

PRODUCTION MANAGEMENT

UNIT – I

INTRODUCTION

Production implies the creation of goods and services to satisfy human needs. It involves conversion of inputs (resources) into outputs (products). It is a process by which, raw materials and other inputs are converted into finished products. Earlier the word “manufacturing” was used synonymously with the word “production”, but nowadays, we use the term “manufacturing” to refer to the process of producing only tangible goods where as the word “production” (or operation) is used to refer to the process of creating both goods (which are tangibles) as well as services (which are intangibles).

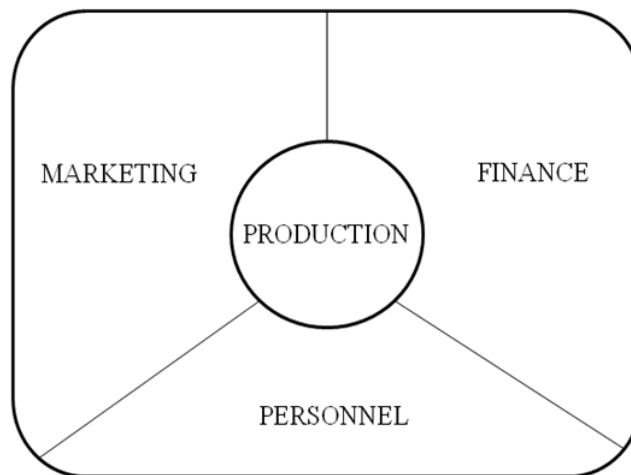
Any process which involves the conversion of raw materials and bought-out components into finished products for sale is known as production. Such conversion of inputs adds to the value or utility of the products produced by the conversion or transformation process. The utility or added value is the difference between the value of outputs and the value of inputs. The value addition to inputs is brought about by alteration, transportation, storage or preservation and quality assurance.

The managing of any organization that produces products demanded by customers presents a greater challenge today than ever before. An organization consists mainly of four functional subsystems, viz. Marketing, Production, Finance and Personnel. Production is the basic activity of all industrial units. All other activities revolve around this activity. The end-product of the production activity is the creation of goods and services for the satisfaction of human wants. The production activity is nothing but the step-by-step conversion of one form of materials into another, either chemically or mechanically. This is done in factories which house manufacturing processes. The basic inputs of the production processes are men, machines, plant, services and methods. The products of the mine, farm, sea and forest are used as raw materials on which the processing is done to create or enhance the form utility. It should be noted that the finished product of one manufacturing unit does not always furnish a ready-made product for the ultimate consumption. In a chain of manufacturing activities, the finished product of the processor sometimes becomes the raw materials (or component) for the other manufacturing firms falling next in the sequence.

Production management does not involve a mechanical assemblage of relevant factors. In contrast to mere transformation of raw materials into finished products, it aims at transmuting and permuting resources of higher productivity so that the greatest outputs are obtained from the least inputs. With its end in views, production management embraces the productive process too and involves planning, directing and controlling operations till their successful completion. Quality, quantity, cost and times of production have an important bearing on productivity of the manufacturing enterprise. Accordingly, it is the task of production management to see that effective utilization of resources is made, time is shortened, wastes and scrapings are avoided, and harmonious working is made to prevail in the plant.

For effective managerial performance, the work of production department is required to be organized on sound lines. All the principles and practices of organizing are to be applied in building a sound structure for improving the result of production management. Successful production management is not practicable without the existence of an appropriate organization structure. Consequently, managerial efforts are to be directed in designing an organization structure that conforms to the needs of the product, size of the enterprise and availability of production facilities. Organizing for production may be conceived in broader sense to include some aspects of works engineering or works organization like plant layout and factory building.

The problems of production management differ from case to case and are mainly related to the system of production. There are several systems of production which determine the magnitude of production work and the problems to be tackled in manufacturing operations. Hence, a familiarity with the different systems of production is required for understanding the intricacies of production management. Of course, the system of production is dictated in a particular case by the volume of sales and the nature of product. The quantity to be produced is nothing but an answer to the question of 'what can be sold'. In the ultimate analysis, therefore, sales are the regulator of a system of production.



The **Marketing function** of an organization aims to promote its products among customers, which helps it to obtain substantial sales order.

The **Finance function** provides authorization and control to all other subsystems to utilize money more effectively through a well designed mechanism.

The **Personnel function** is a supporting function which plans and provides manpower to all other subsystems of the organization and to itself by formulating proper recruitment and training programmes.

Product: Product is anything that is capable of satisfying a person's needs.

Production: It is the process by which raw materials and other inputs are converted into finished products with the help of certain process.

Production Management: The set of interrelated management activities which are involved in manufacturing certain products is called as production management.

If the same concept is extended to services management, then the corresponding set of management activities is called as **operations management**.

Definitions:

"Production/Operation management is the process which combines and transforms various resources used in the Production/Operations subsystem of the organization into value added products/services in a controlled manner as per the policies of the organization"

- Unknown

"Production management deals with decision making related to production process so that the resulting goods or services are produced according to specifications in amounts and by the schedules demanded, and at a minimum cost."

- Elwood S Buffa

"Production management is concerned with those processes which convert the inputs into outputs. The inputs are various resources like raw materials, men, machines, methods, etc. and the outputs are goods and services"

- H.A. Harding

Thus production management is concerned with the decision making regarding the production of goods and services at a minimum cost according to the demands of the customers through the management process of planning, organizing and controlling. In order to attain these objectives, effective planning and control of production activities is very essential. Otherwise, the customers shall remain unsatisfied and ultimately certain activities will have to be closed.

SCOPE OF PRODUCTION MANAGEMENT

- Production management mainly associated with the factory management as the problems of production crept with the development of factory system.
- Before the evolution of factory system, manufacturing activities are carried on by single person that pose no problem or very insignificant problem of production and therefore question of production management did not arise.
- But with for inception of factory system, the situation changed and so many problems of production were begun to creep up and necessity arose to tackle with the problems of quality control, layout facilities, meeting the schedules and organization of production activities.
- Thus the scope of production management began to develop. **In early stage, the stress was on controlling the labour costs because labour cost was the major element of the total cost of production.**
- They had developed devices like designing and packing of products, indirect labour cost control, production and inventory control and quality control.

Since the level of production has increased tremendously, so many other production problems have been added to its scope. On the present era of intense competition, the scope of production management is very wide. The various activities that form scope of production function can be studied in two broad areas:-

- i. Designing or formulating of production system and
- ii. Analyzing and controlling of production operation after production system has been activated.

Activities Relating to Production System Designing:

This activity concerns the production engineering and includes problems regarding design of tools and jigs, the design, development and installation of equipment and the selection of the optimum size of the firm.

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 of the plant, materials handling and time study.

Activities Relating to Analysis and Control of Activities:

The next problem after the designing of the production 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 far as they are applicable to the production system from the subject matter of the production management. These activities are:-

- a) Production Planning
- b) Production Control
- c) Quality Control

OBJECTIVES OF PRODUCTION MANAGEMENT

The objective of the production management is 'to produce goods services of Right Quality & Right Quantity at the Right Time & Right Manufacturing Cost'.

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

2. **Right Quantity:** The manufacturing organization should produce the products in right number. If they are produced in excess of demand the capital will block up in the form of inventory and if the quantity is produced in short of demand, leads to shortage of products.
3. **Right Time:** Timelines of delivery is one of the important parameter to judge the effectiveness of production department. So, the production department has to make the optimal utilization of input resources to achieve its objective.
4. **Right Manufacturing Cost:** Manufacturing costs are established before the product is actually manufactured. Hence, all attempts should be made to produce the products at cost, so as to reduce the variation between actual and the standard cost.

DIFFERENCE BETWEEN GOODS & SERVICES

- Services are usually intangible whereas goods are tangible
- Services are often produced and consumed simultaneously, services cannot be stored whereas goods can be produced and inventoried before consumption of use.
- Services are often unique, for example insurance policies, medical treatment procedures, haircut styles etc.,
- Some aspects of quality of goods are measurable whereas many aspects of quantity of services are difficult to measure
- Selling and production are distinct in case of goods whereas in case of services selling is often a part of the services
- Goods can be transported whereas service cannot be transported but the service provider can be transported
- Location of facility to manufacture goods affects costs whereas location of service facility affects customer contact
- Manufacturing of goods can be easily automated whereas service is often difficult to automate

FUNCTIONS AND RESPONSIBILITIES OF PRODUCTION MANAGER OR PRODUCTION MANAGEMENT

A production manager is responsible for the following functions:

- **Production Planning:** Production Planning is the main concern of the production manager. It facilitates the supply of goods at a proper time to execute the order received by the company. It also helps control over the production process. The function of production planning involves the decision when, what, how and why to produce goods.
- **Production Control:** After planning, the next responsibility of the production manager is to control the production by taking steps to utilize the various factors of production in an efficient manner so that the goods are produced at the lowest possible cost and according to the requirements and satisfaction of the customers and are supplied to them on the delivery dates in the ordered quantity.
- **Quality Control:** The production manager is also responsible for the maintaining a specific quality of the product. Steps should be taken to produce the goods according to the specifications and to minimize the amount of defective work. The defective work should be sorted out and sold separately.
- **Method Analysis:** There may be so many alternatives for manufacturing a product. As because all alternatives for manufacturing a product. As because all alternatives do not work equally, some may be more economical than others. The production manager must study the various alternatives and analyze them in right perspective in order to choose the best one. This activity of choosing best alternative is called methods analysis.
- **Inventory Control:** Production manager is supposed to have control over the cost of production by reducing the wastage of man and materials. So he is to make the best use of material. For this purpose, he is to determine the economic lot size, economic order quantity, reorder levels (minimum, maximum and danger levels of the stock of materials) so that the problems of over and under stock of materials may not arise.

- **Plant Layout and Materials Handling:** Plant layout is an arrangement of machines and equipment in such a manner so as to maintain the flow of production uninterruptedly. An efficient plant layout aims at efficient material handling which in turn reduces wastage of man and material and helps in reducing the cost of production.
- **Work Measurement:** One of the main responsibilities of the production manager is to control and reduce the labour cost per unit. At different levels of production, the labour cost per unit differs. Here work-measurement is necessary. By work-measurement methods we mean the level of performance of work by a worker.
- **Other Functions:** Apart from the above functions, the production manager is to perform certain other functions such as engineering economics, cost control, maximizing the labour efficiency, standardization and storage, price analysis, wage incentives to workers, etc.

CONCEPTS OF PRODUCTIVITY

Productivity is a term that has a number of different meanings although it is most commonly associated with effectiveness of labour or employees in an industry. In a broad sense productivity is the relationship between the output of an organization and the inputs required to produce these outputs.

The dictionary meaning of the word “Productivity” is “the quality or state of being productive”. It is the productive efficiency that improves the economic condition of any enterprise, any industry as a whole resulting in economic prosperity of the country and thereby improving the standard of living of its people.

Productivity is a relationship between the output (product/services) and the input (resources consumed in providing them) of a business system.

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

For the survival of any organization, this productivity ratio must be at least 1. If it is more than one, the organization is in a comfortable position. So, the objective of the organization should be to identify ways and means to improve productivity to the highest possible level. There are several strategies for improving the productivity which are:

1. Increased output for the same input
2. Decreased input for the same output
3. Proportionate increase in the output is more than the proportionate increase in the input
4. Proportionate decrease in the input is more than the proportionate decrease in the output
5. Simultaneous increase in the output with decrease in the input.

1. Increased output for the same input. In this strategy, the output is increased while keeping the input constant.

2. Decreased input for the same output. In this strategy, the input is decreased to produce the same output.

3. Proportionate increase in the output is more than the proportionate increase in the input. Consider the example of introducing a new product into the existing product mix of an organization. If the new product is taken up for production, then the following will result.

- a) There will be an increase in the revenue of the organization by way of selling the new product in addition to the existing product mix.
- b) There will be an increase in the material cost, and operation and maintenance cost of machineries because of producing the new product.

If we closely examine these two increases, we find that the proportionate increase in the revenue will be more than the proportionate increase in the input cost. Hence, there will be a net increase in the productivity ration.

4. Proportionate decrease in the input is more than the proportionate decrease in the output. Let us consider the reverse case of the previous example, i.e. dropping an uneconomical product from the existing product mix. This will result in the following:

- a) There will be a decrease in the revenue of the organization because of dropping a product from the existing product mix.
- b) There will be a decrease in the material cost, and operation and maintenance cost of machineries because of dropping an existing product from the product mix.

If we closely examine these two decreases, we find that the proportionate decrease in the input cost will be more than the proportionate decrease in the revenue. Hence, there will be a net increase in the productivity ratio.

5. Increase in the output with decrease in the input. Let us assume that advanced automated technologies like, Robot, Automated Guided Vehicle System (AGVS), etc., are available in the market which can be employed in the organization of our interest. The outcomes of these modern tools can be summarized as following.

- a) There will be a drastic reduction in the operation cost. Initially, the cost on equipment would be very high.
- b) These advanced facilities would help in producing more number of goods because they don't experience fatigue. The increased production will therefore yield more revenue.

In this example, there is an increase in the revenue while there is a decrease in the input in the long run. Hence, the productivity ratio will increase at a faster rate.

PRODUCTIVITY MEASUREMENT

Since productivity is measured as a ratio of output to input, we have various measures of productivity depending on whether a single input is used or multiple inputs are used. When just one resource (such as labour, or capital or material) is used, the productivity is referred to as single-factor productivity.

When input consists of several factors such as land, capital, labour, material, machinery, energy etc., productivity is referred to as multifactor productivity or total factor productivity or total productivity.

$$\text{Labour productivity} = \frac{\text{Units produced (i.e., Output)}}{\text{Hours worked}}$$

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

$$\text{Material productivity} = \frac{\text{Output}}{\text{Materials input}}$$

$$\text{Machine productivity} = \frac{\text{Output}}{\text{Machine – hours input}}$$

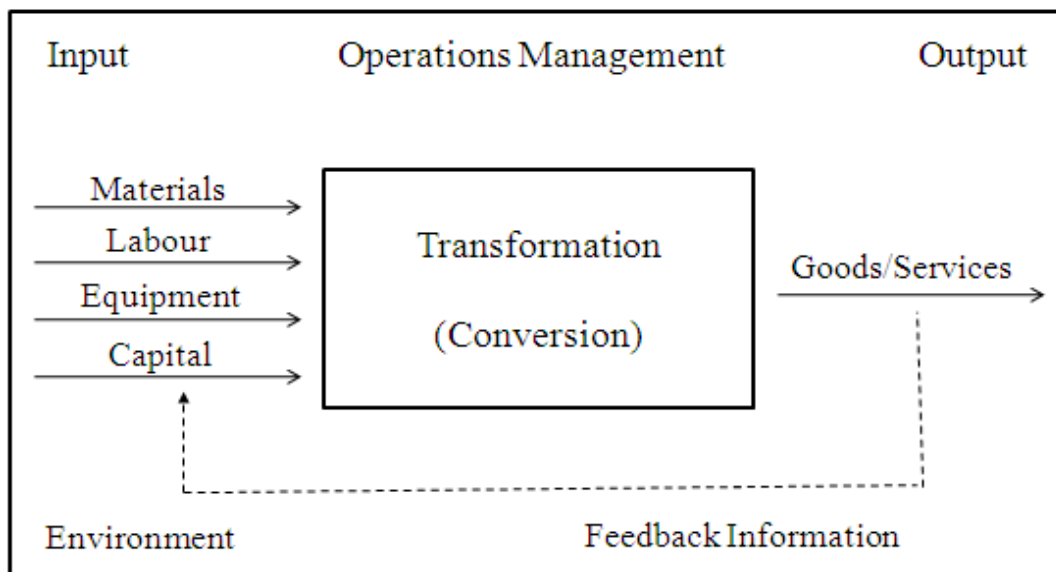
$$\text{Total productivity} = \frac{\text{Output}}{\text{Labour + Material + Energy + Capital}}$$

Since units of inputs vary for different factors of input, it is meaningful to express productivity as the ratio of value of output (goods & services) produced to the value of resources utilized to produce those outputs. Although we are concerned with all factors of inputs affecting productivity, greater emphasis is placed on the effectiveness of labour, the efficient utilization of machinery, equipment and facilities and the economical use of materials, reducing the wastage to the minimum.

SYSTEMS CONCEPT OF PRODUCTION

System is a collection of interrelated entities. The inputs to the system are materials, labour, equipments and capital. These inputs are combined and converted into goods and/or services by a suitable process technology. The types of inputs used vary from one industry to another. In product manufacturing, the major inputs are capital, machines, equipments and tools, and labour is required to operate and maintain the equipments. The material input is the basis for the conversion process.

Production means creation of utility and the framework within which the creation of utility can occur is termed as 'production system'. System is a collection of interrelated entities. At one end of system are inputs and at the other end output. Input and output are linked by certain processed or operation or activities imparting value to the inputs. These processes, operations or activities may be called production systems.



System aspect of production/operations function

In the process of conversion, definitely, there will be some deviations in the product's attributes like quality, size, shape and number of units produced. Just to cope up with the predetermined plans and policies, it is highly essential to communicate these deviations to the input stage in the form of feedback for making necessary corrections.

Based on the feedback, the system once again tries to produce the product/service with modified parameters, in order to meet the specifications. The feedback mechanism is a continuous exercise to monitor the status of the system.

DIFFERENT TYPES OF PRODUCTION SYSTEMS

The production system of a company mainly uses facilities, equipments, and operating methods (called the production system) to produce goods that satisfy customers' demand. The above requirements of a production system depend on the type of product that the company offers and the strategy that it employs to serve its customers.

1. Continuous Production System:

Continuous Production situations are those where facilities are standardized as to routing and flow since the raw material or inputs are standardized. Therefore, a standard set of processes and sequences of processes are adopted. *Examples of industries using such technology are petroleum, chemicals, steel and sugar industry.*

- a. **Mass Production:** This system of production is used by concerns where manufacturing is carried on continuously in anticipation of demand though demand of the product may not be uniform throughout the year. Standardization is the keynote of mass production. In order to maintain a continuous flow of production the layout of the plant and machinery is arranged in conformity with the sequence of operations needed for manufacturing a particular product. This system may also be called “**Flow Production System**” because flow of production is maintained.
- b. **Process Production:** This system is an extended form of mass production where production is carried on continuously through a uniform predetermined sequence of operations. Generally under this system finished product of one process is used in the next process as a raw material till the last process. Process production calls for the setting up of automatic machines and equipment as far as possible. *For example, crude oil is processed into kerosene, gasoline and other products.*

2. Intermittent Production System:

Intermittent production system situations are those where the facilities must be flexible enough to handle a wide variety of products and sizes or where the basic nature of activity imposes change of important characteristics the input. It is done more often on the basis of customer orders.

The chief characteristics of intermittent industries are that components are made for inventory but they are combined differently for different customers.

- a) **Job Production:** In this system, goods are produced according to the orders of the customers. Continuous demand of such items is not assured and therefore production is done only when the orders for the manufacturing of items are produced from the customers. Job production calls for an adjustment of tools and equipment in working out each individual job.
- b) **Batch Production:** Under this system, the manufacturing is done in batches or groups or lots either on the basis of customer's order or with a hope of a continuous demand of the product. Under this system, medium scale production is warranted.

In batch production, machines and equipment are made available for the next batch as soon as the production of first batch is completed. *The best example of this type of production system is chemical industry where different medicines are produced in batches.*

Classification of Production System

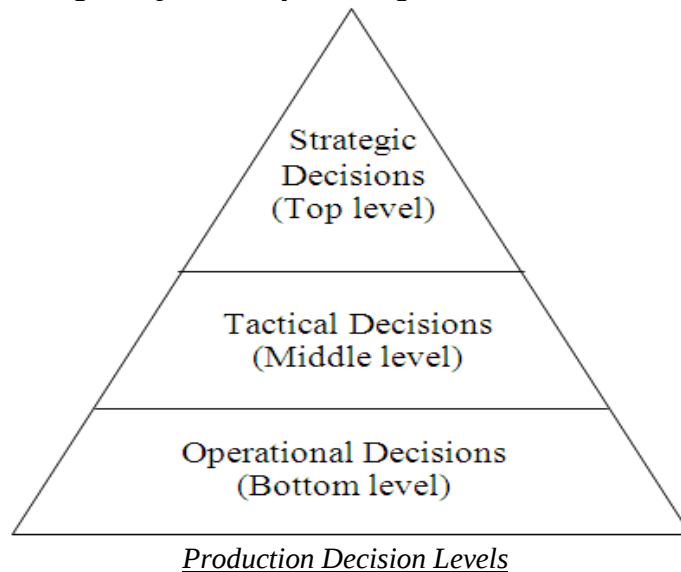
Basis	Classifications	Examples
Type of Output	Products	Consumer goods like furniture, TV, Radio, etc. Producer goods like, lathe, milling machine etc.
	Services	Transportation, health, entertainment, banking services, education system, etc.
Type of Flow	Projects	Construction of bridge, dam, road, etc
	Job Shop	Hospital, auto repair, machine shop, furniture company, etc.
	Flow Shop	High volume TV factory, auto factory, etc.
	Continuous Process	Postal services, telephone company, power corporation, oil refinery, chemical plant
Type of Specification Under Service Type	Customized	Medical care, legal services
	Standardized	Insurance, wholesale stores

- **Flow Shop:** This is conversion process in which successive units of output undergo the same sequence of operations, using specialized equipments usually positioned along a production line. Extreme form of flow shop is sometimes treated as a continuous process in which there is a constant flow of materials, as in oil refining, chemical processing and others in which there is no way to identify successive units of output.
- **Job Shop:** This is a conversion process in which units of different types of products follow different sequences through different shops. This type of system has more flexibility. But this system results into more set-up time, more in-process inventory, complex scheduling, varying quality, and so forth.
- **Batch Manufacturing:** A batch manufacturing facility produces some intermediate varieties of products with intermediate volumes. The volume of any single product may not be sufficient to justify the use of a dedicated set of equipments for its production. Under this condition, a few or several products will have to share the production resources to balance their utilization. Production equipment in batch manufacturing must be capable of performing a variety of tasks, but the range of possible operations is much narrower than in a job shop.
- **The Project:** A project refers to the process of creating a complex one-of-a-kind product or service with a set of well-defined tasks in terms of resources required and time phasing.

PRODUCTION DECISION LEVELS

In the process of managing various subsystems of the organization, executives at different levels of the organization need to take several management decisions. The management decisions are classified into *strategic decisions*, *tactical decisions* and *operational decisions*.

1. **Strategic Decisions:** These decisions are taken by the top level management. These are long-term and broad in nature and usually have a time period of five years or more. Long term strategic decision are concerned with production and process design, facility location and layout, capacity, expansion of existing facilities, etc. these decisions impact the long term profitability of an organization.



2. **Tactical Decisions:** These decisions are taken at the middle management level. These are medium-term in nature and have a time frame of one or two years. These decisions are concerned with identifying the manpower requirement, determining the appropriate inventory level for various materials, determine the reordering level and order quantity, identifying vendors, and so on. Operations managers need to ensure that these decisions are aligned with the strategic decisions of the organization.
3. **Operational Decisions:** These decisions are taken at the bottom level of management. These are short-term in nature and generally have a time frame of less than a week. These are specific in nature, and they address problems and requirements at the operational level, such as scheduling weekly production and assigning jobs/responsibilities to workers.

Matrix of Functional Subsystems and Management Activities

Management Activity Level	Functional Subsystems			
	Marketing	Production	Finance	Personnel
Strategic	Consideration of new markets and new marketing strategies.	Alternative manufacturing approaches had alternative approaches to automation.	Long-run strategy to ensure adequate financing	Strategies for recruitment, salary, training, and benefits.
Tactical	Comparison of overall Performance marketing plan.	Summary reports which compare overall planned or standard performance	Information on budgeted versus actual cost of financial resources	Variance analysis on hiring and firing
Operational	Hiring and firing of sales force, the day-to-day scheduling of sales and promotion efforts and periodic analysis of sales volumes by region, product, customer, etc.	Reports comparing actual performance to production schedule and highlighting areas where bottlenecks occur.	Daily error and exception reports, records of processing delays, reports of unprocessed transactions, etc.	Decision on hiring, training, termination, changing pay rates and issuing benefits.

WORK STUDY

Industry everywhere has been striving hard to discover new work methods and techniques which could help produce goods of required quality at reasonable costs. The search has resulted in finding techniques such as work simplification, job design, value analysis and the like. All these are collectively called methods engineering or industrial engineering. The other names used are work design, work study, methods analysis and operation analysis. Methods engineering is closely affiliated with the functions of work measurement (or time study) and the method study.

In today's competitive business environment, it is necessary that the employees work harder, be more productive so that, the production costs can be kept to meet global competition. Operations managers have to continuously strive for low production costs, high product quality and improve every facet of manufacturing. In this direction, improving labour productivity and reducing costs by improving work methods and simplifying the work needs special attention by operations managers. To facilitate this, work study technique has been developed over a period of time.

Definition:

Work study is defined as that body of knowledge concerned with the analysis of the work methods and the equipment used in performing a job, the design of an optimum work method and the standardization of proposed work methods. Work study has contributed immeasurably to the search for better methods, and the effective utilization of this management tool has helped in the accomplishment of higher productivity. Work study is a management tool to achieve higher productivity in any organization, whether manufacturing tangible products or offering services to its customers.

Work study deals with the techniques of method study and work measurement, which are employed to ensure the best possible of human, machine and material resources in carrying out a specified activity.

Objective: Work study is concerned with finding better ways of doing work and avoiding waste in all its forms. As such the objective of work study is to assist management to obtain the optimum use of the human, machine and material resources available to the organization for the accomplishment of the work upon which it is engaged.

The objective of work study effective use of three aspects:

- The most effective use of plant and equipment
- The most effective use of human effort
- The evaluation of human work.

Work Study has divided into two broad areas:

Method Study is concerned with finding the facts about a situation and after a critical examination of these facts, developing a new and better method of doing that work. It is defined as the existing and proposed ways of doing work and the development and application of easier and more productive methods.

Time Study is concerned with the establishment of time standards for a qualified worker to perform a specified job at a defined level of performance.

Method study must precede time study before any attempt is made to measure and set standards for the various jobs concerned.

METHOD STUDY

It is the systematic recording, analysis and critical examination of existing and proposed ways of doing work and the development and application of easier and new production methods.

Areas of application of method study. It can be applied to any field of work, but the most important areas where it plays a major role in improving productivity are as follows:

- Improved layout of office, working areas of factories
- Improved design of plant and equipment
- Improved use of materials, plant, equipment and manpower
- Most effective handling of materials
- Improved flow of work
- Standardization of methods and procedures
- Improved safety standards
- Better working conditions

STEPS IN METHOD STUDY

Method improvement involves systematic, orderly and scientific approach to problems. One should have an open mind, maintain a questioning attitude, collect all relevant facts, consult others including workers, list reasons/causes for various effects. The given below are the steps in method study:

1. **Select:** Select the work to be studied.
2. **Record:** record all the relevant facts of the present (or Proposed) method by direct observation
3. **Examine:** Examine the facts critically in sequence, using special critical examination sheet.
4. **Develop:** Develop the best method i.e. the most practical, economic and effective method under prevailing circumstances.
5. **Install:** Install that method as standard practice
6. **Maintain:** Maintain that standard practice by regular routine check.

Among all the steps *Record* and *Examine* are very important and it needs detailed discussion.

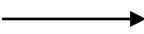
RECORDING

In order to carry out any investigation, data or relevant facts pertaining to the existing method must be collected and recorded. The recording may trace the movements of men, material or details of various processes. The different recording techniques are charts, diagrams, models and photographic aids.

Recording Techniques

Recording Technique		Information Recorded
(a)	Charts	
	1. Outline Process Chart	Principle Operations and inspection of the processes.
	2. Flow Process Chart	Activities of men, material or equipment are analyzed into five events viz., operations, transport, inspection, delay and storage.
	3. Two-handed process chart	Movement of two hands or limbs of the operator
	4. Multiple activity chart	Simultaneous/interrelated activities of operators and/or machines on a common time scale.
	5. Simultaneous motion cycle (SIMO) Chart	Movement of body members of the operator, expressed in terms of therbligs on a common time scale.
(b)	Diagrams and Models	
	1. Flow diagram	Path of men, materials and equipments on a scale model.
	2. String diagram	Same as above except for the variation that it uses string to trace the path.
(c)	Photographic Aids	
	1. Cycle graph	Movement of hand obtained by exposing a photographic plate to the light emitted from small bulbs attached to the operator's fingers.
	2. Chrono-cycle graph	Modification of cycle graph in which recording is made using flash lights.

Symbols used in Process Chart

Symbol	Activity	Purpose for which it is used
	Operation	It indicates the main steps in a process, method of procedure, usually the part, material or product concerned which is modified or changed during the operation.
	Transport	It indicates movement of workers, material or equipment from place to place.
	Inspection	It indicates any type of inspection, check, measurement, visual scrutiny for quality and/or quantity.
	Temporary Storage or delay	It indicated a delay in the sequence of events.
	Storage	It indicates a controlled storage in which material is received into or issued from stores under some form of authorization or an item is retained for reference purpose.

SELECTED RECORDING TECHNIQUES

The following are the selected recording techniques:

- (a) Outline Process Chart
- (b) Flow Process Chart
- (c) Two-Handed Process Chart
- (d) Multiple Activity Chart

(a) Outline Process Chart. An outline process chart is a flow diagram showing only the activities, “Operations” and “inspection”.

(b) Flow Process Chart. A flow process chart is a process chart which shows the sequence of flow of all activities which occur while producing a product/component or executing a procedure. The flow process chart can be classified into three types as listed below.

1. Flow Process Chart (Material type)
2. Flow Process Chart (Man type)
3. Flow Process Chart (Equipment type)

Material type shows the sequence of flow of materials of a product/component while manufacturing/servicing it.

Man type shows the movement of employees related to production/inspection of a product.

Equipment type shows the sequence of usage of equipments.

(c) Two-Handed Process Chart. Two-handed process chart records the sequence of activities performed by both hands of an operator side by side. This chart is very much useful to analyze the activities of the operator and come out with an improved method of performing the integrated task of importance.

(d) Multiple Activity Chart. In many situations, certain facilities/machines/equipments will be managed by a single individual or by a group of individuals. A multiple activity chart is a pictorial representation of activities of individuals and associated facilities/machines/equipments simultaneously on a common time scale.

EXAMINE STEP

This is the most important step in method study. This step aims:

- ✓ To eliminate the activity altogether if it is unnecessary
- ✓ To combine it with other activities
- ✓ To change the sequence of activities so that work delay is reduced
- ✓ To reduce the work content or time consumption.

TIME STUDY

The time study is considered to be one of the most-widely used means of work-measurement. Basically, by using time study, an analyst will be taking a small sample of a single worker's activity and using it to derive a standard for tasks of that nature.

The steps of time study are as follows:

Step – 1: First select the job to be studied. Breakdown the work content of the job into smallest possible elements. Then inform the worker and define the best method.

Step – 2: Observe the time for appropriate number of cycles (such as 25 to 30)

Step – 3: Determine the average cycle time (CT)

$$CT = \frac{\text{Times}}{\text{No. of Cycles}}$$

Step – 4: Determine the normal time (NT)

$$NT = CT (PR)$$

Step – 5: Determine the standard time using the following formula

$$ST = NT (AF)$$

$$\text{Where AF} = \frac{1}{1 - \% \text{ Allowance}}$$

AF being the allowed factor.

In step – 2, n can be calculated using the following formulas.

$$n = \frac{Z^2 [n_1 \sum x^2 - (\sum x)^2]}{h^2 (\sum x)^2}$$

Where, n_1 = Preliminary sample size

x = recorded stopwatch times

h = half the precision interval in % (for example, if the precision interval is $\pm 5\%$, then $h = 0.05$)

z = the standard normal statistic for the desired confidence level.

PROBLEMS

Problem 1: In a welding shop, a direct time study was done on a welding operation. One inexperienced industrial engineer and one experienced industrial engineer conducted the study simultaneously. They agreed precisely on cycle time (shown below) but their opinion on rating the worker differed. The experienced engineer rated the worker 100% and the other engineer rated the worker 120%. They used a 19% allowance

Cycle Time (in minutes)	:	20	24	29	32
Number of Times Observed	:	2	1	1	1

From the above statement,

- Determine the standard time using the experienced industrial engineer's worker rating.
- Find the standard time using the worker rating of inexperienced industrial engineer.
- Comment on the reliability of time study engineers.

Solution:

(a) Rating the worker at 100% by the experienced industrial engineer

$$\begin{aligned}\text{Cycle Time (CT)} &= \frac{20 \times 2 + 24 \times 1 + 29 \times 1 + 32 \times 1}{5} \\ &= 25 \text{ minutes}\end{aligned}$$

$$\begin{aligned}\text{Normal Time (NT)} &= \text{CT} \times \text{PR} \\ &= 25 \times 100\% \\ &= 25 \text{ minutes}\end{aligned}$$

$$\begin{aligned}\text{Standard Time (ST)} &= (\text{NT}) \times [1/(1-\%A)] \\ &= 25 \times 1.23 \\ &= 30.75 \text{ minutes}\end{aligned}$$

(b) Rating the worker at 120% by the inexperienced industrial engineer

$$\begin{aligned}\text{Cycle Time (CT)} &= \frac{20 \times 2 + 24 \times 1 + 29 \times 1 + 32 \times 1}{5} \\ &= 25 \text{ minutes}\end{aligned}$$

$$\begin{aligned}\text{Normal Time (NT)} &= \text{CT} \times \text{PR} \\ &= 25 \times 120\% \\ &= 30 \text{ minutes}\end{aligned}$$

$$\begin{aligned}\text{Standard Time (ST)} &= (\text{NT}) \times [1/(1-\%A)] \\ &= 30 \times 1.23 \\ &= 36.9 \text{ minutes}\end{aligned}$$

(c) *Comment*

The results in part (a) and part (b) show differences in normal time and standard time. The task of estimating performance rating of a worker requires certain experience. So, we can rely on the results obtained by the experienced industrial engineer. Rating exercise is an art. So, the consistency in rating skill can be improved by repeatedly seeing rating films and/or by attending short courses on performance rating.

Problem 2: A time study engineer has studied the time taken to machine crank shafts. He has taken 40 observations and these are summarized in the form of frequency distribution as shown below.

Time (in minutes)	20	21	22	23
Frequency	15	10	10	5

The performance rating of the operator machining the crank shaft is 110%. Find the standard time for machining the crank shaft by assuming allowance of 15%.

Solution:

Rating the operator machining the crank shaft 110%

$$\begin{aligned}\text{Cycle Time (CT)} &= \frac{20 \times 15 + 21 \times 10 + 22 \times 10 + 23 \times 5}{40} \\ &= 21.13 \text{ minutes}\end{aligned}$$

$$\begin{aligned}\text{Normal Time (NT)} &= \text{CT} \times \text{PR} \\ &= 21.13 \times 110\% \\ &= 23.24 \text{ minutes}\end{aligned}$$

$$\begin{aligned}\text{Standard Time (ST)} &= (\text{NT}) \times [1/(1-\%A)] \\ &= 23.24 \times 1.18 \\ &= 27.42 \text{ minutes}\end{aligned}$$

Problem 3: The following data was collected from a time study Job during 40 hours work week. Determine the standard time per part.

Idle time = 20%	Rating factor = 135%
Total parts produced = 300	Allowance for this work = 10%

Solution:

$$\begin{aligned}\text{Total time of study} &= 40 \text{ hours} \\ &= 40 \times 60 \text{ minutes} \\ &= 2400 \text{ minutes}\end{aligned}$$

$$\begin{aligned}\text{Working time} &= 1 - \text{idle time} \\ &= 1 - 20\% \\ &= 0.8\end{aligned}$$

$$\begin{aligned}\text{Performance rating} &= 135\% \\ &= 1.35\end{aligned}$$

$$\text{Normal Time} = \frac{(\text{Total time of study}) \times (\text{Working time in \%}) \times (\text{Performance rating})}{\text{Total units produced}}$$

$$\begin{aligned} &= \frac{2400 \times 0.8 \times 1.35}{300} \\ &= 8.46 \text{ minutes} \end{aligned}$$

$$\begin{aligned} \text{Standard Time (ST)} &= (\text{NT}) \times [1/(1-\%A)] \\ &= 8.64 \times 1.11 \\ &= 9.6 \text{ minutes} \end{aligned}$$

Standard time per part = 9.6 minutes.

Problem 4: A work measurement study was conducted in a company for 8 hours and the following results were obtained. Determine the standard time for this task.

$$\begin{aligned} \text{Idle time} &= 15\% & \text{Rating factor} &= 120\% \\ \text{Total number of task} &= 320 & \text{Allowance time} &= 12\% \text{ of Normal time.} \end{aligned}$$

Solution:

$$\begin{aligned} \text{Total time of study} &= 8 \text{ hours} \\ &= 8 \times 60 \text{ minutes} \\ &= 480 \text{ minutes} \end{aligned}$$

$$\begin{aligned} \text{Working time} &= 1 - \text{idle time} \\ &= 1 - 15\% \\ &= 0.85 \end{aligned}$$

$$\begin{aligned} \text{Performance rating} &= 120\% \\ &= 1.2 \end{aligned}$$

$$\begin{aligned} \text{Normal Time} &= \frac{(\text{Total time of study}) \times (\text{Working time in \%}) \times (\text{Performance rating})}{\text{Total units produced}} \\ &= \frac{480 \times 0.85 \times 1.2}{320} \\ &= 1.53 \text{ minutes} \end{aligned}$$

$$\begin{aligned} \text{Standard Time (ST)} &= (\text{NT}) \times [1/(1-\%A)] \\ &= 1.53 \times 1.21 \\ &= 1.85 \text{ minutes} \end{aligned}$$

Standard time per part = 1.85 minutes.

Problem 5: A time study of an assembly line worker in a car plant produced the following results, Cycle time of 2.5 minutes, worker performance rating of 95%, average allowance for the activity 10% of the job time. Calculate the standard time.

Solution:

Fist we have to calculate normal time, which is given by,

$$\begin{aligned} \text{Normal Time} &= \text{Average cycle time} \times \text{Performance rating} \\ &= 2.5 \times 95\% \\ &= 2.375 \end{aligned}$$

$$\begin{aligned} \text{Standard Time} &= (\text{NT}) \times [1/(1-\%A)] \\ &= 2.375 \times 1.11 = 2.63 \text{ minutes} \end{aligned}$$

Standard Time = 2.63 minutes.

Problem 6: For a certain element of work, the basic time is established to be 20 seconds. If for three observations, a time study observer records ratings of 100, 125 and 80 respectively, on a '100-normal scale', what are the observed timings?

Solution:

$(\text{Observed time}) \times (\text{Observed rating}) = (\text{Basic or Normal time}) \times (\text{Standard rating})$

Therefore, Observed time = $\frac{(\text{Basic or Normal time}) \times (\text{Standard rating})}{\text{Observed rating}}$

Basic or Normal time = 20 seconds

Standard rating = 100

For observation No. 1, Observed rating = 100

Therefore, Observed time = $(20 \times 100)/100 = 20$ seconds

For observation No. 2, Observed time = $(20 \times 100)/125 = 16$ seconds

For observation No. 3, Observed time = $(20 \times 100)/80 = 25$ seconds

Problem 7: Calculate the standard production per shift of 8 hours duration with the following data. Observed time per unit = 5 minutes, Rating factor = 120%, Total allowances = 33.33% of normal time.

Solution:

Normal time per unit = Observed time/unit $\times$ Rating factor
= $5 \times (120/100) = 6$ minutes

Allowances = 33.33% of normal time = $(33.33 \times 6) / 100 = 2$ minutes

Standard time/unit = Normal time/unit + Allowances = $6 + 2 = 8$ minutes/unit

Standard production in shift of 8 hours = $(8 \times 60) / 8 = 60$ units

WORK SAMPLING

Work sampling is also a technique for establishing standard times for activities. This method was introduced by L.H.C. Tippett in 1934. This method is more suitable for analyzing group activities and repetitive activities which take longer duration.

If a given individual performs more than one activity, then the time standard for each activity may be computed using this method. In this method, the standards for these activities may be determined using the work sampling method.

The steps for the work-sampling method are listed below:

1. Perform the following preliminary tasks
 - a) Select the job which is to be studied
 - b) Inform the workers about the method study
 - c) Prepare a detailed list of activities of the job
2. Decide the total duration of observations

Total duration of observations = (No. of hours/shifts) $\times$ (No. of shifts per day) $\times$ (No. of days)

3. Determine the number of observations to be made

$$n^* = \frac{Zpq}{h^2}$$

where,

Z = Standard normal statistic at a given confidence level

p = Value of sample proportion

q = 1 – p

h = Half the precision interval (Half of the width of the confidence level)

This is only a rough estimate. As the study progresses, if the value of **p** is more than **$p \pm h$** , then again the value of n should be revised.

4. Prepare a tour schedule to take the specified number of observations over the specified time duration.
5. Record performance rating of the workers and their activities as per the schedules.
6. Determine the acceptable number of units produced during the period.
7. Compute the percentage of working on a given task using the following formula

$$\text{Percentage of working} = \frac{\text{Frequency of performance of a task}}{\text{Total number of observation}} \times 100$$

8. Determine the normal time

$$NT = \frac{(\text{Total time}) (\% \text{ of working}) PR}{\text{No. of acceptable units produced}}$$

9. Determine the standard time

$$ST = NT \times AF$$

$$= NT \frac{1}{1 - \text{Percentage Allowance}}$$

PROBLEMS

Problem 1: A job consists of three work elements and all are performed by the same operator. An analyst conducted work sampling to determine the standard time for the job. The duration of the study is one shift with 400 minutes of effective time. The details of observations are summarized in the following table. The total number of acceptable units produced during the study period is 150 units. Determine the standard time by assuming allowance of 10%.

Work element No.	:	1	2	3
Frequency of Performance	:	70	80	50
Performance Rating	:	80%	120%	110%

Solution:

Total duration = 400 minutes

Total number of observations = 200

The calculations for determining normal time and standard time of each of the work elements are summarized in the following table.

Work element number	Percentage of working	Normal time (minutes)	Standard Time (minutes)
1	$(70/200) \times 100 = 35\%$	$(400 \times 0.35 \times 0.8)/150 = 0.75$	$0.75/0.9 = 0.83$
2	$(80/200) \times 100 = 40\%$	$(400 \times 0.40 \times 1.2)/150 = 1.28$	$1.28/0.9 = 1.42$
3	$(50/200) \times 100 = 25\%$	$(400 \times 0.25 \times 1.1)/150 = 0.73$	$0.73/0.9 = 0.81$
Total = 3.06			

The Standard time of the job = 3.06 minutes.

Problem 2: A job consists of four work elements and all are performed by the same operator. An analyst conducted work sampling to determine the standard time for the job. The duration of the study is one day with two shifts. Each shift has 420 minutes of effective time. The details of observations are summarized in the following table. The total number of acceptable units produced during the study period is 225 units. Determine the standard time by assuming allowance of 12%.

Work element No.	:	1	2	3	4
Frequency of Performance	:	50	90	75	85
Performance Rating	:	90%	150%	100%	115%

Solution:

Total duration = 420×2 minutes = 840 minutes

Total number of observations = 300 (50+90+75+85)

The calculations for determining normal time and standard time of each of the work elements are summarized in the following table.

Work element number	Percentage of working	Normal time (minutes)	Standard Time (minutes)
1	$(50/300) \times 100 = 16.67\%$	$(840 \times 0.17 \times 0.9)/225 = 0.57$	$0.57 \times 1.14 = 0.65$
2	$(90/300) \times 100 = 30\%$	$(840 \times 0.3 \times 1.5)/225 = 1.68$	$1.68 \times 1.14 = 1.91$
3	$(75/300) \times 100 = 25\%$	$(840 \times 0.25 \times 1.0)/225 = 0.93$	$0.93 \times 1.14 = 1.06$
4	$(85/300) \times 100 = 28.33\%$	$(840 \times 0.28 \times 1.15)/225 = 1.2$	$1.2 \times 1.14 = 1.37$
Total = 5 min			

The Standard time of the job = 5 minutes.

Problem 3: A Work sampling study showed that 20% of a work week of 48 hours was consumed by unavoidable delays. If each time a work sampling observations was made the operation was rated and the average of such ratings was 110%. If 100 units were produced by the operator in that period, calculate the standard time.

Solution:

Total time of study = 48 hours
 = 48×60 minutes
 = 2880 minutes

Working time in % = 80%
= 0.8

Average performance rating = 110%
= 1.1

Number of units produced = 100

Normal time = $\frac{2880 \times 0.8 \times 1.1}{100}$
= 25.34 minutes

Since allowance % is not given. Standard time per unit = Normal time

Standard time = 25.34 minutes

Problem 4: An industrial operation consists of the following observed times along with their performance ratings.

Element	A	B	C	D	E	F
Observed Time (minutes)	0.20	0.10	0.5	0.12	0.18	0.25
Frequency	80	85	90	75	85	90

Assuming rest and personal allowance as 15% and contingency allowance as 4% of the basic time, calculate standard time per piece.

Solution:

Normal time = Sum (Average time x Performance rating)

Element	Observed time (minutes)	Performance rating %	Normal time
A	0.20	80% = 0.8	(0.20 X 0.8) = 0.16
B	0.10	85% = 0.85	0.085
C	0.5	90% = 0.9	0.45
D	0.12	75% = 0.75	0.09
E	0.18	85% = 0.85	0.153
F	0.25	90% = 0.9	0.225
Total: 1.163			

Normal time = 1.163 minutes

Standard time = Normal time + Allowance time (as allowance is given % of normal time)
= 1.163 + 19% (1.163) = 1.384

Therefore, rest, personal + contingency = 15% + 4% = 19%

Standard time per piece = 1.384 minutes

Problem 5: A work study practitioner who conducted a work sampling study assesses the activity level of worker to be 70%. During the space of 8 hours working, this worker turns out 320 components. If the company policy is to inflate the normal time arrived at by work sampling study by 20%, what should be the allowed time per unit?

Solution:

Activity level as per work sampling study = 70%

Actual working time per shift of 8 hours = 8 x (70/100) = 5.6 hours

Normal time taken per unit = $(5.6 \times 60) / 320 = 1.05$ minutes

Allowed time = $1.05 \times (120/100) = 1.26$ minutes

Problem 6: Calculate the standard time per article produced from the following data obtained by a work sampling study.

Total no. of observations = 2500	No. of working observations = 2100
No. of units produced in 100 hours duration = 6000 numbers	
Proportion of manual labour = $2/3$	Proportion of machine time = $1/3$
Observed rating factor = 115%	Total allowances = 12% of normal time

Solution:

Actual working time in the duration of 100 hours = $100 \times (2100/2600) = 84$ hours

Time taken per article = $(84 \times 60)/6000 = 0.84$ minutes

Observed manual labour time per article = $0.84 \times (2/3) = 0.56$ minute

Observed machine time per article = $0.84 \times (1/3) = 0.28$ minutes

Normal labour time per unit = Observed time/unit X rating factor
= $0.56 \times 1.15 = 0.644$ minutes

Standard labour time per unit = $0.644 + (12/100 \times 0.644) = 0.721$ minutes

Standard time per unit of article produced = $0.721 + 0.28 = 1$ minute

UNIT – II

FACILITY OR PLANT LOCATION

Plant location may be understood as the function of determining where the plant should be located for maximum operating economy and effectiveness. The selection of a place for locating a plant is one of the problems, perhaps the most important, which faced by an entrepreneur while launching a new enterprise.

A selection on pure economic considerations will ensure an easy and regular supply of raw materials, labour force, efficient plant layout, proper utilization of production capacity and reduced cost of production. An ideal location may not, by itself, guarantee success: but it certainly contributes to the smooth and efficient working of an organization.

A bad location, on the other hand, is a severe handicap for any enterprise and it finally bankrupts it. It is, therefore, very essential that utmost care should be exercised in the initial stages to select a proper place. Once a mistake is made in locating a plant, it becomes extremely difficult and costly to correct it, especially where large plants are concerned.

Business systems utilize facilities like, plant and machineries, warehouses, etc., while performing the task of producing products/services. A proper planning of these facilities would definitely reduce their cost of operation and maintenance.

One of the most important strategic decisions made by companies engaged either in manufacturing goods or in providing services is where to locate their operations. All firms need to address the location decision because location greatly affects both fixed and variable costs. Also, it has a major impact on the overall profitability of the firm.

Plant location decisions are very important because they have direct bearing on factors like, financial, employment and distribution patterns. In the long run, relocation of plant may even benefit the organization. But, the relocation of the plant involves stoppage of production, and also cost for shifting the facilities to a new location. In addition to these things, it will introduce some inconvenience in the normal functioning of the business.

Hence, at the time of starting any industry, one should generate several alternate sites for locating the plant. After a critical analysis, the best site is to be selected for commissioning the plant. Location of warehouses and other facilities are also having direct- bearing on the operational performance of organizations.

What is Facility or Plant Location?

Facility location or plant location is the process of determining a geographical site for a firm's operations achieving maximum operating economy and effectiveness.

Reasons for plant location study. The following events are quite common in any business venture.

- Establishment of a new venture.
- Expansion of existing business.
- Significant change in existing demand, supply and marketing locations.
- Significant change in the cost structure.
- Government policies.

Because of these events, an organization will be keen in additional or alternate sites for its production activities. So, the plant location becomes an important decision which in turn influences plant layout and facilities needed. Also, it influences capital investment and operating costs.

FACTORS INFLUENCING PLANT LOCATION

The factors which influence plant location can be classified into general factors and specific factors.

General factors

1. Availability of land for present and future needs and cost of land and land development and building etc.
2. Availability of inputs such as labour, raw materials, etc.
3. Closeness to the market places.
4. Stability of demand.
5. Availability of communication facilities.
6. Availability of necessary modes of transportation like road, rail, airport and water ways.
7. Availability of infrastructure facilities such as power, water, financial institutions, banks, etc.
8. Disposal of waste and effluent and their impact on the environment.
9. Government support, grant, subsidy, tax structure.
10. Availability of housing facilities and recreational facilities.
11. Security, culture of society.
12. Fuel cost.

Specific factors

A multinational company, desiring to set up plant should consider the following aspects in addition to the normal factors.

1. The economic stability of the country and the concern of the country towards outside investments are to be considered.
2. The success of operation of the factory depends on the cultural factors, language and cultural differences, which can present operating, control and even policy problems. Units of measurement are also very important in international business.
3. Analysis must be based on the factors like wage rate, policy, duties, etc.
4. The company can set up joint ventures with any leading local giants that will solve many operational problems.

STEPS IN LOCATION

To be systematic, in choosing a plant location, the entrepreneur would do well to proceed step by step, the steps being;

- (a) Within the country or outside;
- (b) Selection of the region;
- (c) Selection of the locality or community;
- (d) Selection of the exact site.

(a) Deciding on Domestic or International Location

The first step in plant location is to decide whether the facility should be located domestically or internationally. A few years ago, this factor would have received little consideration. But with increasing internationalization of business, the issue of home or foreign country is gaining greater relevance. If the management decides on foreign location, the next logical step would be to decide upon a particular country for location.

(b) Selection of Region

The selection of a particular region out of the many natural regions of a country is the second step in plant location. The following factors influence such selection:

(i) Availability of Raw Materials:

As a manufacturing unit is engaged in the conversion of raw materials into finished products, it is very essential that it should be located in a place where the supply of raw materials is assured at minimum transport cost.

Nearness to raw materials offers such advantages as:

- Reduced cost of transportation;
- Regular and proper supply of materials uninterrupted by transportation breakdowns and
- Savings in the cost of storage of materials.

(ii) Nearness to the Market

Since goods are produced for sale, it is very essential that the factory should be located near their market. A reduction in the cost of transporting finished goods to the market; the ability to adjust the production programme to suit the likes and dislikes of consumers; the ability to render prompt service to the consumers, provide after-sale services and execute replacement orders without delay - these are some of the advantages that accrue to the entrepreneur if he establishes his factory near his market.

(iii) Availability of Power

Power is essential to move the wheels of an industry. Coal, electricity, oil and natural gas are the sources of power. Where coal is the source of power, as in the case of the iron and steel industry, the factory has to be located near the coal fields. Examples of such industries are: the iron and steel industry in Germany, Pennsylvania, in the U.S.A. and Jamshedpur in India.

(iv) Transport facilities

While making a study of a location, an entrepreneur considers the question of the availability of transport facilities. Transport facilities are essential for bringing raw materials and men to the factory and for carrying the finished products from the factory to the market. A place, which is well connected by rail, road and sea, is ideal for a plant location. It may be said that industry follows transportation.

(v) Suitability of Climate

The climate has its own importance in the location of a plant because of two reasons. There are certain industries which, because of the nature of their production, require particular climatic conditions; for example, humid climate for cotton textiles and jute. Such industries have to be located in places where humid climatic conditions are available.

(vi) Government Policy

The influence of Government policies and programmes on plant location is apparent in every country, particularly in planned economies like ours. In the name of balanced regional development, many backward regions in India have been selected for the location of new industries, which would generate the regions economy and on a larger canvas, the national economy.

The Government of India has been influencing plant location in a number of ways. Some of these are:

- Licensing policy;
- Freight rate policy;
- Establishing a unit in the public sector in a remote area and developing it to attract other industries;
- Institutional finance and government subsidies.

(vii) Competition Between States

States vie with each other to attract new industries. Various states offer investment subsidies and sales tax exemptions to new units. The incentives may not be of big help to big sized plants. But for small and medium-sized plants, the incentives do matter. The owners of these plants certainly consider incentive in selection of region.

(c) Selection of Community

Selecting a particular locality or community in a region is the third step in plant location. The selection of a locality in a particular region is influenced by the following factors:

(i) Availability of Labour

Despite the talk of mechanization and automation, the importance of labour on the industrial side has not been completely lost. Labour is an important factor in the production of goods. An adequacy of labour supply at reasonable wages is very essential for the smooth and successful working of an organization. The development of the plantation industry in India has been due to, among other things, the availability of adequate labour at cheap rates.

(ii) Civic Amenities for Workers

Besides good working conditions inside the factory, the employees require certain facilities outside it. Recreation facilities such as clubs, theatres and parks must be provided for the employees. They require schools for their children. A place which abounds in all these facilities will naturally be preferred to another place which lacks them.

(iii) Existence of Complementary and Competing Industries

The existence of complementary industries is favourable to the location of industries because an industrial unit, in association with other units, can get the following benefits:

- An industrial unit, in collaboration with other similar units, can secure materials on better terms than it can do it by itself.
- The concentration of similar industries at one place improves the labour market, both for the employer and the employee.
- In specialized centers, banks become familiar with the requirements of the industry. This makes the granting of loans easy.
- A group of plants will attract a variety of ancillary plants such as *foundries*, machine shops tool makers and the like.
- The new units established in the same locality will share the reputation built up by the existing units.

(iv) Finance and Research Facilities

Adequate capital is essential for the successful working of any organization. A place where facilities for raising capital are available attracts new industries. This is particularly true in developing countries, where capital is not available uniformly throughout the country. In advanced countries, the case is different because, in such countries, capital is distributed uniformly.

(v) Availability of Water and Fire-fighting Facilities

Some industries require plentiful supply of water for their working. Water maybe obtained from the local authority, from the canal, from a river or a lake, or by sinking a bore well. In any case, the supply of water should be considered with respect to its regularity, cost and purity.

Industrial units are exposed to fire hazards. A fire may break out either from within or from neighboring units. In either case, adequate fire-fighting facilities must be available.

(vi) Local Taxes and Restrictions

Local authorities collect charges for the supply of water, electricity and other facilities, They also collect various taxes from industrial units. They impose restrictions on the location of new units in the public interest.

(viii) Personal Factors

There are entrepreneurs, especially small industrialists, who locate their plants purely on personal grounds, disregarding economic considerations. Such locations sometimes totally disapprove the many current theories of plant location.

(d) Selection of the Site

The selection of an exact site in a chosen locality is the fourth step in plant location. This selection is influenced by the following considerations:

(i) Soil, Size and Topography

For factories producing engineering goods, the fertility or otherwise of the soil may not be a factor influencing plant location. But for agro-based industries, a fertile soil is necessary for ensuring a strategic plant location.

The area of the land should be such as to accommodate not only the existing manufacturing facilities, but offer scope for future expansion programmes as well. Besides the area, the cost of land deserves consideration.

The topography of the place deserves consideration to some extent. A hilly, rocky and rough terrain is unsuitable for a plant location because a great deal of expenditure has to be incurred to level it.

(ii) Disposal of Waste

The problem of the disposal of effluents is common to many industries, particularly chemical, sugar, steel and leather industries and breweries. The site selected for the location of the plant should have provision for the disposal of waste. There must be enough vacant land for the dumping of solid waste.

LOCATION MODELS

Various models are available which help identify a near location. The most popular models are:

1. Factor Rating Method.
2. Point Rating Method.
3. Quantitative Factor Analysis.
4. Break-even Analysis.

1. Factor Rating Method

These are many factors, both qualitative and quantitative to be considered in choosing a location. Some of these factors are more important than others and hence managers can use weightings to make the decision process more objective.

2. Point Rating Method

The significance of point rating method is the relative importance of tangible cost factors when compared to intangible cost factors. Only intangible factors are assigned points. However, evaluation is done to know whether the difference between the intangible factor is worth between tangible factors of the competing locations.

3. Qualitative Factor Analysis

In economic criteria (costs, revenues or profits) alone are not sufficiently influential to determine the location alternative, a system of assigning weights to qualitative factors and quantitative factors separately and combining them to arrive at a total score is useful in making the location decision. This approach is known as qualitative factor analysis method.

4. Break-even Analysis

Locational break-even analysis is the use of cost-profit-volume analysis to make an economic comparison of location alternatives. By identifying fixed and variable costs and drawing the graphs of quantity versus total costs for each location, we can determine the location which has the lowest cost over a range of volume produced. Locational break-even analysis can be done mathematically or graphically. The locational break-even analysis provides the range of volume over which each location is preferable.

Break even analysis.

- The objective of any location problem is to maximize profit.
- In comparing several potential locations on an economic basis, only revenues and costs need to be considered. These will vary from one location to another.
- An economic analysis can be done by using break-even analysis.
- For any business organization, for manufacturing a product, there are two major costs, namely, fixed cost and variable cost.
- The sum of these two costs is known as the total cost of the product.
- The fixed cost is constant irrespective of production volume of a product which is manufactured by the organization.
- But, the variable cost is a function of the production volume of the product.
- For low volume of production, the sales revenue of the product will be less than the total cost and after reaching a certain level of production volume, it will be more than the total cost.
- The point at which the sales revenue becomes equal to the total cost is known as the break even point. At this point, there is no loss or gain to the organization. This analysis is termed as break even analysis.
- This analysis is termed as break even analysis.

TC represents the Total Cost, and FC represents the Fixed Cost.

$$\text{Total Cost (TC)} = \text{FC} + \text{Variable Cost}$$

Where, B - Intersection point of TC and sales curves (no loss or no gain situation)

A - Break even sales point

C - Break even quantity/Break even point (B.E.P.)

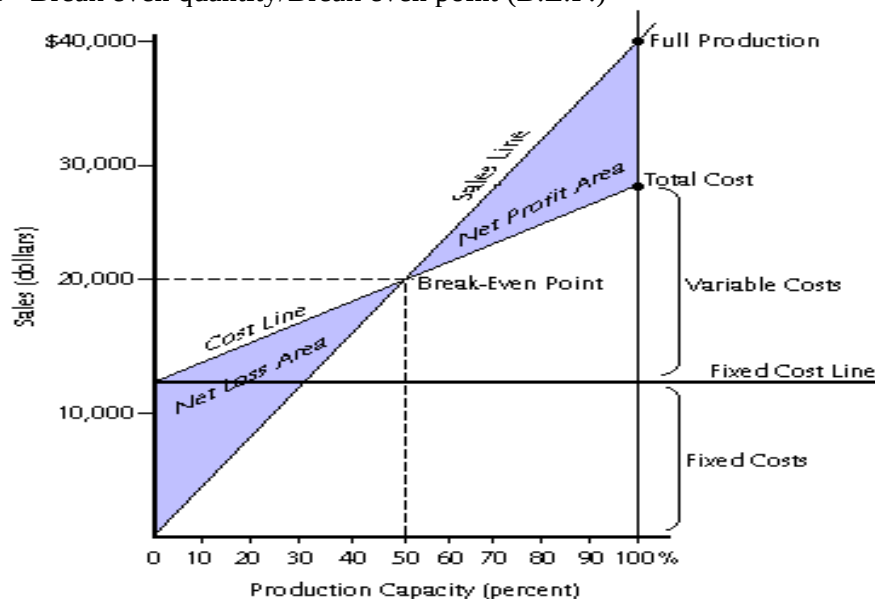


Figure 1
A Break-Even
Graph

The formula for the breakeven point (B.E.P) is given below. Application of this formula to arrive at the make or buy decision is illustrated with some examples.

$$\text{B.E.P.} = \frac{\text{FC}}{\text{Selling price} - \text{Variable cost}}$$

A generalized methodology for locational break-even analysis is given below.

1. Determine all relevant costs for each of the locations.
2. Classify the costs for each location into annual fixed costs (FC) and variable cost per unit (VC).
3. Plot the total costs associated with each location on a single chart of annual cost versus annual volume.
4. Select the location with the lowest total annual cost (TC) at the expected production volume.

PROBLEMS

Problem 1: A manufacture of motor cycles buy side box at RS. 240each. in case he makes it himself , the fixed and variable costs would be RS.300 000 and RS. 90per side box, respectively. Should the manufacture make or buy the side box if there is a demand for 2500 side boxes?

Solution:

Selling price/unit (SP) = Rs. 240

Variable cost/unit (VC) = Rs. 90

Fixed cost (FC) = Rs. 3,00,000

$$\begin{aligned}\text{B.E.P.} &= \frac{3,00,000}{240 - 90} \\ &= 2000 \text{ units}\end{aligned}$$

Problem 2: There are three alternatives available to meet the demand of a particular product. They are as follows:

1. Making the product using Process A.
2. Making the product using Process B.
3. Buying the product.

The details are follows:

Cost Elements	Making using Process A	Making using Process B	Buy
Fixed Cost/year (Rs.)	100,000	300,000	-----
Variable cost/unit (Rs.)	75	70	-----
Purchase price/unit (Rs.)	-----	-----	80

The annual demand for the product is 10,000 units.

1. Should the company make the product using Process A or Process B, or buy it?
2. At what annual volume should the company switch from buying to making using Process A?
3. At what annual volume should the company switch from Process A to Process B?

Solution:

1. *Compute the annual cost for each alternative.*

$$\begin{aligned}\text{Annual cost of process A} &= \text{FC} + (\text{VC} \times \text{Volume}) \\ &= 100,000 + (75 \times 10,000) = \text{Rs. } 850,000\end{aligned}$$

$$\begin{aligned}\text{Annual cost of process B} &= \text{FC} + (\text{VC} \times \text{Volume}) \\ &= 300,000 + (70 \times 10,000) = \text{Rs. } 1,000,000\end{aligned}$$

$$\begin{aligned}\text{Annual cost of buying} &= \text{Purchase price/unit} \times \text{Volume} \\ &= 80 \times 10,000 = \text{Rs. } 800,000\end{aligned}$$

Since, the annual cost of buy option is minimum among all the alternative costs, the company should buy the product.

2. *Let Q be the volume at which the company switches from buying to making, using process A*

Hence, total annual cost of process A $\leq$ Total annual cost of buying

$$\begin{aligned}100,000 + (Q \times 75) &\leq Q \times 80 \\ 100,000 &\leq 5Q \\ 5Q &\geq 100,000 \\ Q &\geq 20,000 \text{ units}\end{aligned}$$

Thus, if the volume of production is more than 20,000 units the company should switch from buying to making option using process A.

3. Let Q be the volume at which the shift from making using process A to making using process B is preferable.

Total annual cost of process A $\geq$ Total annual cost of process B

$$100,000 + 75Q \geq 300,000 + 70Q$$

$$5Q \geq 200,000$$

$$Q \geq 40,000 \text{ units}$$

Thus, if the production volume is more than 40,000 units, the company can shift from process A to process B.

Problem 3: Potential locations A, B and C have cost structures shown below for manufacturing a product expected to sell for 2700 per unit. Find the most economical location for an expected volume of 2000 units per year.

Site	Fixed Cost/Year (Rs.)	Variable Cost/Unit (Rs.)
A	6,000,000	1500
B	7,000,000	500
C	5,000,000	4000

Solution:

For each plant find the total cost using the following formula:

Total cost (TC) = Fixed cost (FC) + (Variable cost x Sales Volume)

$$\text{Total cost at location A} = 6,000,000 + (1500 \times 2000) = 9,000,000$$

$$\text{Total cost at location B} = 7,000,000 + (500 \times 2000) = 8,000,000$$

$$\text{Total cost at location C} = 5,000,000 + (4000 \times 2000) = 13,000,000$$

From the above calculations it is clear that the cost of location B is minimum. Hence, it is to be selected for locating the plant.

In the increasing order of the production volume the switch over from one site to another takes place as per the following order.

Site C to Site A to Site B

Let Q be the volume at which the switch from Site C to Site A

Total cost of Site C $\geq$ Total cost of Site A

$$TC_C \geq TC_A$$

$$FC + (VC \times SV) \geq FC + (VC \times SV)$$

$$5,000,000 + 4000Q \geq 6,000,000 + 1500Q$$

$$4000Q - 1500Q \geq 6,000,000 - 5,000,000$$

$$2500Q \geq 1,000,000$$

$$Q \geq \frac{1,000,000}{2500}$$

$$Q \geq 400 \text{ units}$$

If the production volume is more than 400 units, the company can shift from Site C to Site A

Let Q be the volume at which the switch from Site A to Site B

Total cost of Site A $\geq$ Total cost of Site B

$$TC_A \geq TC_B$$

$$FC + (VC \times SV) \geq FC + (VC \times SV)$$

$$6,000,000 + 1500Q \geq 7,000,000 + 500Q$$

$$1500Q - 500Q \geq 7,000,000 - 6,000,000$$

$$2000Q \geq 1,000,000$$

$$Q \geq \frac{1,000,000}{2000}$$

$$Q \geq 1000 \text{ units}$$

If the production volume is more than 1000 units, the company can shift from Site A to Site B

Problem 4: Location A would result in fixed costs of \$3, 00,000 with variable costs of \$ 63 per unit and revenues of \$ 68 per unit. Annual fixed costs at location B are \$ 8, 00,000 with variable costs of \$ 32 per unit and revenue of \$ 68 per unit. Sales volume is estimated to be 25,000 units/year. Which location is most attractive?

Solution:

$$\begin{aligned}\text{Total cost of production at location A} &= \text{FC} + (\text{VC} \times \text{SV}) \\ &= 300,000 + (63 \times 2500) = \text{Rs. } 1,875,000\end{aligned}$$

$$\begin{aligned}\text{Total cost of production at location B} &= \text{FC} + (\text{VC} \times \text{SV}) \\ &= 800,000 + (32 \times 2500) = \text{Rs. } 1,600,000\end{aligned}$$

$$\begin{aligned}\text{Total revenues at location A} &= \text{Revenues} \times \text{Sales Volume} \\ &= 68 \times 2500 = \text{Rs. } 1,700,000\end{aligned}$$

$$\begin{aligned}\text{Total revenues at location B} &= \text{Revenues} \times \text{Sales Volume} \\ &= 68 \times 2500 = \text{Rs. } 1,700,000\end{aligned}$$

$$\begin{aligned}\text{Total profit at Location A} &= \text{Total revenue at location A} - \text{Total cost of production at location A} \\ &= 1,700,000 - 1,875,000 = - \text{Rs. } 175,000\end{aligned}$$

$$\begin{aligned}\text{Total profit at Location B} &= \text{Total revenue at location B} - \text{Total cost of production at location B} \\ &= 1,700,000 - 1,600,000 = \text{Rs. } 100,000\end{aligned}$$

Since location B gives a profit of Rs. 100,000 as compare to loss of Rs. 175,000 at location A. Hence location B is most attractive.

Problem 5: Potential locations A, B and C have the cost structures shown for producing a product expected to sell at Rs. 100 per unit. Find the most economical location for an expected volume of 2000 units/year. Also determine the range of annual volume of production for which, each of the locations A, B and C would be most economical.

Location	Fixed Cost/Year (Rs.)	Variable Cost/Unit (Rs.)
A	25,000	50
B	50,000	25
C	80,000	15

Solution:

For each plant find the total cost using the following formula:

$$\text{Total cost (TC)} = \text{Fixed cost (FC)} + (\text{Variable cost} \times \text{Sales Volume})$$

$$\text{Total cost at location A} = 25,000 + (50 \times 2000) = 125,000$$

$$\text{Total cost at location B} = 50,000 + (25 \times 2000) = 100,000$$

$$\text{Total cost at location C} = 80,000 + (15 \times 2000) = 110,000$$

From the above calculations it is clear that the cost of location B is minimum. Hence, it is to be selected for locating the plant.

In the increasing order of the production volume the switch over from one site to another takes place as per the following order.

Site A to Site C to Site B

Let Q be the volume at which the switch from Site A to Site C

$$\text{Total cost of Site A} \geq \text{Total cost of Site C}$$

$$\text{TCA} \geq \text{TCC}$$

$$\text{FC} + (\text{VC} \times \text{SV}) \geq \text{FC} + (\text{VC} \times \text{SV})$$

$$25,000 + 50Q \geq 80,000 + 15Q$$

$$35Q \geq 55,000$$

$$Q \geq \frac{55,000}{35}$$

$$35$$

$$Q \geq 1571 \text{ units}$$

If the production volume is more than 1571 units, the company can shift from Site A to Site C

Let Q be the volume at which the switch from Site C to Site B

$$\begin{aligned}\text{Total cost of Site C} &\geq \text{Total cost of Site B} \\ \text{TCC} &\geq \text{TCB} \\ \text{FC} + (\text{VC} \times \text{SV}) &\geq \text{FC} + (\text{VC} \times \text{SV}) \\ 80,000 + 15Q &\geq 50,000 + 25Q \\ 25Q - 15Q &\geq 80,000 - 50,000 \\ Q &\geq \frac{30,000}{10} \\ Q &\geq 3000 \text{ units}\end{aligned}$$

If the production volume is more than 3000 units, the company can shift from Site A to Site C

PLANT LAYOUT

Plant layout is the arrangement of production machinery, machine tools, work centers and additional facilities and activities, e.g., inspection, handling of material, storage and transport, for the purpose of securing efficiency in manufacturing products or supplying consumer services. A bad plant layout would lead to loss of efficiency, waste of time and energy, inconveniences and botherations in the actual operations and in the process of production. A good layout ensures orderly and efficient arrangement of work facilities and personnel.

Plant layout has been defined as: *“A technique of locating machines, processes and plant services within the factory in order to secure the greatest possible output of high quality at the lowest possible total cost of production.”*

The objectives of plant layout are:

- Minimize investment in equipment.
- Minimize overall production time.
- Utilize existing space most effectively.
- Provide for employee convenience, safety and comfort.
- Maintain flexibility of arrangement and operation.
- Minimize materials-handling cost.
- Facilitate the manufacturing process.
- Facilitate the organizational structure.

FACTORS AFFECTING PLANT LAYOUT

1. **Type of Production:** The layout for an engineering unit will be quite different from that of a flour factory.
2. **Production System:** The plant layout in a continuous production system will be totally different from that under the intermittent production system.
3. **Scale of Production:** The plant layout and material handling equipment in the large-scale organization will be different from that in the small-scale manufacturing activity.
4. **Type of Machines:** The use of single-purpose and multipurpose machines substantially affects the plant layout. Similarly noisy and vibrating machines require special attention in the plant layout decision.
5. **Type of Building Facilities:** The plant layout in a single-storey building will be different from that in a multi-storey building.
6. **Availability of Total Floor Area:** The allocation of space for machines, work-benches, sub-stores, aisles, etc. is made on the basis of the available floor area. Use of overhead space is made in-case of shortage of space.
7. **Possibility of Future Expansion:** Plant layout is made in the light of the future requirements and installation of additional facilities.
8. **Arrangement of Material Handling Equipment:** The plant layout and the material handling services are closely related and the latter has a decisive effect on the arrangement of production process and plant services.

CLASSIFICATION OF LAYOUT

A layout essentially refers to the arranging and grouping of machines which are meant to produce goods. Grouping is done on different lines. The choice of a particular line depends on several factors. Layouts can be classified into the following four categories.

1. Process Layout or Functional Layout
2. Product layout
3. Group layout (Combination layout)
4. Fixed position layout

1. PROCESS LAYOUT

Under Process layout, all machines of the same kind, used in a given labour operation, and grouped together in one place. Thus in an engineering factory all types of lathes are placed together. It is the layout by operation for job lot manufacture. Process layout is generally adopted for job order industries like engineering, printing, etc. in which the requirements of every job are different from every other job, making it impossible for materials to flow uniformly through all the processes.

Advantages of Process Layout:

1. Machines are better utilized: fewer machines are required.
2. A high degree of flexibility in terms of task allocation to machines exists.
3. Comparatively low investment in machine is required.
4. The diversity of tasks offers a more interesting and satisfying occupation for the operator.

Limitations of Process Layout:

1. Material handling cost will be high.
2. Production planning and control systems are more involved.
3. Throughput time is longer.
4. Large amounts of in-process inventory will result.
5. Space and capital are tied up by work in process.
6. Higher grades of skill are required.

2. PRODUCT LAYOUT

Under product layout, all the machines of each kind needed for balanced operations on a given production or assembly line are located adjacent to it in labour operation sequence. Product Layout is suitable in continuous flow and mass production industries. It involves a continuous flow of materials through the required processes in a definite sequence.

Advantages of Product Layout:

1. The flow of product will be smooth and logical in flow lines.
2. In-process inventory is less.
3. Throughput time is less.
4. Material handling cost is minimum.
5. Operators need not be skilled.
6. Simple production planning and control systems are possible.
7. Less space is occupied by work in transit and for temporary storage.

Limitations of Product Layout:

1. A breakdown of one machine in a product line may cause stoppages of machines in the downstream of the line.
2. A Change in product may require major alterations in the layout.
3. The line output is decided by the bottleneck machine.
4. Comparatively high investment in equipments is required.

Difference between Process & Product Layout

Process Layout	Product Layout
1. Reduction in the investment on machines as they are general purpose machines	1. Mechanization of materials handling and consequent reduction in materials handling cost.
2. Greater flexibility in production	2. Avoidance of bottlenecks
3. Better and more efficient supervision possible through specialization	3. Economy in manufacturing time
4. Better scope for expansion	4. Better production control
5. Better utilization of men and machines	5. Less floor area required per units production
6. Easier to handle breakdown of equipment by transferring work to another machine or station	6. Minimum investment in work-in-progress
7. Full utilization of the plant	7. Early detection of mistakes or badly produced items
8. Greater incentive to individual workers to raise the level of their performance	8. Greater incentives to group of workers to raise their performance

3. GROUP LAYOUT

A group layout is a combination of the product layout and process layout. It combines the advantages of both layout systems. If there are m machines and n components, in a group layout, the m-machines and n-components will be divided into distinct number of machine-component cells such that all the components assigned to a cell are almost processed within that cell itself.

Advantages: Group technology layout can increase the items given in List A and it can decrease the items given in List B.

List A

1. Component Standardization and rationalization
2. Reliability of estimates
3. Effective machine operation
4. Productivity
5. Costing accuracy
6. Customer services
7. Order potential

List B

1. Planning effort
2. Paper work
3. Setting time
4. Down time
5. Work in progress
6. Work movement
7. Overall production times
8. Finished part stock
9. Overall cost

Limitations: This type of layout may not be feasible for all situations. If the product mix is completely dissimilar, then we may not have meaningful cell formation.

4. FIXED POSITION LAYOUT

As the term itself implies, the fixed position Layout involves the movement of men and machines to the product which remains stationary. In this type of layout, the material or major component remains in a fixed location and tools, machinery and men as well as other pieces of materials are brought to this location. The movement of men and machines to the product is advisable because the cost of moving them would be less than the cost of moving the product which is very bulky.

Advantages of Fixed Position Layout:

1. Men & machines can be used for a wide variety of operations producing different products.
2. The investment on layout is very small.
3. The worker identifies himself with the product and takes pride in it when the work is completed.
4. The high cost and difficulty in transporting bulky product are avoided.

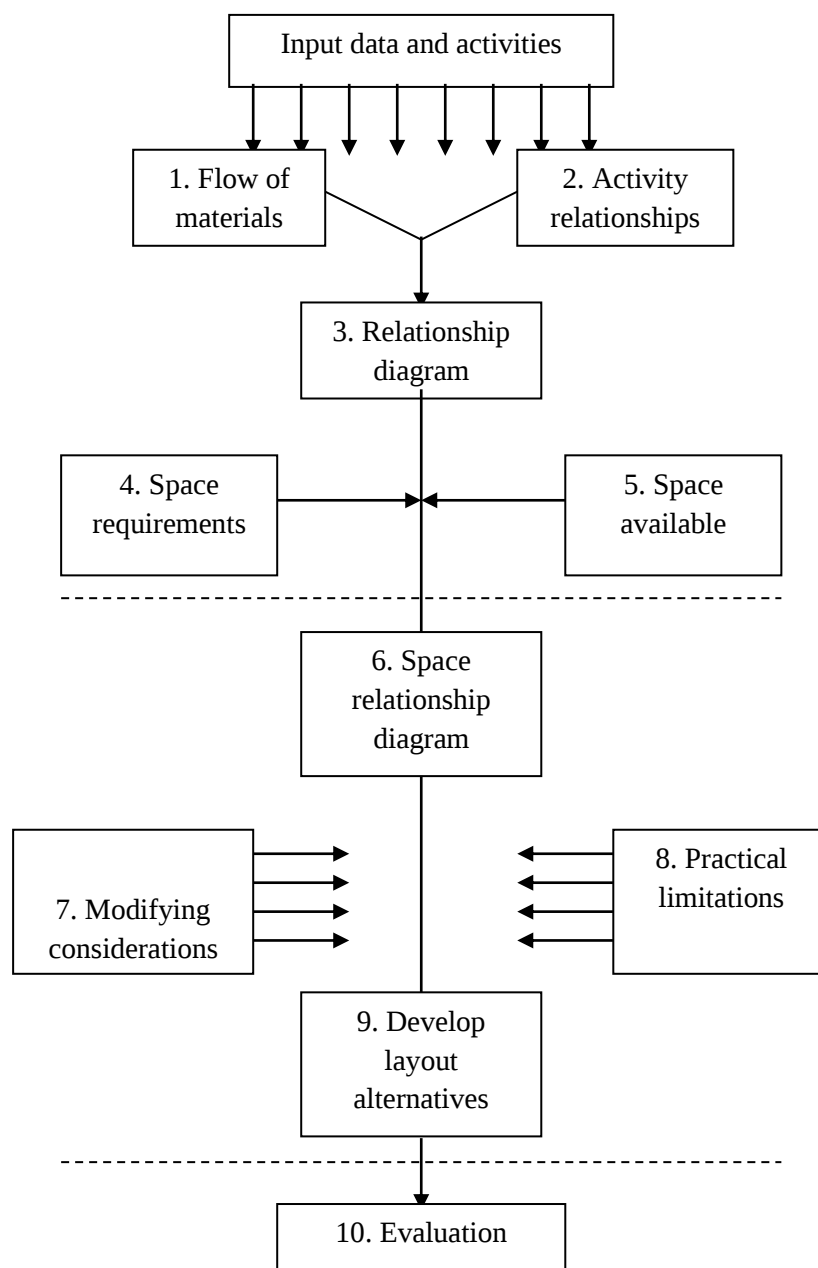
Limitations of Fixed Position Layout:

1. Transportation of all production facilities such as (machines, tools, equipments etc.) consumes more time.
2. Highly skilled workers are required.
3. Complicated jigs and fixtures may be required in fixing jobs and tools etc.

LAYOUT DESIGN PROCEDURES

Layout design procedures can be classified into *Systematic Layout Design Procedure (SLDP)* and *Computerized Relative Allocation of Facilities Technique (CRAFT)*.

1. SYSTEMATIC LAYOUT DESIGN PROCEDURE (SLDP)



Systematic layout planning procedure (from France and White, 1974)

An organizational approach to layout planning has been developed by Muther and has received considerable publicity due to the success derived from its application in solving a large variety of layout problems. This approach is referred to as systematic layout planning or simply SLP. The Space Relationship diagram is constructed by combining space considerations with the relationship diagram. In comparison with the steps in the design process, SLP begins after the problem is formulated.

2. COMPUTERIZED RELATIVE ALLOCATION OF FACILITIES TECHNIQUE (CRAFT)

CRAFT algorithm was originally developed by Armour and Buffa. It starts with an initial layout and improves the layout by interchanging the department's pair wise so that the transportation cost is minimized. The algorithm continues until no further interchanges are possible to reduce the transportation cost. The result given by CRAFT is not optimum in terms of minimum cost of transportation. But the result will be good and close to optimum in majority of applications.

CRAFT Requirements:

1. Initial layout
2. Flow data
3. Cost per unit distance
4. Total number of departments
5. Fixed departments
 - Number of such departments
 - Location of those departments
6. Area of departments

CRAFT Procedure:

The steps of CRAFT algorithm are summarized below:

Step 1. Input: 1. Number of departments
2. Number of interchangeable departments
3. Initial layout
4. Cost matrix
5. Flow Matrix
6. Area of departments

Step 2. Compute centroids of departments in the present layout.

Step 3. Form distance matrix using the centroids.

Step 4. Given data on flow, distance and cost, compute the total handling cost of the present layout.

Step 5. Find all the possible pair wise interchanges of departments based on common border or equal area criterion. For each possibility, interchange the corresponding centroids and compute approximate costs.

Step 6. Find the pair of departments corresponding to the minimum handling cost from among all the possible pairs of interchanges.

Step 7. Is the cost in the previous step less than the total cost of the present layout? If yes, go centroids, distance matrix and total cost.

Step 8. Interchange the selected pair of departments. Call this as the NEW LAYOUT. Compute centroids, distance matrix and total cost.

Step 9. Is the cost of new layout less than the cost of the present layout? If yes, go to step 10. If not, go to Step 11.

Step 10. The new layout is here after considered as the PRESENT LAYOUT. Its data on centroids, layout matrix and the total cost is retained. Go to Step 5.

Step 11. Print the present layout as the FINAL LAYOUT.

Step 12. Stop.

FACILITY MANAGEMENT (MAINTENANCE MANAGEMENT)

MEANING AND DEFINITION

Maintenance may be understood as a set of activities, which help keep plant, machinery and other facilities in good conditions. A formal definition of maintenance is “*that function of manufacturing management that is concerned with the day-to-day problem of keeping the physical plant in good operating condition.*”

It is an essential activity in every manufacturing establishment, because it is necessary to insure the availability of machines, buildings and services needed by other parts of the organization for the performance of their functions at an optimum return on the investment, whether this investment is in machinery, materials or employees.

Viewed from this, it may be stated that maintenance is not just repairs. Maintenance is much wider in its scope unlike repairs.

Maintenance is one function, which has not been rendered obsolete by, advanced technology, has not faded away with the passage of time and has not lost its stature in the industry, though other functions have witnessed fluctuating fortunes from time to time.

SCOPE OF MAINTENANCE

Every manufacturing organization needs maintenance because,

- Machines break down
- Parts wear out
- Buildings deteriorate over a period of time of use

All segments of a factory – *buildings, machinery, equipments, tools, cranes, jigs and fixtures, heating and generating equipments, waste disposal system, air-conditioning equipments, wash rooms, dispensaries* and so on, need attention.

Maintenance covers two broad categories of functions as outlined below:

(a) *Primary functions*

1. Maintenance of existing plant and equipments
2. Maintenance of existing plant buildings and grounds
3. Equipment inspection and lubrication
4. Alterations to existing equipments and buildings
5. New installations of equipments and buildings

(b) *Secondary functions*

1. Storekeeping
2. Plant protection including fire protection
3. Waste disposal
4. Salvage
5. Insurance administration
6. Property accounting
7. Pollution and noise abatement or control
8. Any other service delegated towards maintenance by the plant management

IMPORTANCE OF MAINTENANCE MANAGEMENT

1. Dependability of service is one of the performance measures by which a company can distinguish itself from others.
2. Maintenance is an important factor in quality assurance, which is another basis for the successful competitive edge.
3. Many manufacturing organizations, particularly those with JIT (Just-In-Time) programmes are operating with inventories so low that, they offer no protection in the event of a lengthy equipment failure.

4. Good Maintenance Management is important for the company's cost control.
5. Organizations like airlines and oil refineries have huge investments in the equipment.

IMPACT OF POOR MAINTENANCE

Maintenance operations include all efforts to keep production facilities and equipments in an acceptable operating condition. Failure or mal-functioning of machines and equipments in manufacturing and service industries have a direct impact on the following:

1. **Production capacity:** Machines idled by breakdowns cannot produce, thus the capacity of the system is reduced.
2. **Production costs:** Labour costs per unit rise because of idle labour due to machine breakdowns. When machine malfunctions result in scrap, unit labour and material costs increases.
3. **Product and service quality:** Poorly maintained equipments produce low quality products. Equipments that have not been properly maintained have frequent break downs and cannot provide adequate service to customers.
4. **Employee or customer safety:** Worn-out equipment is likely to fail at any moment and these failures can cause injuries to the workers, working on those equipments
5. **Customer satisfaction:** When production equipments break down, products often cannot be produced according to the master production schedules, due to work stoppages. This will lead to delayed deliveries of products to the customers.

OBJECTIVES OF MAINTENANCE MANAGEMENT

The following are some of the objectives of maintenance management:

1. Minimizing the loss of productive time because of equipment failure (i.e., minimizing idle time of equipment due to break down)
2. Minimizing the repair time and repair cost
3. Minimizing the loss due to production stoppages
4. Efficient use of maintenance personnel and equipments
5. To keep all productive assets in good working condition.
6. To minimize accidents through regular inspection and repair of safety devices.
7. To minimize the total maintenance cost which includes the cost of repair, cost of preventive maintenance and inventory carrying costs, due to spare parts inventory.
8. To improve the quality of products and to improve productivity.

AREAS OF MAINTENANCE

The major areas of maintenance are:

1. **Civil Maintenance:** Building construction and maintenance, maintaining service facilities such as water, gas, steam, compressed air, heating and ventilating, air conditioning, painting, plumbing and carpentry work.
2. **Mechanical Maintenance:** Maintaining machines and equipments, transport vehicles, material handling equipments, steam generators, boilers, compressors and furnaces. Lubricating the machines is also part of mechanical maintenance work.
3. **Electrical Maintenance:** Maintaining electrical equipments such as generators, transformers, switchgears, motors, telephone systems, electrical installations, lighting, fans, meters, gages instruments, control panels and battery charging.

In all the above stated areas, organization may use any or all the five types of maintenance, viz.:

- I. Break down maintenance or corrective maintenance
- II. Preventive maintenance

- III. Predictive maintenance
- IV. Routine maintenance
- V. Planned maintenance

I. Break down Maintenance or Corrective Maintenance

As the name suggests, corrective maintenance occurs, when there is a work stoppage because of machine breakdown. In this sense, maintenance becomes repair work. Repairs are made after the equipment is out of order – an electric motor will not start, a conveyor belt is ripped, or a shaft has broken. In cases such as these, the maintenance department checks into the difficulty and makes the necessary repairs. Role of the department is almost passive.

Nevertheless, corrective maintenance seeks to achieve the following objectives:

1. To get equipment back into operation as quickly as possible in order to minimize interruption to production. These objectives can directly affect production capacity, production costs, and product quality and customer satisfaction.
2. To control the cost of repair crews, including regular time and overtime labour costs.
3. To control the cost of the operation of repair shops.
4. To control the investment in replacement spare parts that is used when machines are repaired.
5. To control the investment in replacement spare machines, which are also, called stand-up or back-up machines, these replaces manufacturing machines until the needed repairs are completed.
6. To perform the appropriate amount of repairs to each malfunction. The decision about how far to go with a repair ranges from a band-aid and bubble gum fix to a complete overhaul. Some parts can be replaced early to extend the time until the next repair is required.

II. Preventive Maintenance

In marked contrast to corrective maintenance, is preventive maintenance, which is undertaken before the need arises and aims to minimize the possibility of un-anticipated production interruptions or major breakdowns. Preventive maintenance consists of:

1. Proper design and installation of equipment,
2. Periodic inspection of plant and equipment to prevent break downs before they occur
3. Repetitive servicing, upkeep and overhaul of equipment and
4. Adequate lubrication, cleaning and painting of buildings and equipment

The key to all good preventive maintenance is inspection. Inspection should cover virtually everything. Including production machinery, motors it controls materials handling equipment, process equipment, lighting, buildings and plant services. Some organizations inspect only costly items, but others cover almost all.

Preventive maintenance offers several benefits to the users: They include greater safety for worker decreased production downtime, fewer large scale and repetitive repairs, less cost for simple repairs made before breakdown, less standby equipment required, better spare parts control, identification of items with high maintenance costs and lower unit cost of manufacture.

III. Predictive Maintenance

One of the newer types of maintenance that may be anticipated to gain increasing attention is called predictive maintenance. In this, sensitive instruments (eg., vibration analyzers, amplitude meters, audio gauges, optical tooling, pressure, temperature and resistance gauges) are used to predict trouble.

IV. Routine Maintenance

This includes activities such as periodic inspection, cleaning, lubrication and repair of production equipments after their service life.

1. Running maintenance in which, the maintenance work is carried out while the equipment is in the operating condition
2. Shut down maintenance in which the maintenance work is carried out when the machine or equipment is out of service i.e., after shutting down the machine or equipment, e.g., repairing (i.e., discaling) boiler tubes of a boiler.

V. Planned Maintenance

Breakdown of a machine or equipment does not occur in a planned manner but maintenance work can be planned well in advance. Planned maintenance is also known as *scheduled maintenance* or *productive maintenance*.

MODELS OF MAINTENANCE MANAGEMENT

1. Expected Value Model for Estimating Breakdown Cost

Preventive maintenance is more effective when service requirements are well known or failures can be predicted with some degree of reliability. When the firm has maintained good records of the frequency and cost of breakdowns in the past, by using a simple concept of expected value, the current breakdown policy can be compared with a given maintenance policy.

Illustration: XYZ firm has experienced the stated number of break-downs per month over the past n years.

Number of break-downs	X_0	X_1	X_2	X_3	X_4
Number of months this occurred	m_0	m_1	m_2	m_3	m_4

Average breakdown cost = C_{bm}

Preventive maintenance cost under a preventive maintenance cost under a preventive maintenance policy which limits the break downs to X per month = C_{pm}

Which maintenance policy is preferable from cost point view?
The current breakdown or a new preventive maintenance policy?

Solution:

No. of break downs x	Frequency in months f(x)	Frequency P(x)	Expected Value x.P(x)
X_0	m_0	m_0/M	$X_0 * m_0/M$
X_1	m_1	m_1/M	$X_1 * m_1/M$
X_2	m_2	m_2/M	$X_2 * m_2/M$
X_3	m_3	m_3/M	$X_3 * m_3/M$
X_4	m_4	m_4/M	$X_4 * m_4/M$
Total = M months			Total = Y

Expected breakdown cost per month under current breakdown policy = $Y * C_{bm} = YC_{bm}$

Preventive maintenance cost per month under new preventive maintenance policy = $(X * C_{bm} + C_{pm})$
 $= XC_{bm} + C_{pm}$

If $\rightarrow XC_{bm} + C_{pm} < YC_{bm}$, then the new preventive maintenance policy is advisable.

Problem: PQR Company has kept records of breakdown of its machines for a 300 day work year as shown below:

No. of break down	0	1	2	3	4	Total
Frequency in days	40	150	70	30	10	300

The firm estimated that each breakdown cost Rs. 650/- and is considering adopting a preventive maintenance program, which would cost Rs. 200 per day and limit the number of break down to an average of one per day. What is the expected annual savings from preventive maintenance programme?

Solution:

To determine the expected number of breakdowns per year:

No. of breakdowns (x)	Frequency of breakdowns in days i.e, f(x)	Probability distribution of breakdowns P(x)	Expected value of breakdowns [x P(x)]
0	40	$40/300 = 0.133$	Nil
1	150	$150/300 = 0.5$	0.5
2	70	$70/300 = 0.233$	0.466
3	30	$30/300 = 0.1$	0.3
4	10	$10/300 = 0.033$	0.132
Total	300	1	1.4

Total no. of breakdowns per day = 1.4

Cost of breakdown per day = $1.4 \times 650 = \text{Rs. } 910$

Cost of preventive maintenance programme per day = Rs. 200 + Rs. 650 = Rs. 850

Expected annual savings from the preventive maintenance programme = $(910 - 850) \times 300 \text{ days}$
= Rs. 18, 000.

2. Simulation Model for Estimating Break-down Cost

Simulation technique enables maintenance managers to 'try out' numerous maintenance policies on a computer before actually implementing them. The data regarding simulated breakdowns and repair time values could be used to estimate the breakdown cost and reach a decision about the appropriate crew size.

Problem: In a simulated operation, a firm's maintenance crew received requests for service and provided services during an 8 hour period as shown below:

Request arrival (clock) time	0.00	1.00	3.30	4.0	7.0
Service time (hours)	1.5	0.5	2.0	0.5	1.0

The maintenance labour cost is Rs. 140 per hour and the delay time cost is Rs. 450 per hour.

- Find the idle time cost for the maintenance crew.
- Find the delay time cost for the machinery.

Solution:

Request arrival time (Clock time)	Repair time for one crew		Repair time (clock time)		Machine down time		
	Hours	Minutes	Begins	Ends	Waiting time	Repair time	Total time
00.00	1.50	90	00.00	01.30	Nil	1.5	1.5
01.00	0.50	30	01.30	02.00	0.5	0.5	1.0
03.30	2.00	120	03.30	05.30	Nil	2.0	2.0
04.00	0.50	30	05.30	06.00	1.5	0.5	2.0
07.00	1.00	60	07.00	08.00	Nil	1.0	1.0
Total	5.50 hrs				2.0	5.5	7.5

Idle time for the maintenance crew = $8 - 5.5 = 2.5$ hrs

Idle time cost for maintenance crew = $2.5 \times 140 = \text{Rs. } 350$

Delay time or waiting time = 2.0 hrs

Delay time cost for the machinery = $2.0 \times 450 = \text{Rs. } 900$

3. Probability Model for Selecting Preventive Maintenance Policy

This helps decide whether to follow breakdown or preventive maintenance policy. The model involves the following steps:

Step No. 1: Data are collected on

- The preventive maintenance servicing cost
- The breakdown cost and
- The probability of breakdown.

Step No. 2: The cumulative expected number of breakdowns B in M (month) is

$$B_n = N [\sum P_n] + B_{n-1}P_1 + B_{n-2}P_2 + \dots B_1P_{n-1}$$

Where N = Number of units or machines/equipments

P = Probability of breakdown during a given month after maintenance

n = Maintenance period in which maintenance is performed.

Step No. 3: After calculating the expected number of breakdown B_n for various preventive maintenance policies, the cost of preventive maintenance and expected cost of breakdown maintenance and the total maintenance cost per month is determined.

Step No. 4: The policy, which minimizes the total maintenance cost per month, is the choice.

Problem 1: The probability of failure after maintenance for a machine is given in the table below:

Years after maintenance	1	2	3	4	5
Probabilities of breakdown	0.2	0.4	0.2	0.1	0.1

If there are 50 machines in the facility, what is the expected number of breakdowns in the 3rd year?

Solution:

Expected no. of breakdowns (B_n) = $N [\sum P_n] + B_{n-1}P_1 + B_{n-2}P_2 + \dots B_1P_{n-1}$

Where,

N = Number of units or machines/equipments

P = Probability of breakdown during a given month after maintenance

n = Maintenance period in which maintenance is performed.

Given that $N = 50$; $n = 3$; $P_1 = 0.2$; $P_2 = 0.4$; $P_3 = 0.2$

Put $n = 1$, $B_1 = N P_1 = 50 \times 0.2 = 10$

Put $n = 2$, $B_2 = N (P_1 + P_2) + B_1P_1 = 50 (0.2 + 0.4) + (10 \times 0.2) = 32$

Put $n = 3$, $B_3 = N (P_1 + P_2 + P_3) + B_2P_1 + B_1P_2$
 $= 50 (0.2+0.4+0.2) + (32 \times 0.2) + (10 \times 0.4) = 40+6.4+4 = 50.4$

Therefore, expected no. of breakdowns in a 3rd year = 50.4

Problem 2: It costs Rs. 4,000 to perform preventive maintenance on a group of 10 machines. If one of the machines breaks down between preventive maintenance inspections, the breakdown maintenance costs Rs. 8000. The break down history on the machines is given below:

Weeks b/n PM (n)	1	2	3	4
Probability of breakdown	0.1	0.2	0.3	0.4

If only costs are considered, how often preventive maintenance should be performed to minimize the total maintenance cost (i.e., cost of preventive maintenance + Cost of breakdown maintenance).

Solution:

Step 1: Calculation of expected no. of breakdowns for each preventive maintenance policy.

Expected no. of breakdowns (B_n) = $N [\sum P_n] + B_{n-1}P_1 + B_{n-2}P_2 + \dots + B_1P_{n-1}$

Where,

N = Number of units or machines/equipments

P = Probability of breakdown during a given month after maintenance

n = Maintenance period in which maintenance is performed.

Given that N = 10; n = 4; P₁ = 0.1; P₂ = 0.2; P₃ = 0.3; P₄ = 0.4

Put n = 1, $B_1 = N P_1 = 10 \times 0.1 = 1$

Put n = 2, $B_2 = N (P_1 + P_2) + B_1P_1$
 $= 10 (0.1 + 0.2) + (1 \times 0.1) = 3.1$

Put n = 3, $B_3 = N (P_1 + P_2 + P_3) + B_2P_1 + B_1P_2$
 $= 10 (0.1+0.2+0.3) + (3.1 \times 0.1) + (1 \times 0.2) = 6+0.31+0.2 = 6.51$

Put n = 4, $B_4 = N (P_1 + P_2 + P_3 + P_4) + B_3P_1 + B_2P_2 + B_1P_3$
 $= 10 (0.1+0.2+0.3+0.4) + (6.51 \times 0.1) + (3.1 \times 0.2) + (1 \times 0.3)$
 $= 10+0.651+0.62+0.3 = 11.57$

Step 2: Calculation of expected breakdown cost, preventive maintenance cost and total maintenance cost for each preventive maintenance policy.

PM policy every 'n' weeks	Expected no. of breakdowns	Expected no. of breakdowns per week	Expected cost of breakdown per week (Rs.)	Cost of PM per week	Total maintenance cost
1	1	1/1 = 1	1x8000 = 8000	4000/1 = 4000	8000+4000 = 12000
2	3.1	3.1/2 = 1.55	1.55x8000 = 12,400	4000/2 = 2000	12400+2000 = 14400
3	6.51	6.51/3 = 2.17	2.17x8000 = 17,360	4000/3 = 1333	17360+1333 = 18693
4	11.57	11.57/4 = 2.89	2.89x8000 = 23,120	4000/4 = 1000	23120+1000 = 24120

The policy that minimize at the cost is to perform preventive maintenance every week i.e. n = 1.

UNIT – III

PRODUCTION PLANNING AND CONTROL

The planning process within an organization is dynamic and continuous. It is nothing but deciding future courses of action of the organization well in advance so that executives at different level will play their role as per these guidelines.

- Strategic decisions, which are taken at top, level management.
- Tactical decisions, which are taken at middle level management.
- Operational decisions, which are taken at bottom level management.

Strategic Decisions

Some examples of strategic decisions are warehouse location, distribution systems, building a new plant, mergers and acquisitions, new product planning, compensation planning, quality assurance planning, R&D planning, forming new technology department, dropping a product from the existing product mix, social responsibility planning, etc. The type of decisions taken at this level is often highly unstructured in nature.

Tactical Decisions

Some examples of tactical decisions are pricing a product, product improvement through value analysis, maintenance crew size determination, preventive maintenance policy, budget analysis, short-term forecasting, make or buy analysis, credit evaluation, plant layout, project scheduling, reward system design, negotiating, buying equipments etc. The type of decision taken at this level is mostly semi-structured in nature.

Operational Decisions

Some examples of operational level decisions are designing sampling plan to inspect the raw materials at stores while receiving materials from vendors, deciding price discount at salesman level in the field, scheduling of maintenance manpower, machine loading, daily operator scheduling, order entry, production scheduling, inventory control, buying software, approving loans etc. The type of decision taken at this level is mostly structured in nature.

The planning is considered to be an essential step in any business mainly because the end results depend on the input and the approach followed at this stage. So, the productivity of an organization can be improved by better planning efforts. Similarly, control process within an organization plays a major role in organizational productivity improvement. In reality, most of the decisions may not be implemented as per the plans. This is because of uncertainty, which is involved in many of the business processes.

The raw material quality may not be as per the assessed level. The machine breakdown rate may be higher than the predicted rate of breakdown. The operator efficiency may not be matching with the time standards. All these deviations would introduce some difficulty in producing products and services as per the plan. So, a careful control system with a proper feedback mechanism is a must to correct the whole business process at appropriate time to manufacture and deliver the goods as per the plan.

Production planning and control has three phases.

1. Planning phase
2. Action phase
3. Control phase

Production planning is an exercise of intelligent anticipation in order to establish how an objective can be achieved or a need fulfilled in circumstances, which are invariably restrictive. The outcome of planning is either dropping the whole idea or the formulation of a new plan in-line with the objective. Production planning determines the optimal schedule and sequence of operations, economic batch quantity, machine assignment and dispatching priorities for sequencing.

Action phase provides guidelines for implementing all the plans into practice.

Production control phase provides necessary guidelines to control the production system through a feedback mechanism. It involves follow up of the production plans. The detailed steps of production planning, action and control are discussed below.

1. Planning phase: It has two categories of planning namely prior planning and active planning. *Prior planning* means pre-production planning. This includes all the planning efforts, which are taking place prior to the active planning. *Active planning* means the actual production planning which includes various activities directly related to the production at micro level immediately following the prior planning.

The modules of **prior planning** are Product development and design, Forecasting, Aggregate planning, Master scheduling, Order writing, MRP, etc.

The modules of **active planning** are: Process planning and routing, Materials planning, Tools planning, Loading, Scheduling, etc.

2. Action phase: Action phase has the major step of dispatching. Dispatching is the transition from planning phase to action phase. In this phase, the worker is ordered to start manufacturing the product.

The tasks, which are included in dispatching, are Job order, Store issue order, Tool order, Time ticket, Inspection order, Move order, etc.

3. Control phase: The control phase has the following two major modules:

- *Progress reporting.* In progress reporting, the data regarding what is happening with the job is collected. Also, it helps to make comparison with the present level of performance. The various data pertaining to materials rejection, process variations, equipment failures, operator efficiency, operator absenteeism, tool life, etc., are collected and analyzed for the purpose of progress reporting. These data are used for performing variance analysis, which would help us to identify critical areas that deserve immediate attention for corrective actions.
- *Corrective action.* The tasks under corrective action primarily make provisions for an unexpected event. Some examples of corrective actions are: creating schedule flexibility, schedule modifications, capacity modifications, make or buy decision, expediting the work, pre-planning, and so on.

Due to unforeseen reasons such as, machine breakdown, labour absenteeism, too much rejection due to poor material quality etc., it may not be possible to realize the schedule as per the plan. Under such conditions, some minor adjustments are required to have schedule flexibility in short-run (day-to-day basis or, weekly basis).

After having initiated the process of manufacturing a product, sometime we may receive message to cancel a portion of the order size, which has been previously confirmed or, ordered. This would seriously affect the whole production schedule starting from materials procurement. Under such condition, it is better to reschedule the whole product mix so that we get a clear picture of the situation to progress further.

SCHEDULING

INTRODUCTION

- Scheduling is considered to be a major task for shop floor productivity improvement.
- Scheduling is the allocation of resources applying the limiting factors of time and cost to perform a collection of tasks.
- Scheduling problem is taken up only after solving the fundamental planning problem.
- It is of secondary importance when compared to the planning problem.
- Scheduling is considered only after answering these planning questions and knowing the availability of resources.
- Scheduling theory is concerned primarily with mathematical models that relate to the scheduling function and the development of useful models and techniques.

- The objective function generally consists of all costs in the system depending upon the type of scheduling decisions.

Technological planning deals with questions of facility design, vehicle/equipment utilization and personnel deployment. Once these decisions have provided a profile of the resources available, it is then possible to deal with scheduling problems. These examples address themselves to three kinds of questions:

- ✓ What product or service is to be provided?
- ✓ On what scale will it be provided? and
- ✓ What resources will be made available?

Planning function provides answers to these questions. The scheduling function assumes that answers to these questions are already available. In particular, the quantitative approach translates the decision-making goals into an explicit objective function and various decision making restrictions into explicit constraints.

Frequently, an important cost-related measure of system performance (such as machine idle time, job waiting time or job lateness or a combination of these measures) can be used as a substitute for total system cost.

Two kinds of feasibility constraints are commonly found in scheduling problems.

1. The first set of constraints is related to the amount of resource available (like number of machines available in each type).
2. The second set of constraints is based on technological restrictions on the sequence in which tasks can be performed.

The objectives of the scheduling problem are listed below. Determining the sequence in which tasks are to be performed.

- Determining the start time and finish time of each task.
- In other words, the essence of scheduling is to make allocation decisions pertaining to start and finish times for tasks

Scheduling can be classified into

- 1) Single Machine Scheduling
- 2) Flow shop Scheduling and
- 3) Job shop Scheduling.

LINE BALANCING

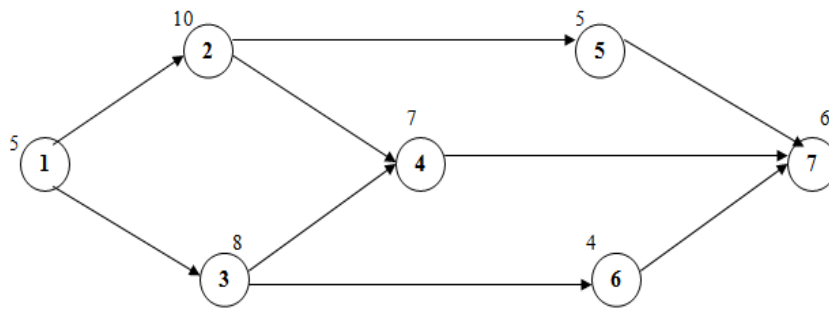
CONCEPT OF MASS PRODUCTION SYSTEM

Many differences exist in the management of production activities in make-to-order and make-to-stock firms. In make-to-order situations, due dates are important, and hence the sequencing of customer orders at various machine centers is an essential function. This involves both planning and control of activities. Make-to-stock products are generally high-volume consumer goods, such as telephones, automobiles, wristwatches, etc.

In high-volume items, it requires flow shops control for effective production. A flow shop consists of a set of facilities through which work flows in a serial fashion. The same operations are performed repeatedly in every workstation, thus requiring lower-level skilled workers. The flow shop generally represents a mass production situation.

In flow shops, items enter the finished goods inventory one after another, often in the same order of the inputs for these goods, leaving very low in-process inventories. Since the items are mostly make-to-stock, forecasting is a difficult job, and hence the finished goods levels in terms of anticipation inventories are very high.

The production control system of continuous production is called flow control. The main objective of flow control in flow shop is to balance the assembly line. The assembly line is represented in the form of a precedence diagram.



A Sample precedence diagram (timings are in minutes)

A precedence diagram specifies the order or sequence in which the activities must be performed.

- Each Circle [O] is a node
- Number inside the circle identifies particular operation
- Number outside the circle represents the duration of the operation
- Arrow indicates the direction of flow of operation
- Timings will be in minutes

CYCLE TIME

Cycle Time (CT) is directly related to the production rate of the assembly line.

$$CT = \text{Productive Time} / \text{Demand per period}$$

The range for the cycle time is given below:

$$t_{\max} \leq CT \leq t_i$$

Where t_i is the processing time of the operation i and $t_{\max}$ is the maximum processing time among various operations.

OBJECTIVE OF ASSEMBLY LINE BALANCING

The objective of assembly line balancing is to subdivide the network into several sub networks (stations) without violating the precedence relationships and allocating operations to each station without exceeding the cycle time, i.e., the sum of the times of operations allocated to each station without exceed the cycle time.

While allocating operations to each station, the precedence relationship must be maintained. If these are followed, then we can ensure production of the specified volume of products or items using the assembly line.

This type of problem comes under combinational category. So we will have to use some efficient heuristics for this purpose.

In this section the following heuristics are discussed.

1. Ranked Positional Weight (RPW) method.
2. COMSOAL

The first one is mainly based on the ranks generated for each operation. The second heuristic uses simulation as the basis. Irrespective of techniques, a generalized procedure for line balancing is given below.

GENERALIZED ALGORITHM OF LINE BALANCING

Step 0: Input: Cycle Time (CT), precedence matrix, total number of work elements (M), work elements times.

Initialize: unassigned cycle time (UACT) = CT, station number (SN =1) and total number of assigned work elements (N) = 1.

Step 1. Print the station number (SN)

Step 2. Initialize the total number of assigned work elements counter to one, i.e. $I = 1$.

Step 3. If the I^{th} work element is already assigned, go to step 7, otherwise go to step 4.

Step 4. If all the immediate precursors of the I^{th} work element are assigned, then go to step 5; otherwise go to step 7.

Step 5. In the I^{th} work element time is less than or equal to the unassigned cycle time (UACT), then go to Step 6, otherwise go to Step 7.

Step 6. Include the I^{th} work element in the List A which consists of work elements whose all immediate precursors are assigned and the processing time of each work element is less than the unassigned cycle time (UACT).

Step 7. Increment the total number of assigned work elements counter by one, i.e. $I = I + 1$.

Step 8. If $I \leq M$, then go to Step 3; otherwise go to step 9.

Step 9. If the number of work elements in the List A is more than 0, then go to step 11; otherwise go to Step 10.

Step 10. Perform the following and then go to Step 2.

- i. Add UACT to the sum of unassigned cycle time (SUACT)
- ii. Update $UACT = CT$
- iii. Update $SN = SN + 1$
- iv. Print SN

Step 11. If the number of work elements in the List A is equal to one, then assign that work element to the current station; otherwise select a work element from the List A using a given HEURISTIC.

Step 12. Subtract the recently assigned work element time from UACT and print the recently assigned work element's number.

Step 13. Update $N = N + 1$

Step 14. If $N \leq M$, then go to Step 2; otherwise go to Step 15.

Step 15. Compute the Balancing Efficiency (BE) in percentage.

$$BE = [1 - (SUACT / CT * SN)] * 100$$

Step 16. Stop.

RANKED POSITIONAL WEIGHT METHOD

- Helgeson and Brinie developed the ranked positional weight method.
- This method assigns those jobs first whose followers have the largest total time.
- The positional weight of a work element is its own processing time plus the processing times of all the following work elements.
- The work element with the highest positional weight is selected and assigned to the current station.

COMSOAL METHOD

- Arcus developed the Comsoal Method.
- It generates large number of feasible solutions using a simulation (the process of designing the data) method.
- Among them we choose the solution that satisfies our needs most.

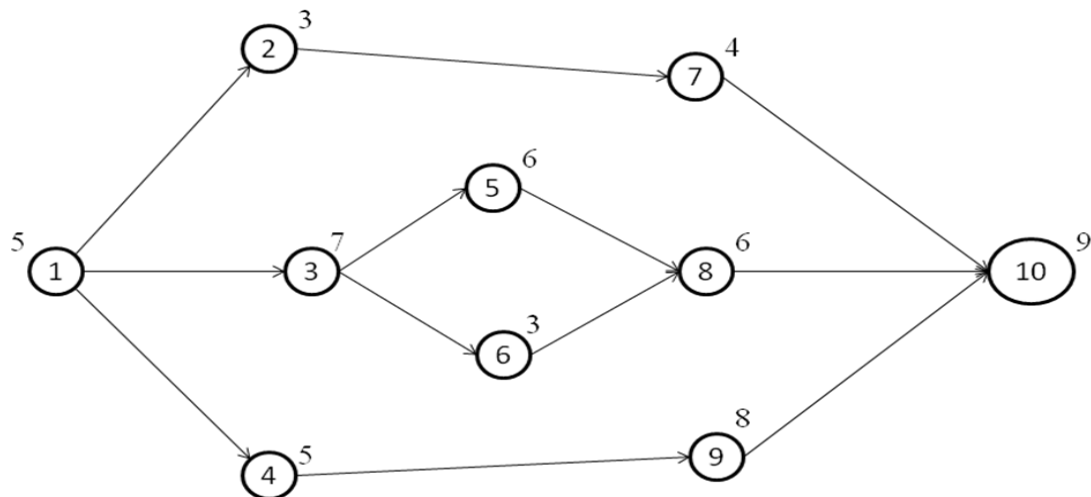
After forming the list A, use the following rules in the Step 11 of the generalized algorithm for assigning tasks to the current station from the List A. Rules are as follows:

1. All its immediate predecessors are already assigned.
2. Its processing time is less than or equal to the UACT.

Apply all steps to get a complete solution. Comsoal is an iterative method.

The solution with the maximum Balancing Efficiency out of several iterations is selected as the best solution for implementation.

Problem: Consider the assembly network shown below which shows the precedence relationships in assembling a product.



The number by the side of each node represents the processing time in minutes. The required production volume in 8 hour shift is 24 completed assemblies. Design an assembly line using RPW method.

Solution:

$$\text{Cycle time (CT)} = \frac{\text{Production time}}{\text{Production volume}}$$

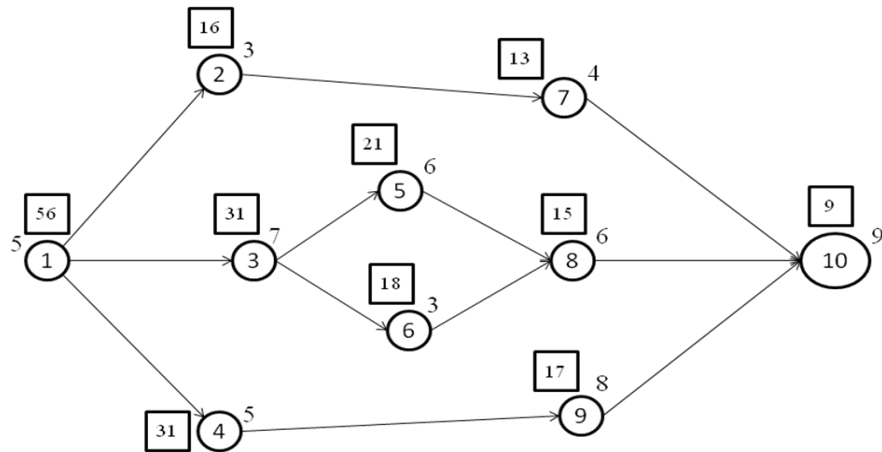
$$= \frac{8 \times 60}{24} = 20 \text{ minutes}$$

Compute the positional weight of all the work elements in the network as shown below:

Details of Work Element

Work Element No.	Time	Positional Weight	Immediate Predecessors		
1	5	56	-	-	-
2	3	16	1	-	-
3	7	31	1	-	-
4	5	31	1	-	-
5	6	21	3	-	-
6	3	18	3	4	-
7	4	13	2	-	-
8	6	15	5	6	-
9	8	17	4	-	-
10	9	9	7	8	9

Precedence Diagram with Positional Weights



A work element can be included in the List A if it can satisfy the following two conditions:

1. All its immediate predecessors are already assigned to some stations.
2. Its processing time is less than or equal to the UACT.

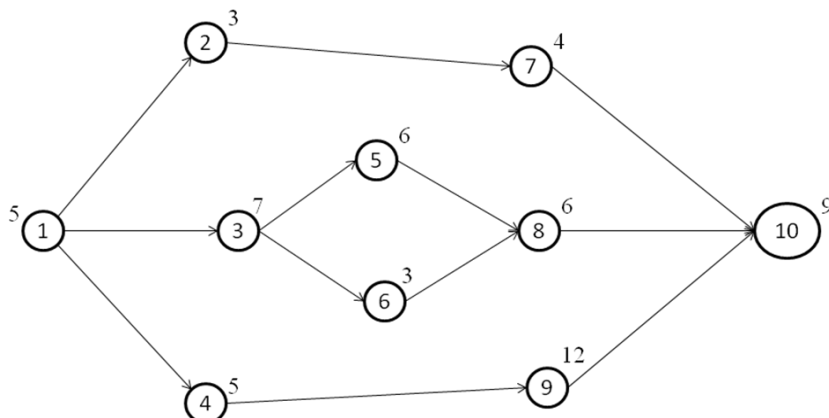
Details of Station

Station No.	List A	Work Element Selected	Unassigned Cycle Time UACT	Remarks
1	-	-	20	-
	1	1	20 - 5 = 15	-
	2, 3, 4	4	15 - 5 = 10	Break tie b/n 3 & 4 randomly
	2, 3, 9	3	10 - 7 = 3	-
	2, 6	6	3 - 3 = 0	Change over to next station
2	-	-	20	-
	2, 5, 9	5	20 - 6 = 14	-
	2, 8, 9	9	14 - 8 = 6	-
	2, 8	2	6 - 3 = 3	Change over to next station
3	-	-	20	-
	7, 8	8	20 - 6 = 14	-
	7	7	14 - 4 = 10	-
	10	10	10 - 9 = 1	-

$$\text{Balancing Efficiency (BE)} = [1 - (\text{SUACT} / \text{CT} * \text{SN})] * 100$$

$$= [1 - (4 / 20 \times 3)] * 100 = 93.33\%$$

Problem: Consider the assembly network shown below which shows the precedence relationships in assembling a product.



Production Management

The number by the side of each node represents the processing time in minutes. The required production volume in 8 hour shift is 24 completed assemblies. Design an assembly line using COMSOAL method.

Details of Work Element

Work Element No.	Time	Immediate Predecessors		
1	5	-	-	-
2	3	1	-	-
3	7	1	-	-
4	5	1	-	-
5	6	3	-	-
6	3	3	4	-
7	4	2	-	-
8	6	5	6	-
9	8	4	-	-
10	9	7	8	9

Iteration I

Details of Station

Station No.	List A	Work Element Selected	Unassigned Cycle Time UACT	Remarks
1	-	-	20	-
	1	1	20 – 5 = 15	No need to use any rule
	2, 3, 4	3	8	Task 3 is selected
	2, 4, 5	5	2	Task 5 is selected
2	-	-	20	-
	2, 4	4	15	Task 4 is selected
	2, 6, 9	9	3	Task 9 is selected
	2, 6	2	0	Task 2 is selected
3	-	-	20	Task 7 is selected
	6, 7	7	16	No need to use any rule
	6	6	13	No need to use any rule
	8	8	7	Change over to next station
4	-	-	20	-
	10	10	11	-

$$\text{Balancing Efficiency (BE)} = [1 - (\text{SUACT} / \text{CT} * \text{SN})] * 100$$

$$= [1 - (20 / 20 \times 4)] * 100 = 75\%$$

Station Details

Station No.	1	2	3	4
Work Element Assigned	1, 3, 5	2, 4, 9	6, 7, 8	10

Iteration II

Details of Station

Station No.	List A	Work Element Selected	Unassigned Cycle Time UACT	Remarks
1	-	-	20	-
	1	1	15	No need to use any rule
	2, 3, 4	3	8	Task 3 is selected
	2, 4, 5	5	2	Task 5 is selected
2	-	-	20	-
	2, 4	4	15	Task 4 is selected
	2, 6, 9	9	3	Task 9 is selected
	2, 6	6	0	Task 6 is selected
3	-	-	20	-
	2, 8	8	14	Task 8 is selected

Production Management

	2 7	2 7	11 7	No need to use any rule Change over to next station
4	- 10	- 10	20 11	- -

$$\text{Balancing Efficiency (BE)} = [1 - (\text{SUACT} / \text{CT} * \text{SN})] * 100$$

$$= [1 - (20 / 20 \times 4)] * 100 = 75\%$$

Station Details

Station No.	1	2	3	4
Work Element Assigned	1, 3, 5	4, 6, 9	2, 7, 8	10

Extra Problems:

Problem 1: Consider the following assembly network relationship of the product. The number of shifts per day is 3 and the number of working hours per shift is 8. The company aims to produce 60 units of the product per day. Group the activities into work stations using RPW method and compute balancing efficiency.

S. No.	Immediate Preceding Task	Duration (Minutes)
1	-	8
2	1	12
3	1	15
4	2	10
5	2	14
6	2	9
7	3	11
8	3	16
9	3	20
10	4, 5	8
11	6, 7	13
12	7, 8, 9	17
13	10, 11	6
14	11, 12	5
15	13, 14	12

(Answer: BE = 81.48%)

Problem 2: Considered the following assembly network relationship of a product. The number of shifts per day is 1 and the number of working hours per shift is 8. The company aims to produce 40 units of the product per shift. Group the activities into work stations using RPW method and compute balancing efficiency.

S. No.	Immediate Preceding Task	Duration (Minutes)
1	-	8
2	1	3
3	1	2
4	1	4
5	1	7
6	3, 7	4
7	2	5
8	4, 5	6
9	2, 6	8
10	6, 8, 9	9
11	5	4
12	9, 10	3
13	8, 10, 11	6
14	12, 13	3

(Answer: BE = 85.71%)

Problem 3: Consider the following assembly network relationship of a product. The number of shifts per day is 2 and the number of working hours per shift is 8 hours. The company aims to produce 80 units of the product per day. Group the activities into work stations using RPW & COMSOL method and compute balancing efficiency.

S. No.	Immediate Preceding Task	Duration (Minutes)
1	-	7
2	1	2
3	1	2
4	1	5
5	2, 3	8
6	3, 4	3
7	5	4
8	5, 6	7
9	4, 6	9
10	7, 8, 9	8

(Answer: RPW: BE = 76.39% & COMSOL: BE = 76.39%)

Problem 4: Assembly line for manufacture of the company considered the precedence diagram of the assembly line is shown below. If the production time volume per shift is 300 units. They require production volume per day in one shift is 28,800 seconds. Design the assembly line using RPW method such that the balancing efficiency is maximized.

S. No.	Immediate Preceding Task	Duration (Seconds)
1	-	15.3
2	1	43.3
3	2	61.4
4	3	65
5	4	57.2
6	5	3.3
7	6	2.2
8	7	4.5
9	8	20.3
10	-	17.5
11	10	9.4
12	11	10
13	12	7
14	-	9
15	13, 14	30
16	15	10.5
17	16	6.3
18	17	25
19	9, 18	94.1
20	19	32.3
21	19	62.5
22	21	10.5
23	20, 22	95.7

(Answer: BE = 85.71%)

QUALITY CONTROL

Those activities which assure that quality creation is performed in such a manner that the resulting product will be, in fact performing its intended function. When used in this sense, quality control can be divided into two fundamental endeavors: assurance that the product characteristics selected will achieve the intended result and assurance that items produced contain the specified characteristics. In a more limited sense, quality control is frequently used to refer to a specific organization within the industrial enterprise which is assigned responsibility for many of the activities necessary to achieve quality objectives. In short, we can say that quality control is a technique of management for achieving required standard of products.

- In any business organization, profit is the ultimate goal. To achieve this, there are several approaches.
- Profit may be maximized by cutting costs for the same selling price per unit.
- If it is a monopolistic business, without giving much of importance to the cost reduction programs, the price may be fixed suitably to earn sufficient profit.
- But, to survive in a competitive business environment, goods and services produced by a firm should have the minimum required quality.
- Extra quality means extra cost. So, the level of quality should be decided in relation to other factors such that the product is well absorbed in the market.
- In all these cases, to have repeated sales and thereby increased sales revenue, no one will deny the fact that the basic quality is considered to be one of the supportive factors.

Quality is a measure of how closely a good or service conforms to specified standard. Quality standards may be any one or a combination of attributes/variables of the product being manufactured. The attributes will include performance, reliability, appearance, commitment to delivery time, etc. Variables may be some measurement variables like, length, width, height, diameter, surface finish, etc. Quality assurance is the system of policies, procedures and guidelines which help in building specified standards of product/service quality.

There is no simple way to define a quality system. In general, a quality system is a part of overhead. The system does not add any value to the products. It only ensures that the product works and meets customer expectations.

A quality system is a process that combines with manufacturing process *to ensure that a manufacturing process produces quality-perfect products*. The scope of a quality system is more than a manufacturing process.

A quality system covers areas related to the suppliers who produce parts for the product. It also covers other departments in the company to ensure that customers are properly informed, trained and serviced whenever problems are presented. Finally, it covers the design department to ensure that products are designed to specifications and they perform as intended.

What Is Quality? Quality may be defined as the sum total of features of a product which influence its ability to satisfy a given demand.

Basically the quality of products and services is not defined or determined by producing firms, it is determined by customers.”The quality of Product or service is a customer’s perception of the degree to which the product or service meets his expectations.

Dimensions of product Quality: Some dimensions of product quality are:

- (1) **Performance:** How will the product service perform and meet the customer’s intended use. For example, the speed of a sports car.
- (2) **Features:** The special characteristics that appeal to customers. For example, the power steering of an automobile.
- (3) **Reliability:** The likelihood of breakdowns, malfunctions, or need fort pianos. Higher the reliability lesser will be the likelihood of breakdowns.

- (4) **Serviceability:** The speed, cost and convenience of repairs and maintenance. Higher the serviceability better will be the quality of the product.
- (5) **Appearance:** The effect on human senses, the look, feel, taste, smell or sound.
- (6) **Customer Service:** The treatment received by customers before, during and after the Sale.
- (7) **Safety:** How well the product protects users before, during and after use.

Objectives: The ultimate aim of quality control is to provide Products which are dependable, satisfactory and economical. A quality control system is designed to ensure economical production of products of uniform quality which is acceptable to the customer.

Quality control aims at preventing the defects rather than detecting the defects.

Benefits of Quality Control

- Minimum scrap or rework due to reduced defectives.
- Reduced cost of labour and material as a result of reduced defectives.
- Uniform quality and reliability of product help in increasing sales turn over.
- Reduced variability resulting in higher quality and reduced production bottle necks.
- Reduced inspection and reduced inspection costs.
- Reduced customer complaints.
- Increased quality consciousness among employees.
- Higher operating efficiency.
- Better utilization of resources.
- Better customer satisfaction and employee satisfaction.

Quality Assurance: Quality assurance is the activity of providing the evidence needed to establish confidence that the quality related activities are being performed effectively. It is defined as “all those planned or systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirement for quality”. Quality assurance encompasses **Quality planning, quality control, quality improvement, quality audit and reliability.**

Organization for Quality Control

Quality control is a staff function concerned with the prevention of defects in manufacturing so that items may be made right at the first time and not to be rejected later. In order to achieve this end, several activities to be performed. There must be inspection and control of incoming raw materials to ensure that they meet specification there must be planning and control of manufacturing processes to ensure that suitable methods are being used and that machines and equipment are performing satisfactorily there must be in process inspection and testing for product performance. In pursuance of these activities, several techniques must be employed.

In order to carry on these functions a separate department is created which is called Quality control department or simply, department of quality. The person who heads this department carries the title of manager of quality control, assurance or chief inspector. The level quality control in an organization is influenced by several factors, namely, the quality level of significance thus each company must establish a type of organization which best fulfils its needs. Frequently, the quality control department is composed of a quality engineering function, an inspection function, and a laboratory function. It should be stated that quality control is not the responsibility of only the personnel in the quality control department. Everybody in the organization must be equally responsible to ensure quality of the end product.

Quality involves the members of management who set the quality policies, the salesmen who contract to sell products of a certain quality, the design engineers who set the product specifications, the buyers who purchase raw materials of the right quality and the manufacturing personnel who are responsible for making product according to the prescribed specification. It is only through the whole heated cooperation of all the people that a sustained quality control programme can be maintained.

Ensuring Quality

Ensuring Quality involves action on several fronts. To be specific, quality control involves the following steps:

A. Control of Engineering Quality

- Assist in the evaluation of customer requirements to arrive at a clear understanding of the product quality objectives.
- Review design documentation for conformance to design standards and practice and for identification of potential quality problems.
- Validate the accuracy and completeness of design proof tests and qualification tests.
- Audit the release and distribution of design documents to assure that all drawings and specifications in use are current and correct.
- Provide information on previous quality problems encountered for consideration in new product designs or current product improvements.

B. Control of Purchased Material Quality

- Assist in the evaluation and selection of potential suppliers or subcontractors.
- Review purchase orders and subcontractors for correctness and completeness of quality requirements.
- Assure that purchased material conforms to the requirements of purchase orders and specifications.
- Initiate corrective action with suppliers and subcontractors when purchased material is not of an acceptable quality level.

C. Control of Manufacturing Quality

- Evaluate and approve manufacturing equipment, processes, testing, and test equipment.
- Assure that measuring and test equipment is properly calibrated and maintained.
- Establish points of inspection and tests at selected points in the production processes.
- Perform inspection and tests at selected points in the production processes.
- Collect and analyze inspection and test data and provide information on process and product quality levels.
- Initiate corrective action on out of control conditions and related quality problems.
- Conduct follow up to assure that corrective action is accomplished in a timely manner.
- Control the handling, preservation, and packaging of material and equipment from receipt through shipment of the final product.

D. Action Supporting the Product after Delivery

- Assure that product service specifications are clear and correct.
- Assure that spare parts conform to quality requirements.
- Assure that repair and modification are performed in accordance with company quality requirements.
- Gather and analyze complaint data from the field to measure the degree of customer satisfaction and initiate appropriate corrective action.

NEED FOR QUALITY CONTROL

In the absence of quality, the following will result:

- (a) No yardstick for comparing the quality of goods/services.
- (b) Difficulty in maintaining consistency in quality.
- (c) Dissatisfied customers due to increased maintenance and operating costs of products/ services.
- (d) Increased rework cost while manufacturing products/providing services.
- (e) Reduced life time of the products/services.
- (f) Reduced flexibility with respect to usage of standard spare parts.

Hence, controlling quality is an essential activity.

OBJECTIVES OF QUALITY CONTROL

- To make the company's product more acceptable by the customer and thereby increase the sales of the company.
- To reduce cost of production by proper control of outgoing products by reducing the defects.
- To maintain quality of products by taking necessary corrective measures.
- To develop quality consciousness in the organization.
- To ensure that sub-standard products do not reach the customers.

The basic components of product quality are listed below:

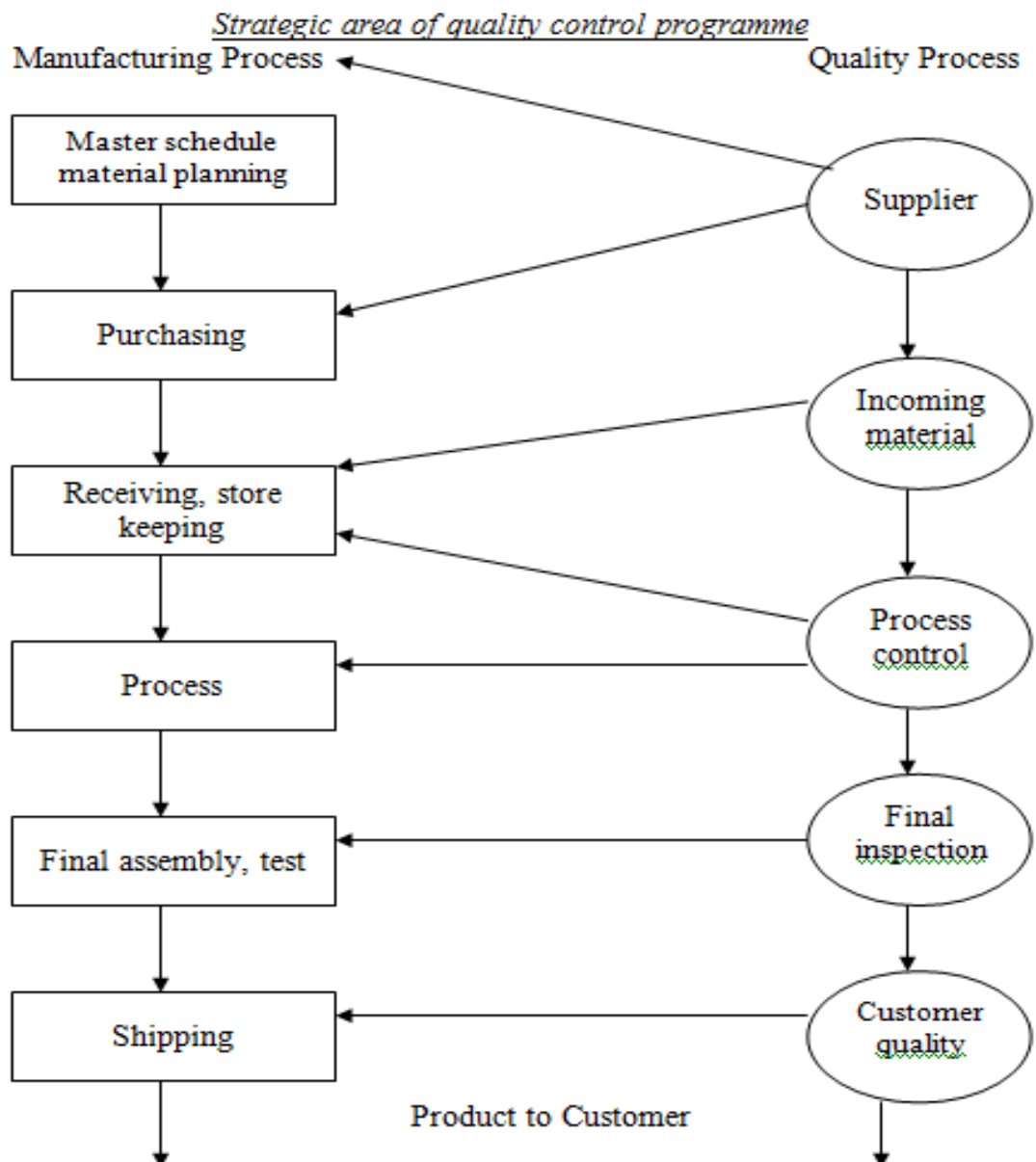
- Careful consideration of product design specifications.
- Adequate inspection procedures for manufactured or assembled products.
- Acceptance procedures for purchased raw materials and parts, and control practices to maintain quality levels in in-process stage.
- Commitment from top management, lower levels of management and supervisors towards quality.
- Formulation for quality assurance procedures which are necessary to integrate and coordinate all these functions

STRATEGIC AREA OF QUALITY CONTROL PROGRAMME

Strategic areas of quality control program in manufacturing are as follows:

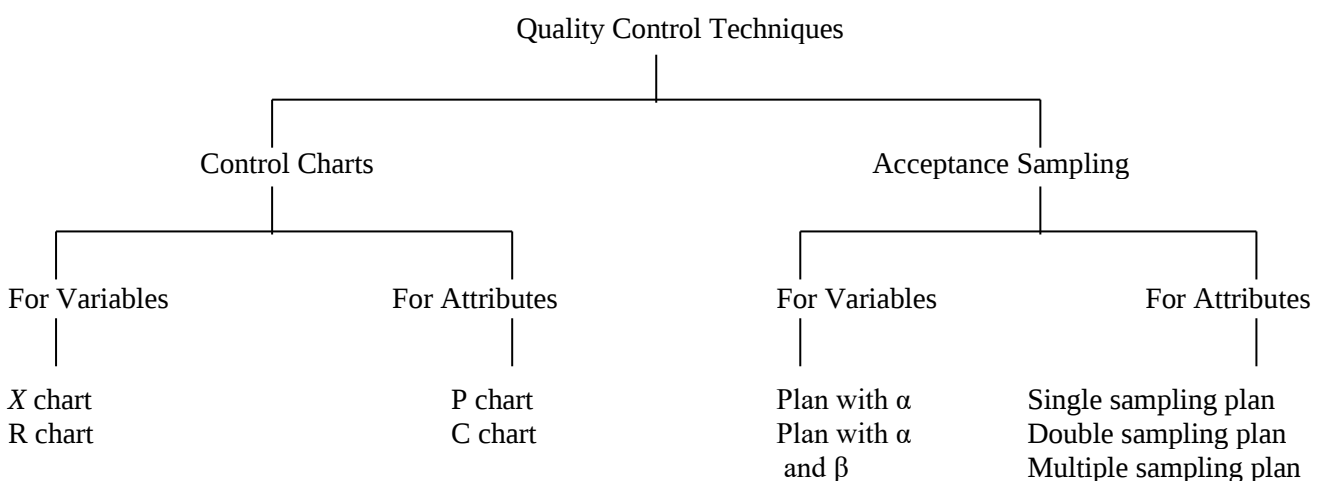
- | | |
|---------------------|-----------------------------------|
| 1) Supplier quality | 2) Incoming raw materials quality |
| 3) Process quality | 4) Final Inspection |
| 5) Customer quality | |

Statistical quality control deals with decisions related to the functions of specification, production or inspection.



CLASSIFICATION OF QUALITY CONTROL TECHNIQUES

The quality control techniques can be classified as shown below:



CONTROL CHARTS

It is very simple but powerful graphic method of finding if a process is in statistical control or not. The chart contains 3 horizontal lines viz.

1. Control line to indicate the process control level
2. An upper control limit (UCL) – upper limit of tolerance
3. A lower control limit (LCL) – lower limit of tolerance.

Control chart has a central line which indicates the desired average quality level of the product. The two lines, one above and one below this line are called the upper and the lower control limits, respectively. These limits are established to assist in judging the significance of the variation in the quality of the product. It may be noted that the control limits are different from the specification limits. Whereas the specification limits refer to the quality characteristic of an individual unit of the product, the control limits are used to evaluate the variation in quality from sample to sample.

ACCEPTANCE SAMPLING

The objective of acceptance sampling is to take decision whether to accept or reject a lot based on sample's characteristics. The lot may be incoming raw materials or finished parts. An accurate method to check the quality of lots is to do 100% inspection. But, 100% inspection will have the following limitations.

- The cost of inspection is high.
- Destructive methods of testing will result in 100% spoilage of the parts.
- Time taken for inspection will be too long.
- When the population is large or infinite, it would be impossible or impracticable to inspect each unit.

Hence, acceptance sampling procedure has lot of scope in practical application. Acceptance sampling can be used for attributes as well as variables.

Acceptance sampling deals with accept or reject situation of the incoming raw materials and finished goods. Let the size of the incoming lot be N and the size of the sample drawn be n . The probability of getting a given number of defective/good parts out of a sample consisting of n pieces will follow Binomial Distribution. If the lot size is infinite or very large, such that when a sample is drawn from it and not replace, then the usage of binomial distribution is justified. Otherwise, we will have to use hyper-geometric distribution.

Specifications of a single sampling plan will contain a sample size (n) and an acceptance number C . As an example, if we assume the sample size as 50 and the acceptance number as 3, the interpretation of the plan is explained as follows: Select a sample of size 50 from a lot and obtain the number of defective pieces in the sample. If the number of defective pieces is less than or equal to 3, then accept the whole lot from which the sample is drawn. Otherwise, reject the whole lot. This is called single sampling plan. There are several variations of this plan.

In this process, one will commit two types of error, viz. Type I error and Type II error. If the lot is really good, but based on the sample information, it is rejected, and then the supplier/producer will be penalized. This is called producer's risk or Type I error. The notation for this error is α . On the other hand, if the lot is really bad, but it is accepted based on the sample information, then the customer will be at loss. This is called consumer's risk or Type II error. The notation for this error is β . So, both parties should jointly decide about the levels of producer's risk (α) and consumer's risk (β) based on mutual agreement.

TOTAL QUALITY CONTROL (TQC)

It is quality control and improvement from shop floors to board rooms. It is an effective system for integrating quality development, quality maintenance and quality improvement efforts of various groups in an organizations.

What is Total Quality Management (TQM)

A philosophy that involves everyone in an organization in a continual effort to improve quality and achieve customer satisfaction.

Six Basic Concepts in TQM

1. Top management commitment and support.
2. Focus on both internal and external customers.
3. Employee involvement and empowerment.
4. Continuous improvement (KAIZEN)
5. Partnership with suppliers
6. Establishing performance measures for processes

8 Essentials of TQM Focus

1. Customer satisfaction
2. Leadership
3. Quality policy
4. Organization structure
5. Employee involvement
6. Quality costs
7. Supplier selection and development
8. Recognition and reward

Seven Underlying Principles in TQM

1. Strive for quality in all things
2. The customer is the creation of quality
3. Improve the process or systems by which products are produced
4. Quality improvement is continuous, never ending activity
5. Worker involvement is essential
6. Ground decisions and actions on knowledge
7. Encourage teamwork and cooperation

Scope of TQM

- Are integrated organizational infrastructure
- A set of management practices
- A wide variety of tools and techniques

Deming's 14 Points for Quality Management

W. Edwards Deming is an USA statistician & consultant known as father of quality control.

1. Create constancy of purpose for continual improvement of product/services
2. Adopt the new policy for economic stability
3. Cease dependency on inspection to achieve quality
4. End the practice of awarding business on price tag alone
5. Improve constantly and forever the system of production and service
6. Institute training on the job

7. Adopt and institute modern method of supervision and leadership
8. Drive out fear
9. Breakdown barriers between departments and individuals
10. Eliminate the use of slogans, posters and exhortations
11. Eliminate work standards and numerical quotas
12. Remove barriers that rob the hourly worker of the right to pride in workmanship
13. Institute a vigorous program of education and retraining
14. Define top management's permanent commitment to ever improving quality and productivity

Deming Wheel / Deming Cycle / P-D-C-A Cycle

- P – Plan (process) the improvement
- D – Do implement the plan
- C – Check-Check how closely result meets goals
- A – Act-Use the improved process as standard practice

ISO CERTIFICATION

ISO is the International Organization for Standardization, set up with the objective to promote the development of standards and related activities, for facilitating international exchange of goods and services.

It is mechanism by which customer can have confidence in a company and is most effective when carried out by a national certification body. The ISO certification is application to quality management system encompassing quality in all functions such as marketing design, purchase, manufacture, assembly testing, packing, shipping, installations, after sales service and all other activities of an organization. A properly established quality management system will help to reduce cost, improve quality, and develop confidence and a good image in the minds of customers and public. This requires consistent implementation, careful auditing and total commitment of the whole organization.

CHARACTERISTICS OF ISO

1. ISO 9000 is the only available internationally accepted standard for quality management system.
2. It does not replace but complements the product standards.
3. ISO 9000 is applicable to all types of industries or organization in manufacturing or service sector.
4. It stands for systematic standardization and certification rather than product standardization and certification.
5. ISO 9000 is a documentation oriented system which allows complete freedom on selection and use of processes and framing of operating procedures and work instruction.
6. A mistake made in selection of proper product standard can never be compensated by ISO 9000 implementation.

ISO 9000: ISO 9000 series of standards developed in 1987, relate to quality systems. It has evolved from the standardization of quality policy assurance system standards of several nations all over the world. The standards allow a wide flexibility, but at the same time, are rigid too. They permit a supplier to formulate his own quality policy and write the quality manual, producers and instructions in his own way, within the framework of the system elements, but does not allow rendering on non-conforming products or services.

CHARACTERISTICS OF ISO 9000

1. ISO 9000 can be implemented in any type and size of organization.
2. It is independent of the product, size and country.
3. It has international acceptance and recognition.
4. It ensures consistent improvement in quality.

DIFFERENT AREAS IN ISO 9000 SERIES

There are five standards in the ISO 9000 series Viz. ISO 9000, ISO 9001, ISO 9002, ISO 9003 and ISO 9004. ISO 9000, 9001, 9002 & 9003 are applicable to contractual situation.

ISO 9004 is for non-contractual cases and is used for internal management purpose.

1. ISO 9000 provides the guidelines for selection and use of the quality standards.
2. ISO 9001 is a quality system model for quality assurance in design/development, production, installation and servicing. This is most exhaustive standard. The engineering organizations, where the manufacturing capabilities are based on in-house designs have to work for ISO 9001 certification manufacturing of
 - i) Household goods like TV, refrigerator etc,
 - ii) Perishable consumer goods like toothpaste etc., which have both servicing and design/development, have to work towards ISO 9001.
3. ISO 9002 provides a model for quality assurance only in production and installation. This does not cover areas of design or development and servicing. ISO 9002 also looks at internal quality audits, steel plants, department stores, hospitals, chemical plants etc., where the designing and servicing do not constitute the key activities, may prefer ISO 9002.
4. ISO 9003 deals only with quality systems related to final inspection and testing.
5. ISO 9004 provides guidelines for quality management and quality system elements.

In addition to the ISO 9000 series, ISO 8402 deals with vocabulary used in the ISO 9000 series.

ADVANTAGES OF ISO STANDARDS

ISO standards give tremendous advantages to those holding their certification. Some of these advantages are briefly discussed below for different categories of groups or institutions.

1. For Users

- a) Confidence in quality and reliability of product and services received
- b) Economy and competitive prices
- c) Assured after sales services
- d) Traceability of manufacturer, design and specification

2. For Suppliers

- a) Easy vendor identification
- b) Rationalization of component product based on international standard/specification.
- c) Simplified controls for long-range contracts
- d) Availability of a worldwide on-line database called CODUS

3. For Manufacturers

- a) Rationalization of product range
- b) No huge investment of Inward Goods Inspection (IGI) departments
- c) No need to have separate vendor identification/development/evaluation process
- d) No multiple agency certification of quality
- e) Cost reduction due to reduced reward and scraps

4. For Marketing

- a) Global Visibility
- b) Provide national/international reputation
- c) Competitiveness
- d) Assured international quality level

UNIT – IV

MATERIALS MANAGEMENT AND INVENTORY CONTROL

INTEGRATED MATERIALS MANAGEMENT

- ✓ As mentioned earlier, the main activity of production system is to convert raw materials into useful products by value addition process.
- ✓ If we closely examine the various elements of *prime cost*, *materials cost would dominate other costs*.
- ✓ The materials, which are required for the production purposes are normally, procure and stored in raw materials warehouses and then they are shifted to manufacturing plants if an organization has a number of plants.
- ✓ The raw materials are to be *purchased in advance and stocked stores mainly to smoothen the production process*.
- ✓ Each functional head of materials department will try to optimize the operation of his own function.
- ✓ But, all of them should aim for a common goal of providing materials with minimum total cost (cost of carrying, ordering cost, purchase cost, etc.) for better functioning of the organization.

For example, let us assume that the purchasing function plans to buy huge quantity of raw materials, just to exploit seasonal availability of the material. If the rent paid on the storage is abnormal in a place like Mumbai, then the purchasing function and the stores function will have conflicting objectives. This can be resolved if a proper trade-off analysis is done by taking the objectives together. This is possible if these two functions are integrated together. This is only a small example involving two functions. In reality, all the functions of materials management are to be integrated.

The different functions of materials management are:

- Materials planning
- Purchasing
- Receiving
- Stores
- Inventory control
- Scrap and Surplus disposal.

If these systems are designed to function independently, there won't be close coordination among them. But we need complete integration of these functions for better operation of the system.

The integrated materials management will result in the following advantages:

- Better accountability.
- Better coordination.
- Better performance.
- Adaptability to computerized systems.

COMPONENTS OF INTEGRATED MATERIALS MANAGEMENT

The components of the integrated materials management can be classified into the following modules.

1. Materials planning
2. Inventory Control
3. Purchase Management
4. Stores Management

1. Materials Planning

Sales forecasting and aggregate planning are the basic inputs for materials planning. The different tasks under planning are listed below:

- Estimating the individual requirements of parts
- Preparing materials budget
- Forecasting the levels of inventories
- Scheduling the orders and
- Monitoring the performance in relation to production and sales.

2. Inventory Control

This includes the following:

- ABC analysis
- Fixing economical order quantity
- Lead time analysis
- Setting safety stock and reorder level

3. Purchase Management

The tasks under purchasing are listed below:

- Evaluating and rating suppliers
- Selection of suppliers
- Finalization of terms of purchase
- Placement of purchase orders.
- Follow-up.
- Approval of payments to suppliers.

4. Stores Management

The different tasks under stores are listed below:

- Physical control of materials
- Preservation of obsolescence and damage through handling
- Disposal and efficient handling
- Maintenance of stores records
- Proper location and stocking of materials
- Reconciling the materials with book figures.

INVENTORY CONTROL

Inventory is essential to provide flexibility in operating a system. The inventory can be classified into:

Raw materials inventory remove dependency between suppliers and plants.

In-process inventory remove dependency between machines of a product line.

Finished goods inventory remove dependency between plant and its customers/market.

The main functions of inventory are summarized below.

- Smoothing out irregularities in supply
- Minimizing the production cost
- Allowing organizations to cope with perishable materials

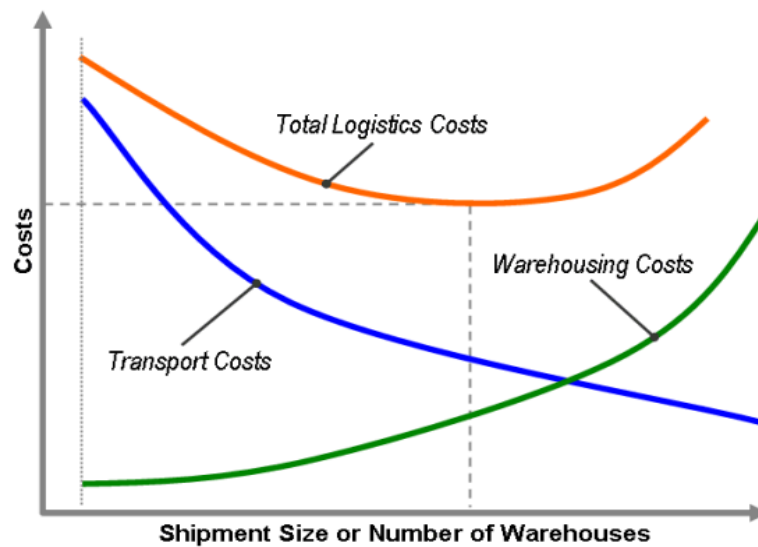
Inventory Decisions

Managers generally take the following two basic inventory decisions.

1. When to replenish the inventory of that item.
2. How much of an item to order when the inventory of that item is to be replenished.

Costs Trade-off

If the order quantity is less, the cost of order will be more, but the inventory carrying cost will be less. On the other hand, if the order quantity is more, the ordering cost will be less, but the carrying cost will be more.



Total cost curve represents the sum of ordering cost and carrying cost for each order size. The order size at which the total cost is minimum, called Economic Order Quantity (EOQ) or Q^* (optimal order size).

MODELS OF INVENTORY

There are different models of inventory.

- Purchase model with instantaneous replenishment and without shortages
- Manufacturing model without shortages.
- Purchase model with instantaneous replenishment and with shortages
- Manufacturing model with shortages.

1. Purchase Model with Instantaneous Replenishment and without Shortages

In this model of inventory, orders of equal size are placed at periodical intervals. The items against an order are replenished instantaneously and the items are consumed at a constant rate. The purchase price per unit is the same irrespective of order size.

Let, D = the annual demand in units.

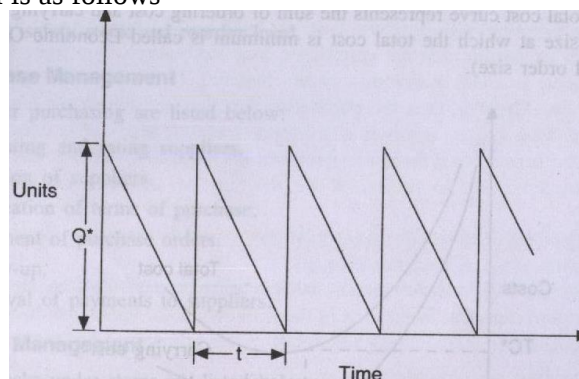
C_c = the carrying cost/unit/year

Q = the order size

C_o = the ordering cost/order

P = the purchase price per unit

Then, the corresponding model is as follows



Purchase Model Without Shortages

Therefore,

$$\text{The number of orders/year} = \frac{D}{Q}$$

$$\text{Average inventory} = \frac{Q}{2}$$

$$\text{Cost of ordering/year} = \frac{D}{Q} \times C_o$$

$$\text{Cost of carrying/year} = \frac{Q}{2} \times C_c$$

$$\text{Purchase cost/year} = D \times P$$

$$\text{The total inventory cost (TC)/year} = \frac{D}{Q} \times C_o + \frac{Q}{2} \times C_c + D \times P$$

Differentiating w.r.t Q yields

$$\frac{d(TC)}{dQ} = \frac{-D}{Q^2} C_o + \frac{C_c}{2}$$

$$\text{The second derivative} = \frac{+2D}{Q^3} C_o$$

Since the second derivative is positive, we can equate the first derivative to zero to get the optimal value for Q.

$$\frac{-D}{Q^2} C_o + \frac{C_c}{2} = 0$$

$$Q^2 = \frac{2C_o D}{C_c}$$

$$Q^* = \sqrt{\frac{2C_o D}{C_c}}$$

$$\text{Number of orders} = \frac{D}{Q^*}$$

$$\text{Time between orders} = \frac{Q^*}{D}$$

Problem 1: Alpha industry estimates that it will sell 12,000 units of its product for the forthcoming year. The ordering cost is Rs. 100 per order and the carrying cost per unit per year is 20% of the purchase price per unit. The purchase price per unit is Rs. 50.

Find, (a) Economic Order Quantity (EOQ)

(b) No. of orders per year

(c) Time between successive orders

Problem 2: Beta industry estimates that it will sell 15,000 units of its product for the forthcoming year. The ordering cost is Rs. 125 per order and the carrying cost per unit per year is 20% of the purchase price per unit. The purchase price per unit is Rs. 75.

Find, (a) Economic Order Quantity (EOQ)

(b) No. of orders per year

(c) Time between successive orders

Problem 3: Ram Industry needs 5400 units/year of a bought out component, which will be used in its main product. The ordering cost is Rs. 250 per order and the carrying cost per unit per year is Rs. 30.

Find, (a) Economic Order Quantity (EOQ)

(b) No. of orders per year

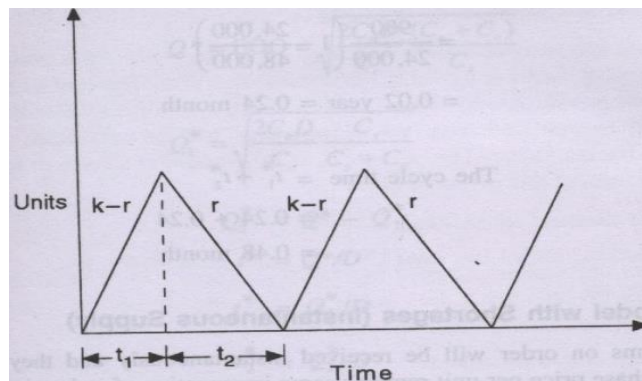
(c) Time between successive orders

2. Manufacturing Model without Shortages

If a company manufactures its components which is required for its main product, then the corresponding model of inventory is called “*Manufacturing model*”.

This model will be with shortages or without shortages. The rate of consumption of items is uniform throughout the year. The cost of production per unit is same irrespective of production lot size.

Let, r = the annual demand of an item k = the production rate of the item
 C_0 = the cost per set up C_c = the carrying cost/unit/period
 p = the cost of production per unit EBQ = Economic Batch Quantity



Manufacturing Model Without Shortages

During the period t_1 , the item is produced at the rate of k units per period and simultaneously it is consumed at the rate of r units per period. So, during this period, the inventory is built at the rate of $k - r$ units per period. During the period t_2 , the production of the item is discontinued but the consumption of that item is continued. Hence, the inventory is decreased at the rate of r units per period during this period. The operation of the manufacturing model without shortages is shown below.

The various formulas for this situation are given below:

$$EBQ = \sqrt{\frac{2C_0r}{C_c(1 - r/k)}}$$

$$t_1^* = Q^*/k$$

$$t_2^* = [Q^*(1 - r/k)]/r$$

$$\text{Cycle time} = t_1^* + t_2^*$$

Problem 1: If a product is to be manufactured within the company, the details are as follows:

$R = 24,000$ units/year

$k = 48,000$ units/year

$C_0 = \text{Rs. } 200$ per set-up

$C_c = \text{Rs. } 20$ /unit/year

Find the EBQ and cycle time.

Problem 2: An automobile factory manufactures a particular type of gear within the factory. This gear is used in the final assembly. The particulars of this gear are presented below:

Demand rate = $14,000$ units/year

Production rate = $35,000$ units/year

Set-up cost = $\text{Rs. } 500$ per set-up

Carrying cost = $\text{Rs. } 15$ /unit/year

Find the EBQ and cycle time.

Problem 3: A product is to be manufactured within the company, the details of which are as follows:

$r = 36,000$ units/year

$k = 72,000$ units/year

$C_0 = \text{Rs. } 250$ per set-up

$C_c = \text{Rs. } 25$ /unit/year

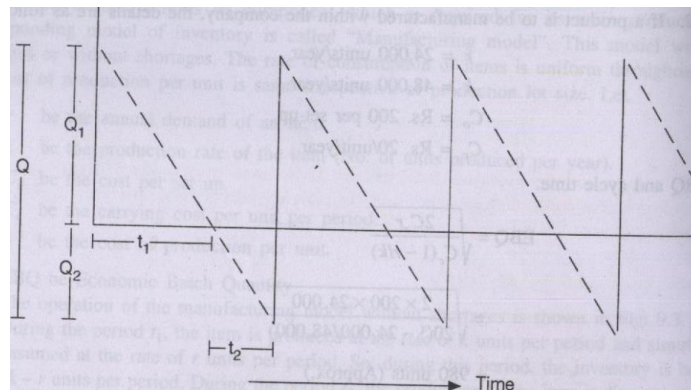
Find the EBQ and cycle time.

3. Purchase Model with Shortages (Instantaneous Supply)

In this model, the items on order will be received instantaneously and they are consumed at a constant rate. The purchase price per unit remains same irrespective of order size. If there is no stock at the time of receiving a request for the items, it is assumed that it will be satisfied at a later date with a penalty. This is called backordering.

The variables which are used in this model are given below:

- D = Demand/period
- C_o = Ordering cost/order
- C_c = Carrying cost/unit/period
- C_s = Shortage cost/unit/period



Purchase Model With Shortages

In the above model,

- Q represents Economic order quantity,
- Q_1 , Maximum inventory, and
- Q_2 , Maximum stockout

$$EOQ = Q^* = \sqrt{\frac{2C_o D}{C_c} \times \frac{C_s}{C_s + C_c}}$$

$$Q_1^* = \sqrt{\frac{2C_o D}{C_c} \times \frac{C_s}{C_s + C_c}}$$

$$Q_2^* = Q^* - Q_1^*$$

$$t^* = Q^*/D$$

$$t_1^* = Q_1^*/D$$

$$t_2^* = Q_2^*/D$$

Problem 1: The annual demand for an automobile component is 24,000 units. The carrying cost is Re. 0.40/unit/year, the ordering cost is Rs. 20.00 per order and the shortage cost is Rs. 10.00/unit/year. Find the optimal values of the following:

1. Economic Ordering Quantity
2. Maximum inventory
3. Maximum shortage quantity
4. Cycle time
5. Inventory period (t_1)
6. Shortage period (t_2)

Problem 2: The annual demand for a component is 7200 units. The carrying cost is Rs. 500/unit/year, the ordering cost is Rs. 1500 per order and the shortage cost is Rs. 2000/unit/year. Find the optimal values of the following.

1. Economic Ordering Quantity
2. Maximum inventory
3. Maximum shortage quantity
4. Cycle time
5. Inventory period (t_1)
6. Shortage period (t_2)

Problem 3: The annual demand for an automobile component is 36,000 units. The carrying cost is Rs. 0.50/unit/year, the ordering cost is Rs. 25.00 per order and the shortage cost is Rs. 15.00/unit/year. Find the optimal values of the following.

1. Economic Ordering Quantity
2. Maximum inventory
3. Maximum shortage quantity
4. Cycle time
5. Inventory period (t_1)
6. Shortage period (t_2)

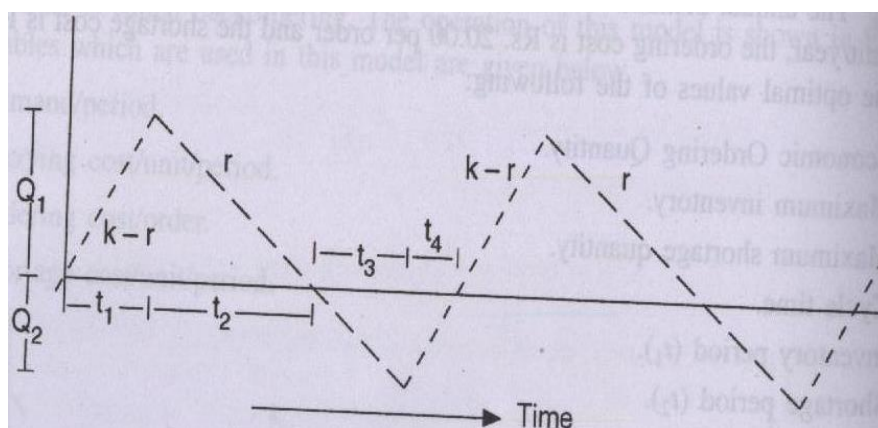
4. Manufacturing Model with Shortages

In this model, the items are produced and consumed simultaneously for a portion of the cycle time. The rate of consumption of items is uniform throughout the year. The cost of production per unit is the same irrespective of production lot size. In this model, stockout is permitted. It is assumed that the stockout units will be satisfied from the units which will be produced at a later date with a penalty. This is called backordering.

The variables which are used in this model are:

r = the annual demand of an item
 C_0 = the cost/set up
 C_s = the shortage cost/unit/period
EBQ = Economic Batch Quantity

k = the production rate of the item
 C_c = the carrying cost/unit/period
 p = the cost of production per unit



Manufacturing Model With Shortages

In the above model,

Q = Economic Batch Quantity
 Q_1 = Maximum inventory
 Q_2 = Maximum stockout

$$EBQ = Q^* = \sqrt{\frac{2C_o}{C_c} \times \frac{kr}{(k-r)} \times \frac{C_c + C_s}{C_s}}$$

$$Q_1^* = \sqrt{\frac{2C_o}{C_c} \times \frac{C_s}{C_s + C_c} \times \frac{r(k-r)}{k}}$$

$$Q_2^* = \sqrt{\frac{2C_o C_c}{C_s (C_c + C_s)} \times \frac{r(k-r)}{k}}$$

$$t^* = Q^*/r \quad t_1^* = Q_1^* / (k - r) \quad t_2^* = Q_1^*/r \quad t_3^* = Q_2^*/r \quad t_4^* = Q_2^* / (k - r)$$

Problem 1: The demand for an item is 18000 per year. Its production rate is 3000 per month. The carrying cost is Re. 0.15/unit/month and the set-up cost is Rs. 500 per set-up. The shortage cost is Rs. 20 per unit per year. Find the various parameters of the inventory system.

Problem 2: The demand for an item is 6000 per year. Its production rate is 1000 per month. The carrying cost is Rs. 50/unit/year and the set-up cost is Rs. 2000 per set-up. The shortage cost is Rs. 1000 per unit per year. Find various parameters of the inventory system.

Problem 3: The demand for an item is 24,000 per year. Its production rate is 4000 per month. The carrying cost is Rs. 0.25/unit/year and the set-up cost is Rs. 800 per set-up. The shortage cost is Rs. 15 per unit per year. Find various parameters of the inventory system.

PURCHASING MANAGEMENT

The objective of the purchasing function is to ensure continuity of supply of raw materials, subcontracted items and spare parts and at the same time reduce the ultimate cost of the finished goods. The different parameters of purchasing are as listed below:

- Purchasing items with right price.
- Purchasing items with right quality.
- Purchasing items at right time so that the items are available when needed.
- Purchasing items from right source. Here, the dependability of the vendors is estimated using vendor rating. The location of vendors, nature of items, mode of transportation, vendor's commitments to due dates, etc. should be taken into account.
- Purchasing items of right quantity. Generally, there is a trade-off between cost of ordering and cost of carrying inventory. Hence, orders should be placed with optimal quantity.

PURCHASE SYSTEMS

The purchase system may be classified into Pre-Purchase System, Ordering System and Post-Purchase System.

1. Pre-purchase system. This includes making requisitions, requirement programmes, selection of suppliers, obtain quotations and evaluating them.

2. Ordering system. Once the decision on supplier and the rates are finalized, the order is placed with the selected supplier. The next task is to place order. The details of order form are listed as

- Purchase order reference number.
- Description of the materials and detailed specifications.
- Quantity required and delivery schedule
- Price and discounts.
- Shipping instructions.

- Location where the materials are to be shipped.
- Signature of the materials manager.
- Detailed terms of conditions.

3. Post purchase system. The activities which are included under this system are follow-up procedure, receipt and checking invoices.

Whenever an order is placed, it should be continuously monitored. The whole system operates under probabilistic environment. Though orders are placed based on demand and lead time, these are subjected to variation.

SPECIAL PURCHASE SYSTEMS

The following are some special purchase systems.

1. **Forward Buying:** In Forward Buying, the purchasing decision for a period (say 1 year) will be taken in advance and the organization will commit accordingly in terms of order quantity, rate and delivery schedule, by taking into consideration the availability of funds and the requirements. Generally, this is used for public buying to avoid favoritism to a specific vendor.
2. **Tender Buying:** In Tender Buying the steps are: preparing bidder's list, advertising tenders, receiving bids, evaluating bids and placing order with the bidder with the lowest cost.
3. **Blanket Order:** In Blanket Ordering system, the organization will enter into an agreement with its supplies to receive items for a required quantity at a particular rate over a period of time.
4. **Zero Stock:** Zero Stock purchase system is in-line with using the just-in-time manufacturing system. The main idea of this system is to operate the plant with near zero inventories. If the suppliers are situated nearer to the company, they are more reliable in terms of making supply in time. The company can place orders with such suppliers.
5. **Rate Contract:** Rate Contract is very much used in public sectors and government departments. The suppliers are on 'rate contract' with DGS&D for a specific period. The organizations can place orders straightaway with such firms without going through the lengthy procedure of purchasing.

ASPECTS OF PURCHASE MANAGEMENT

The different aspects of purchasing management are as follows:

1. Price forecasting
2. Purchasing of capital equipments
3. International purchasing
4. Public buying

Price forecasting: Forecasting is nothing but prediction of a future event. In Materials Management, predicting the prices of materials is of utmost importance. The precise prediction of prices would help us in buying the materials in right time and of right quantity. The different methods which are used for price forecasting are as follows:

- ✓ Charting Method
- ✓ Moving Average Method
- ✓ Regression Method
- ✓ Exponential Smoothing Method

Purchasing of capital equipments: All machineries and equipments which are used in value addition process are termed as capital equipments. The frequency of purchase of these equipment is very less, may be once in five years or ten years. While comparing different alternatives, one can use any one of the following approaches to select the best alternative:

- ✓ Payback Period Method
- ✓ Rate of Return Method
- ✓ Present Worth Method
- ✓ Annual Equivalent Method
- ✓ Future worth Method

The various options to satisfy the demand for capital equipment are listed below:

- ✓ Purchase of new equipment
- ✓ Purchase of used equipment
- ✓ Leasing

For the purchase of new equipments, any one of the methods which are mentioned above may be used to judge each alternative. Then the best alternative is to be selected

International purchasing: In view of the growing global economy, many countries are importing major raw materials, sub assemblies which are available elsewhere at a cheaper rate at the same time the total cost of procurement is cheaper when compared to indigenous production/supply of the same.

Procedure in international purchasing: If a company is planning to import an item, first it should find out whether such item is allowed to be imported. This is done by contacting the Ministry of trade, foreign consulates and embassies, Indian consulates in foreign countries, etc. In this process, the importer will be using some special documents like, *bill of lading, invoices, and certificates of origin, weight certificates, insurance policy and markings of packages.*

Public buying: Many organizations are duplicating the same task of purchasing even though the specifications of the materials are the same. Whenever, an order is to be placed, there is a minimum lead time involved to get the items in addition to the minimum time required to source a supplier. These will certainly introduce delay in the purchase of materials and also adds a significant cost to the total cost of purchasing. Hence, a centralized buying concept was promoted to satisfy the demand of the following organizations through Directorate General of Supplies and Disposals (DGS&D) which is the central purchasing organization of Government of India.

- Defence organizations
- Railway departments
- Post and Telegraph departments
- State governments
- Public sector enterprises
- Quasi-public bodies

Any proposal for the purchase of materials from abroad is to be scrutinized by the DGS&D. The other activities of the DGS&D are as follows:

1. It inspects stores purchased by government departments and other bodies if they need its services.
2. It performs laboratory testing and analysis of stores on behalf of government departments.
3. It makes arrangement for shipment of stores exported and clearance of stores imported.
4. It undertakes the responsibility of disposal of surpluses declared by the central government departments and the state government departments.

STORES MANAGEMENT

The purchased materials are to be stored in stores/warehouses and issued for production as and when they are required. As already stated, store contains inventory mainly to provide uninterrupted supply of materials to the production divisions. So, stores play a vital role in the operation of any production system. The functions of stores are as follows:

1. It receives raw materials, tools, equipments and other necessary materials and accounts them.
2. It makes arrangement to store and preserve the items in good conditions for later use.
3. It maintains a proper account on issue of items on demand from shop floor/production division.
4. It maintains a classification and codification system to minimize obsolescence, surplus and scrap of items.
5. It provides information reports to support purchase activities to take place at right times.

An efficient store layout would assist proper stocking of raw materials and items and also quick retrieval of items at the time of issue. Nowadays, the stocking of items and issue of items in stores are done by 'pick and place' robot. They even take the items from the store and deliver them in the demanding work stations of the factory. It is also highly essential to follow all safety measures in the stores mainly to avoid accident.

Once the items are cleared from the receiving section, a Provisional Goods Inward Notes (PGI) is prepared and it is sent along with the materials to the Inspection Section. The different systems in stores are as listed below.

- Receipt system
- Stocking system
- Issue system.

At the time of receiving the items at the stores, necessary arrangement should be made to check the quality, quantity and weight of the items before they are accepted for stocking in the stores. There should be a proper system for maintaining accounts of issues made to internal divisions or external divisions.

STORES ACCOUNTING

The product cost consists of materials costs, labour costs and machine hour costs. Stores accounting is very much useful in determining the materials cost of a product. The different elements of cost of the material received are material price, freight charges, insurance and taxes.

The issues of the stores are accounted using any one of the following methods:

1. First in First Out (FIFO) method
2. Last in First Out (LIFO) method
3. Average Cost method
4. Standard Cost method
5. Market Price method

1. **First in First Out (FIFO) method:** The assumption is that the old stock is depleted first. This means that the rate pertaining to that will be applied while accounting issues.
2. **Last in First Out (LIFO) method:** The assumption is that the most recent receipts are issued first.
3. **Average Cost method:** The issues to the production department are divided into equal batches from each shipment at stock.
4. **Standard Cost method:** A standard rate for the material is fixed based on the detailed analysis of market prices. This cost would be used for a fixed period, say six months or above.
5. **Market Price method:** The prevailing market rate of the material is applied for costing the material at the time of issue.

OBSOLETE SURPLUS AND SCRAP MANAGEMENT

The materials and parts which are used in industries for carrying out production activity become obsolete because of so many reasons. This in turn results in surplus and scrap. The following are the main reasons for accumulation of obsolete, surplus and scrap items:

1. Change in product design;
2. Rationalization of raw materials so as to minimize variety and simplify procurement procedure;
3. Cannibalization: This is due to the usage of components of failed machineries which are not in operation for a long time, in order to rectify some of the similar machineries which are actively used in production process. This will make the old machineries obsolete after some time because of missing components.
4. Faulty planning, over estimation of demand and wrong indenting are some of the main reasons.
5. Faulty purchase procedure, just to avail quantity discount, seasonal availability, some industry will make bulk purchase. But, this will introduce surplus and scrap.

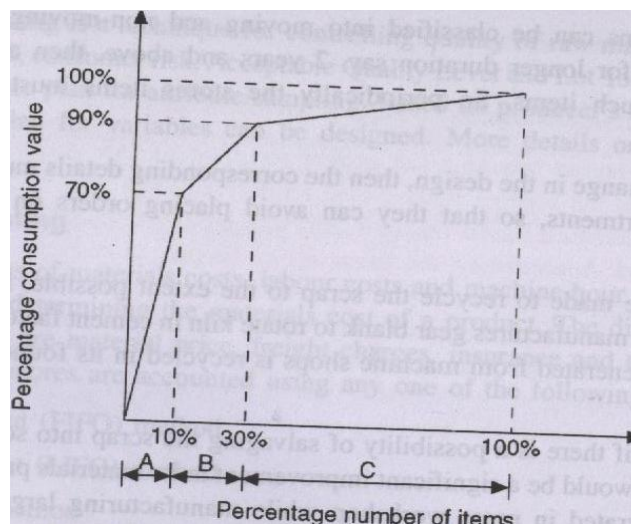
We can avoid such accumulation of obsolete, surplus and scrap items by using the following measures

1. Periodically, items can be classified into moving and non-moving items.
2. If there is any change in the design, then the corresponding details must be circulated among concerned departments.
3. Effort should be made to recycle the scrap to the extent possible.
4. In some cases, if there is a possibility of salvaging the scrap into some useful components/products, there would be a significant improvement in its materials productivity.
5. It is possible to generate substantial amount of money by way of disposing scrap by using optimal methods.

ABC ANALYSIS

- ABC analysis is a technique which is used to classify the items in store based on the demand of the stock.
- There may be variety of items that need to be purchased and stocked in advance for issuing the same to various production departments.
- If the Stock on hand of a particular item becomes less than or equal to its reorder level, immediately an order is to be placed for its economical quantity.
- It is highly essential to classify the items of the stores into different categories.

ABC analysis is one such technique which classifies the items into A, B and C class items. It is clear that 10% of the items accounts for 70% of the annual consumption value of the items. 20% of the items accounts for 20% of the annual consumption value of the items and 70% of the items accounts for 10% of the annual consumption value of the items. The percentages on the annual consumption of items will be used as a criterion for classifying the items into A, B and C classes.



Cumulative Curve of ABC Analysis

PROCEDURE FOR ABC ANALYSIS

Step 1: Input the following

- Total number of items
- Item code, Annual consumption in terms of units and unit price for each of the items.

Step 2: For each item, compute annual consumption value in terms of rupees by multiplying its annual consumption units with its unit price.

Step 3: Arrange the items and their details in descending order of the annual consumption values computed in *Step 2*.

Step 4: Compute cumulative values of the annual consumption values.

Step 5: Group the items into A, B and C classes by dividing the items into 70%, 20% and 10% of the annual consumption values, respectively from top to bottom in the sorted list of *Step 3*.

Production Management

Problem 1: The store of an oil engine repair shop has 10 items whose details are shown in the following table. Apply ABC analysis to the store.

Details of Store

Component Code	Description	Price/Unit (Rs.)	Units/Year
C01	Packing thread	100	100
C02	Tower bolt	200	300
C03	Hexagonal nut	50	700
C04	Bush	300	400
C05	Coupling	500	1000
C06	Bearings (Big)	3000	30
C07	Bearings (Small)	1000	100
C08	Fuel pump	7000	500
C09	Fixture	5000	105
C10	Drill bit	60	1000

Solution: The preliminary working for ABC analysis with the annual consumption for various items is summarized in below table.

Preliminary Workings

Component Code	Description	Price/Unit (Rs.)	Units/Year	Annual Consumption Rs./Year
C01	Packing thread	100	100	10000
C02	Tower bolt	200	300	60000
C03	Hexagonal nut	50	700	35000
C04	Bush	300	400	120000
C05	Coupling	500	1000	500000
C06	Bearings (Big)	3000	30	90000
C07	Bearings (Small)	1000	100	100000
C08	Fuel pump	7000	500	3500000
C09	Fixture	5000	105	525000
C10	Drill bit	60	1000	60000

Rearrange the rows of the above table as per the decreasing order of annual consumption (Rs./Year) and compute the cumulative annual values as shown in below table.

Final Workings of ABC Analysis

Component Code	Price/Unit (Rs.)	Units/Year (Rs.)	Annual Consumption Rs./Year	Cumulative Value of Annual Consumption (Rs.)	Class
C08	7000	500	3500000	3500000	A
C09	5000	105	525000	4025000	B
C05	500	1000	500000	4525000	
C04	300	400	120000	4645000	C
C07	1000	100	100000	4745000	
C06	3000	30	90000	4835000	
C02	200	300	60000	4895000	
C10	60	1000	60000	4955000	
C03	50	700	35000	4990000	
C01	100	100	10000	5000000	

From the above table the summary of ABC classification as per 70%:20%:10% of the total consumption value is presented in below table.

Summary of A, B and C Items

Class	Items Code	Description
A	C08	Fuel Pump
B	C09	Fixture
	C05	Coupling
C	C04	Bush
	C07	Bearing (Small)
	C06	Bearing (Big)
	C02	Tower bolt
	C10	Drill bit
	C03	Hexagonal nut
	C01	Packing thread

Problem 2: An engine manufacturing company stocks the items as shown in the following table in its stores. The unit price, annual consumption quantity in terms of units/year is also given in the same table. Classify the items into A, B and C categories.

Component Code	Description	Price/Unit (Rs.)	Units/Year
C001	Connecting rod	500	600
C002	Crank case	4000	600
C003	Cylinder	2000	600
C004	Cylinder head	3000	600
C005	Crank Shaft	4000	600
C006	Cam	500	1200
C007	Nozzle	500	600
C008	Valve set	1000	1200
C009	Fuel injection pump	1500	600
C010	Exhaust pipe	500	600

Problem 3: The stores of a repair shop have 10 items whose details are shown in the following table. Apply ABC analysis to the stores and indentify A Class, B Class and C Class items.

Component Code	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10
Price/unit (Rs.)	110	3000	225	60	310	7000	500	1000	7000	800
Unit/year	125	40	310	720	425	525	900	90	510	600

REFERENCES

1. R. Panneer Selvam : **Production and Operations Management** (Prentice Hall)
2. Chunnawala and Patel : **Production and Operations Management** (Himalaya)
3. K. Aswathappa & K. Shridhara Bhat : **Production and Operations Management** (Himalaya)
4. B. Mahadevan : **Operations Management** (Pearson)
5. Adam E bert : **Production of Operations Management** (Prentice Hall)
6. S.N. Chary : **Production and Operations Management** (McGraw Hill)