow to reduce pollution levels?
33. What are the benefits of renewable resources?
34. "Environmental education can play an important role in preventing environmntal pollution". Give your views about the statement.

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