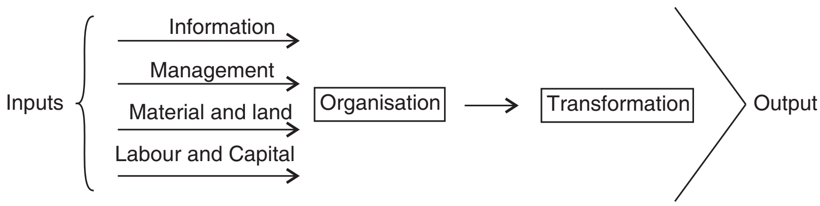
1. INTRODUCTION TO PRODUCTION AND OPERATIONS MANAGEMENT

STRUCTURE

- Functions of Production Management
- Production System
- Operative Management
- Product Design (New Product Development)

Production is the foundation on which every organisation is built. Production and marketing of goods and services are the fundamental objectives of a business organisation. Production is an intentional act of producing something in an organised manner. It is the fabrication of a physical object through the use of men, material and machine, similarly, in a service organisation production means discharge of some function which has some utility. *e.g.,* repair of automobile, legal service/ advice to a client, bank, hotel, transport companies etc.

Thus irrespective of the nature of organisation, production is some act of transformation *i.e.,* inputs are processed and tranformed into some output. The main inputs are information, management, material and land, labour and capital.



Thus the basis of production is the transformation of inputs into goods and services. The main objectives of a production process are:

1. Optimum use of resources at optimum cost.
2. Manufacture of the desired quality and quantity of goods and services.

Management can be defined as—"*the art and science, concerned with planning, directing and controlling the work of human beings towards a common aim, in accordance with agreed policies*". Planning implies what to do in future ? Directing comprises the operations of issuing orders, instructing those who have to do the work and finally coordinating the work of different people involved and of motivating their activity. Controlling is constraining the event to follow plans. All these three management processes have to be carried out to complete any management task although they need not necessarily all be carried out by the same individual. Also,

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management is the practice of determining what has to be done and then to accomplish this goal in the best possible way through other people.

Thus production management is to be said as—"*the management of transformation process of input into output is production management*".

Following definitions try to explain main characteristics of production management:

1. According to **E.L. Brech**—It is the process of effective planning and regulating the operations of that section of an enterprise which is responsible for the actual transformation of materials into finished goods or products.
2. Production management deals with decision making services to production process. So that the resulting goods and services are produced in accordance with the quantitative specifications and demand schedule with minimum cost.
3. Production management is a set of general principles for production economics. Facility design, job design,schedule design, quality control, inventory control, work study and cost and budgetary control. This definition explains the main areas of a enterprise where the principles of production management can be applied.

It is evident from above definitions that production planning and its control are the main characteristics of production management.

The main activities of production management are as below:

(*a*) Specification and procurement of input resources namely management, material, land, labour, equipment and capital.

(*b*) Product design and development to determine the production process for transforming the input factors into output of goods and services.

(*c*) Supervision and control of transformation process for efficient production of goods and services.

FUNCTIONS OF PRODUCTION MANAGEMENT

With the development and expansion of production organisation in the shape of factories more complicated problems like location, layout, inventory control, quality control, renting and scheduling of the production process etc., came into existence which required more detailed analysis and study of the whole phenomenon. This resulted in the development of production management in the area of factory management.

In the beginning the main function of production management was to control labour cost which at that time constituted the major proportion of costs associated with production. But with the development of factory system towards mechanisation and automation the indirect labour cost increased tremendously in comparison to direct labour cost. For example, designing and packing of the products, production and inventory control, plant layout and location, transportation of raw material and finished products etc. The planning and control of all these activities required more expertise and special techniques.

In modern times production management has to perform a variety of functions such as:

(*i*) Design and development of production process.

(*ii*) Production planning and control.

(*iii*) Implementation of the plans and related activities to produce the desired output.

(*iv*) Administration and coordination of the activities of various components and departments responsible for producing the necessary goods and services.

PRODUCTION SYSTEM

A system is an assemblage of objects united by some form of regular interaction.

Production can be seen in the form of goods and services provided by factories, offices, hospitals, market etc. It is a process of creating goods and services by transforming inputs *i.e.*, materials, capital, labour etc., in the form of some desired output.

The production process consists of a number of activities and operations. These operations and activities can be applied in different combinations and order to achieve the desired objective. The operations can be purchase of raw material, maintenance of inventory, transportation of goods etc. The combination of two or more operations/ activities, constitute a system.

In any production process two or more systems can be combined in series or in parallel *e.g.*, when a number of factories produce similar products to supply several market areas than these may constitute a parallel system of manufacturing.

According to **Webster** "*system is a regularly interacting or inter-dependent group of items forming a unified whole*".

Any system may have many components and variations in one component is likely to affect the other components of the system. *e.g.*, change in rate of production will affect inventory, overtime hours etc.

Problems associated with production system can be divided into two types of decision making namely: long-term and short-term problems.

Long-term problems of system include selection of production process, production design, plant location and layout etc.

Short-term problems can be inventory and production control, quality control, labour administration, cost control etc.

Production management is related with techniques to take suitable decisions for solving long-term and short-term problems in a manufacturing system.

Responsibilities of Production Manager

In the present era of cut throat competitions at various stages of operations, an enterprise should produce goods and services keeping into consideration the requirement and satisfaction of the potential customers. The objective should be to produce goods at least cost and to the maximum satisfaction of the buyer. To meet this objective the role of production manager in an enterprise is most important.

In an organisation production manager has to administer a great variety of activities. He assembles appropriate resources and direct the use of these resources by the people, machines, processing etc., in transforming material and time of people into products and services. Managers also have to respond to other forces from the external environment such as government regulation, labour organisation as well as local, regional, national and international economic conditions. Thus managers have to pay more attention not only to what their customers might buy but also to increasing

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government regulations and behaviour of customers and enivornmental protection groups.

The manager should be able to channelise the production process in a manner which ensures most efficient use of the resources to the best advantage for the enterprise. He is responsible for producing right quantity of goods at the right time, and should be able to do something real and constructive about production problems. He should be well conversant with the way and means to attain the desired goals. The duties of the production manager in general can be classified as below:

1. Production manager should concern himself with production planning.
2. Production control.
3. Production manager should concern himself with quality control.
4. Method of analysis:
   (*i*) Plant layout and material handling
   (*ii*) Proper inventory control
   (*iii*) Work study
   (*iv*) Labour welfare and labour productivity
   (*v*) Cost control.

1. **Production Manager should Concern himself into Production Planning.** In every enterprise, production manager is responsible for producing the required quantity of product in time to meet the stipulated delivery date. The quantity to be produced depends on the magnitude of demand whereas the time by which the production should be completed is determined by delivery date. Besides this the production department has to make arrangements for input factors and also to produce in economic lot size. To achieve all these objectives proper production planning is necessary. Production planning involves the generation and identification of alternative courses of action and to select the optimum alternative. This can be done by:

(*i*) assessing the requirement of various factor of production on the basis of demand forecasts.

(*ii*) formulating demand schedule for factors of production to permit purchase of raw materials and the production of product in economic lot size.

2. **Production Control**. It is the duty of the production manager to use the resources at his disposal in the best possible manner as well as to regulate the operation in such a way that desired delivery schedule is maintained. This is done by routing, scheduling and inspection during the production process.

3. **Production Manager should Concern himself with Quality Control**. It is the responsibility of the production manager to manufacture the goods and services of desired specifications. Though the quality of the finished goods can be ensured by the inspection of finished goods but it is better to employ measures which minimise the likelihood of producing defective items.

4. **Method of Analysis.** There can be a number of ways in which some operation can be executed. Production manager should select the most efficient and economical method to perform the operations.

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

(*ii*) **Proper Inventory Control**. Inventory implies all the materials, parts, supplies, tools in process *i.e.,* work in progress and finished products kept in stocks for sometime, the procurement policy of these items requires careful consideration and analysis. The purchases should be so scheduled that the investment in the inventory is at lowest possible level. This implies determination of economic lot size and re-order level.

(*iii*) **Work Study**. Method study and work measurement technique are applied to find the relationship between output of goods and services and input of human and material resources. The production manager should try to find the most appropriate method of performing various operations involved in a production process so as to obtain the optimum use of the resource as well as increasing the productivity.

(*iv*) **Labour Welfare and Labour Productivity**. Production manager should be able to generate the interest of the workers to increase their efforts by providing them wage incentives. This will result, an increase in labour productivity.

(*v*) **Cost of Production.** Cost of production varies with different methods of production. The production manager is responsible to follow a systematic approach to control capital and expenditure designed in a way that derived profit is ensured.

The nature of problems associated with production management are such that the production manager should have the capability as well as the aptitude to use qualitative and quantitive methods of analysis to get the desired solution.

OPERATIVE MANAGEMENT

It is the process whereby resources or inputs are converted into more useful products. Apparently it seems synonymous to the production management but there are two points which are differentiating the production management from the operation management and these are:

1. The term production management is often used for a system where tangible goods are produced whereas, operations management is frequently used where various inputs are transformed into intangible services, means operations management will cover such service organisations as banks, airlines, utilities, pollution control agencies, super bazars, educational institutions, libraries, consultancy firms and police departments, in addition to manufacturing enterprises.
2. Production management precedes operation management.

Scope of Production and Operation Management

The scope of production and operation management is indeed vast. Commencing with the selection of location, production management covers such activities as acquisition of land, construction of building, processing and installing machinery, purchasing and storing raw materials and converting them into saleable products.

Added to the above are other related topics such as quality management, maintenance management, production planning and control, methods of improvement and work simplification and other related areas.

Characteristics of Modern Production and Operation Function

The production management of today presents certain characteristics which make it look totally different from what it was during the past. Today's production system is characterised by following four features:

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(*i*) Manufacturing as competitive advantages
(*ii*) Services orientation
(*iii*) Disappearance of smokestackes
(*iv*) Small has become beautiful.

Manufacturing as Competitive Advantages

Earlier, production was considered similarly as other functions is an organisation. When demand was high and production capacities were inadequate, the concern was to somehow muster all inputs and use them to produce goods which would be grabbed by potential market.

In today's scenario, plants have excess capacities, competition is mounting and firms look and gain competitive advantages to survive and succeed.

Production system offers vast scope to gain a competitive edge and firms intend to exploit the potential. Total Quality Management (TQM), Time Based competition, Business Process Re-engineering (BPRE). Just in Time (JIT), Focussed factory (Revised), Flexible Manufacturing System (FMS), Computer Integrated Manufacturing (CIM) and virtual corporation are the techniques to enhance the competitive advantages. Out of these techniques a few or the combination of few are being used in the present production system by all leading manufacturing organizations.

Services Orientation

These day's, the services sector is gaining greater relevances, therefore, production system needs to be organized in the view of peculiar requirements of this sector. The entire manufacturing needs should to be geared to serve.

(*a*) intangible and perishable nature of the services.
(*b*) constant interaction with clients or customers.
(*c*) small volumes of production to serve local markets.
(*d*) need to locate facilities to serve local markets. There is increased presence of professionals on the production side, instead of techniques and engineers.

Disappearance of Smokestackes

From the industrial revolution to the middle of 20^{th} century production system was dominated by smokestackes. Smokestackes represented industrial establishments which ejected thick smoke, polluting the environment around.

Protective labour legislation, environmental movement and gradual emergence of knowledge based organizations have brought total transformation in the production system. These days factories are designed and built, environment friendly. Now the philosophy about work place is "*A home away from home*".

Small has become Beautiful

One great economist advocated for intermediate technology based on smaller working units, community ownership and regional work places utilizing local labour and resumes. This was criticised as to enhance profit, economics of scale, the organization has to be huge with mass production capacity.

These days, small and tiny manufacturing units are coming up at a very fast rate which helps in increasing customisation, flexible manufacturing system and similar other developments have made economics of scale.

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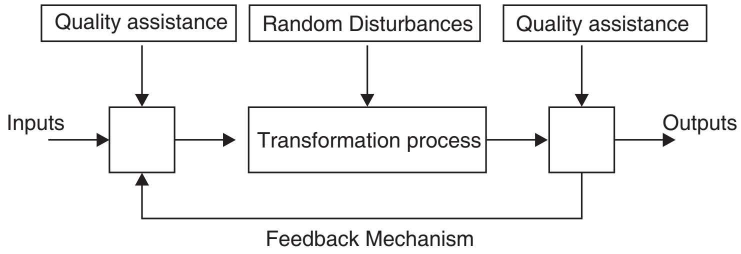
Transformation Process

Every organization, whether be it a product or service organization transforms certain input into outputs. To get the desired output the quality of the inputs are to be assumed. Again the quality of the actual output so obtained is also to be continually compared with the desired output.



Feedback Mechanism

Feedback mechanisms are required to monitor the performances of the transformation process. There may be some random disturbances hampering the transformation process of converting the inputs into desired outputs. Random disturbances can be planned and are due to internal environment.

Inputs

Inputs can be classified into the following classes:

1. Planning
2. Manpower
3. Materials
4. Machinery
5. Money or funds
6. Technology
7. Time
8. Organization
9. Government policies

Planning. It involves forecasting, identification of alternatives and preparation of corporate plans. The common managerial aids used are forecasting models, decision tree, games theory, economic evaluation and use of computers.

Manpower. This involves recruitment and training and their retention through adequate motivation involving proper merit rating, realistic wages and effective administration.

Materials. It includes effective material management organization to create conditions to generate adequate motivation and to design necessary vendor rating and development schemes. Inventory control, purchasing and stock keeping are also its function.

Machinery. Proper selection of machinery to achieve cost effectiveness or cost reduction. Different methods are employed such as cost benefit analysis, BE analysis economic evaluation and replacement analysis.

Money (funds). These play an important role in every organization. In the absence of fund the other resources cannot alone be converted into desired output, rather it can be said it provide wheel to the economy.

More emphasis has to be paid in terms of the funds/capital/money used and returns desired/derived. The proper allocation of this resource leads to a competitive advantage.

Technology. It also plays an important role these days because with the help of latest and modern technology better products can be produced at a cheaper rates thereby giving an edge in the competitive market or a possibility for the future grow.

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Time. Time management is one of important factor of production. It is integrated with almost all the resources of production. To achieve the quality products at the right time *i.e.,* in time (in given time frame) all the resources are to made available at their specific time and must be used in the correct place.

Organization. It bears a direct impact on the operations of the organization as all the operations are to be carried out or executed to achieve the organizational aim. The philosophy of the organization, culture etc., do play a role in the atmosphere which prevail in the organization.

Government policies and plans. Though these are the internal factors but are very essential for the development of any organization as well as in the production process. A little swing in the policies and plans of the Government from its mean position change many folds in the production process whether it is for the goods or services.

Processor. It means the organization itself, which is subjected to many factors for its performance. These factors are:

(*a*) Labour cost
(*b*) Material cost
(*c*) Material handling equipments
(*d*) Plant
(*e*) Product cost
(*f*) Product mix.

Labour Cost. It is an important factor in the total cost of the product or services so produced. It can be direct or indirect cost. The control of this cost leads to the reduction in total cost whereby increase in the profit margins, or a scope to play around in the industry as well in the market.

To achieve the cost effectiveness in respect of labour cost, following two are to monitored, continuously.

(*i*) Number of effective workers
(*ii*) Cost of labour

To strive for the best results following tools are being used.

(*a*) Method study
(*b*) Work measurement
(*c*) Ergonomics
(*d*) Incentives
(*e*) Training and development.

Material Cost. This is a major factor in production around 60% cost of production is due to the material cost in any given organization.

In respect of material cost there are many activities which are to be performed in any organization are as below:

(*i*) Monitoring and searching of sources of supplies.
(*ii*) Substitution of materials
(*iii*) Monitoring of vendors, search for probable vendor of future, selection and development
(*iv*) Indigenisation (substitution in terms of imports to the local market)
(*v*) Standardization in quality, quantity, time frame and cost.

Material Handling Equipments. It includes all the following activities:

(*i*) Plant selection
(*ii*) Plant location
(*iii*) Plant layout
(*iv*) Accounting
(*v*) Replacement in terms of more automation to reduce cost.

Material handling equipments are those which are used in the process of production to help the desired out in the given time frame with quality and quantity.

Plant. The conversion of resources into product takes place in the plant. Following are a few important factors in this regard.

(*i*) Plant location in terms of availability of all the resources.

(*ii*) Building in terms of proper utilization of space as well incorporation of all the activities of production.

(*iii*) Services in terms of availability for the optimum/desired output.

(*iv*) Plant layout in terms of proper operations in schedule of production.

(*v*) Plant facilities in terms of monitoring the production and future development with CAD and CAM.

(*vi*) Manuals to be referred at the time of use.

(*vii*) Semiautomatic/fully automatic/manual facilities depending upon the methods or procedure of production and conversion from one to another depending upon the future requirements along with cost effectiveness.

Production Cost. It depends on the cost of productions and overheads. Cost of production depends upon:

(*i*) product
(*ii*) technology
(*iii*) production cycle
(*iv*) delivery terms

Overheads depend on many factors like

(*a*) fixed cost
(*b*) supervision
(*c*) other infrastructure.

Note. 1. High control on production cycle and delivery schedule optimizes production cost.

2. Effect Production Planning and Control (PPC) is the essential managerial technique used.

Product Mix. The primary concern of the processor is the product mix. Decisions on product mix are influenced by the market potential, infrastructure availability and competition in the industry as a whole.

The next step is optimum capacity utilization of the product mix.

There are several managerial tools which are used in this regard are as follow:

(*a*) Market research
(*b*) Make or buy decisions
(*c*) Brain storming
(*d*) BE analysis
(*e*) Operation research techniques as—PERT, CPM etc.
(*f*) Computer application.

PRODUCT DESIGN (NEW PRODUCT DEVELOPMENT)

Product can be anything that is capable of satisfying a felt need.

A new product is the one which is truly innovative and is significantly different from other existing products.

The development of a new product passes through following seven distinct stages:

1. Identification of needs.
2. Advanced product planning.
3. Advance design.

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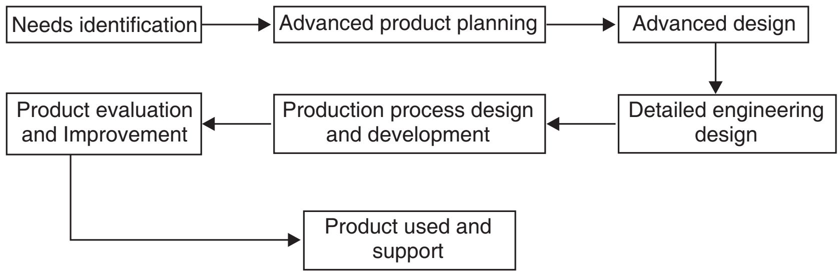
4. Detailed engineering design.
5. Production process design and development.
6. Product evaluation and improvement.
7. Product use and support.

The flow chart for these stages is as below:



Identification of Needs

Needs identification must be proceeded by idea generation. New product development starts with an idea. Ideas enranate from customers, top management, staff of the marketing department, production department or from the engineering section.

Once a product idea surfaces, it must be demonstrated that the new product fulfils some consumer needs and that existing products do not satisfy the need.

Advanced Product Planning

It is also called feasibility study and includes preliminary market analysis, creating alternative concepts for the product, clarifying operational requirement, establishing design criteria and their priorities and estimating logistics requirements for producing, distributing and maintaining the product in the market.

At this stage, conceptual design of the product shall emerge. The conceptual design will articulate the different parameter and dimension of the new product. Concept design is finalized by the production and operational personal jointly such joint efforts would also help design and test new production processes early in the development process.

Advance planning passes a point of friction between business and technical personal. When solid technical ideas are adjudged to have insufficient business merits and hence, fall by the wayside. Preliminary market analysis including sales projections and economic analysis including estimates of operating costs of production, overheads and profitability may suggest abandoning a technologically attractive new idea.

Advance Design

The next step in new product development process is the advance design, which involves detailed investigation by basic and applied researchers into technical feasibility and also identifying the trade off in product design. Promising design alternatives are evaluated according to critical parameter to determine whether design support such as analytical testing, experimentation, physical modelling and prototype testing will be required.

Detailed Engineering Design

This stage involves a series of engineering activities to develop a detailed definition of the product, including its sub-systems and components, materials sizes and so on. The engineering process typically involves analysis, experimentation and data collection to find designs that meet following design objectives.

(*i*) Design for function
(*ii*) Design for reliability
(*iii*) Design for maintainability
(*iv*) Design for safety
(*v*) Design for producibility.

Design for function—to ensure that the product will perform as intended.

Design for reliability—to ensure that the product will perform consistently.

Design for maintainability—to ensure product can be economically maintained.

Design for safety—to ensure that the product will perform with least physical and environmental hazards.

Design for producibility— to ensure that the product can be produced at the intended cost and volumes.

Computer analysis simulation and physical prototypes allow for testing various design alternatives and validate that, the final design meets the design objectives. Since, objectives can conflict with each other, trade offs are incredible in the optimal design. Typically, the final design includes drawings and other documentation as well as a prototype or a trial model of the product.

Production Process Design and Development

Having with the detailed product design, engineering and manufacturing specialists prepare plans for material acquisitions, production, warehousing, transportation and distribution etc. This stage also involves planning for other supporting systems such as controls, informations and human resources.

Product Evaluation and Improvement

After the launching of the product, it needs constant evaluation and improvement. Field performance and failure data, technical break throughs in materials and equipment and formal research are used to monitor analyses and if necessary redesign the product.

Product Use and Support

An important stage of product development considers support for consumers who use the product. Support system might:

(*i*) educate users on specific application of the product
(*ii*) provide warranty and repair services
(*iii*) distribute replacement parts
(*iv*) upgrade the product with design improvements.

Product Life Cycle

Every product passes through a life cycle and the life cycle can have a direct bearing on a company's or organisational's survival. The life cycle of a product consists of following four stages.

(*i*) Introduction
(*ii*) Growth
(*iii*) Maturity
(*iv*) Decline.

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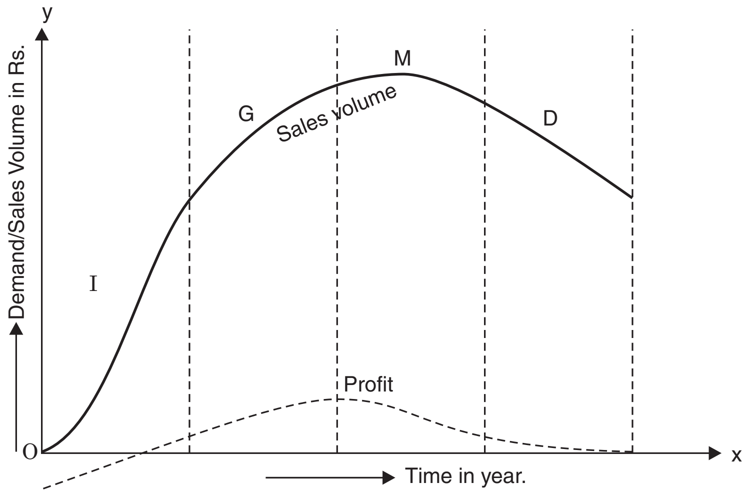
Note. The concept of product life cycles applies to a generic category of a product and not to specific brands.

A product life cycle consists of the aggregate demand over an extended period of time for all brands comprising a generic product category.



A life cycle can be graphed by plotting aggregate sales volume for a generic product category over time usually a year. It is also useful to plot profit curve along with the sales volume curve because, any company should be interested in profitability but not in just sales.

Characteristics of Stages in Life Cycle

	Introduction	*Growth*	*Maturity*	*Decline*
Characteristics of customers	Innovators	Mass Market	Mass Market	Loyal customers
Competition	Little (if any)	Increasing	Intense	Decreasing
Sales	Low level, then rises	Rapid growth	Slow no annual growth	Declining
Profits	None	Strong then at a peak	Declining annually	Low/none

The activities in operations, marketing and engineering functions relating to product development are intense, as new products are developed. As products move through the later phase of their life cycles, these efforts diminish somewhat in intensity and shift to concerns about redesigning product for maintaining market share and improving production.

Note. There is a trend towards shortened life cycle, particularly in industries such as electronics, computers and consumer goods. Shortened life cycles have had at least following four important effects:

(*a*) The total amount of spending on product development is increased.

(*b*) Production system tends to be whipsawed by continuously changing product models converted to other products.

(*c*) Operations strategies emphasise the ability to bring new product design on stream quickly. Computer-Aided-Design (CAD) is allowing some companies to respond faster to designing and redesigning these products.

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(*d*) Computer Aided Manufacturing is allowing some companies to put these new product designs into production more quickly.

SUMMARY

- Production is an intentional act of producing something in an organised manner. It is the fabrication of a physical object through the use of men, material and machine, similarly, in a service organisation production means discharge of some function which has some utility.
- Thus irrespective of the nature of organisation, production is some act of transformation *i.e.,* inputs are processed and tranformed into some output. The main inputs are information, management, material and land, labour and capital.
- Management can be defined as—"*the art and science, concerned with planning, directing and controlling the work of human beings towards a common aim, in accordance with agreed policies*". Planning implies what to do in future ? Directing comprises the operations of issuing orders, instructing those who have to do the work and finally coordinating the work of different people involved and of motivating their activity. Controlling is constraining the event to follow plans.
- Production management is related with techniques to take suitable decisions for solving long-term and short-term problems in a manufacturing system.
- The objective should be to produce goods at least cost and to the maximum satisfaction of the buyer. To meet this objective the role of production manager in an enterprise is most important.
- Product can be anything that is capable of satisfying a felt need.

QUESTIONS

1. What is Production? How is mangement defined?
2. What are the functions of a Production Manager?
3. What is the meaning of a Production System?
4. Why is the role of a Production Manager said to be most important?
5. What is the difference between production management and operations management?
6. How can inputs be classified?
7. What is need identification? Explain advanced product planning.
8. How can you explain the advance designing step in the new product development process?
9. Explain in product life cycle.
10. When do me evaluate a production and plan for its important?

2. MANUFACTURING

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STRUCTURE

- Product Strategies
- The Product Life Cycle
- Productive System Types
- Production To-stock or To-order
- Type of Operation
- Typical Production System
- Continuous Production
- Intermittent System
  Summary

If we examine the array of products available to the public and to producers, it may seem unreasonable that the productive system that manufacture them could have common characteristics the materials vary widely; the sizes, shapes, and weights are diverse; and the applications and uses are equally variegated. But if there were no common characteristics among systems for diverse products-if each system were entirely unique-we could learn nothing transferable by studying production management, and such is not the case.

By examining the nature of the product in its growth from introduction to maturity and by relating it to the competitive criteria of cost, quality, on-time delivery, and flexibility. We can develop logical types of manufacturing systems that much market place needs. Therefore, the place to start in defining types of manufacturing system is with product strategies.

PRODUCT STRATEGIES

Though products occur in great diversity, we seek to classify them in relation to the four competitive criteria.

At one extreme, we might have products that are custom in nature: that is, products, especially designed to the specifications and needs of customers or clients. Examples are a prototype spacecraft, many producer goods, and construction. A **custom product** is not available from inventory because it is one of a kind. The emphases in the custom product strategy are on uniqueness, dependability of on-time delivery, quality, and flexibility to change the production process in accordancce with changing customer preferences. Cost or price is a lesser consideration. Part of the strategy is to obtain the high profit margins that typically are available for custom designs.

At the other extreme are highly standardized products. Products of this type are available from inventory. They are "off-the-shell" products because each unit is identical and the nature of demand is such that availability and cost are important elements of competitive strategy. There is very little product differentiation between produers, and there are limited options available in produts. The most extreme examples are products thatt have virtually no variety, such as standard steel and aluminium shapes, and commodites like sugar or gasoline. Important managerial concerns for highly standardized products are dependability of delivery and low cost.

Between the extremes of custom-desgined product strategies and highly standardzed product strategies, we have **mixed strategies** that are sensitive to variety, some flexibility, moderate cost, and dependability of supply. In these situations, quality of product is important, but it is not the overwhelming criterion as with custom products. Multiple sizes and types of products are available, possibly from inventory or by order, depending on enterprise strategy. Some of these products are available in fairly low volume, but some, such as automobiles, are available in high volume. The great majority of products available today are in this middle category. Most consumer products are available from inventory. Most producer goods are available by order and may be subject to some special design modifications to meet individual needs, through the basic designs are quite standard.

THE PRODUCT LIFE CYCLE

The concept of the product life cycle unifies the previous discussion of product strategies. Figure below shoes products that currently sll in relatively low volume, intermediate volume, and high volume in relaton to stages of product introduction, growth, maturity, and decline. If we traced the development of a product now available in high volume highly standardized form from tis original introduction, we would find that t had gone through the first three stages shown in Figure below; introduction at low volume and with custom design; growth in sales, during which variety became more limited; and maturity, during which the product variety became even more limited as the product became basically a commodity. Finally, the product will enter the decline stage as substitutions become available that may be superior in terms of function, quality, cost, or availability.

Typical Product Life Cycle Curve for the Introduction Growth, Maturity, and Decline in the Sales of Products

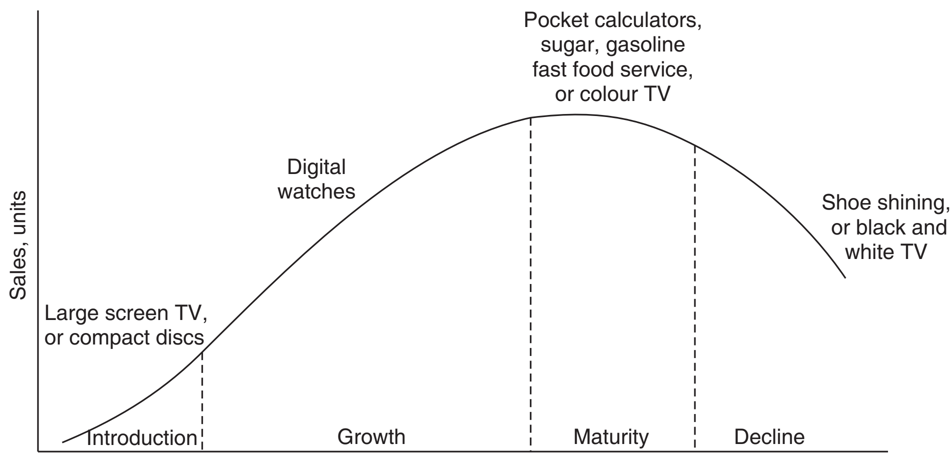

Fig. 2.1. Product life cycle

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The product life cycle curve is particularly important in formulating marketing strategies for pricing and market penetration. Of course, one of the objectives in marketing strategy is to find ways to renew the life cycles of produts that have matured or are in a state of decline. For example, there has been a market for calculators for a long time. It was satisfied by mechanical calculators for many years. But the mechanical calculators was replaced by the electrochemical calculator, then by the electronic calculator, and most recently by the pocket electronic calculator. Each generation of calculators has had its own product life cycle.

We should note that there are some custom products that are mature but do not go through the phases we have discussed. For example, there is a market for custom-built homes. Architects design such homes and contractors build them to specifications. The industry involved is mature in that it regularly produces custom-desgined and has refined a system, but if the custom home were produced in volume, it would no longer be a custom home.

PRODUCTIVE SYSTEM TYPES

The basic managerial strategies adopted for the productive system must be related to the product strategies. Obviosuly, it would be inappropriate to use a high-volume process capable of producing millions of gallons to produce an expermental chemical. Again, we should thing in terms of alternative strategies for the extremes as well as for the middle ground.

Process-Focussed Systems

A productive system for custom products must be flexible. It must have the ability to produce according to customer or client specifications. For example, an aerospace manufacturer must fabricate special component part designs. The equipment and personnel must be capable of meeting the individual component specifications and of assembling the components in the special configurations of the custom product.

Physical facilites are organized around the nature of the processes, and personnel are specialized by generc process type. For example, in a machine shop we might expect to find milling machine departments, lathe departments, drill departments, and so on. The flow of the item being processed is such productive systems is dictated by individual product requirements, so the routes through the system are variable.

The nature of the demand on the productuve system results in intermittent demand for the system's facilities and each component flows from one processes to the next intermttenly. Thus, the process-focussed system with intermittent demand on process types must be flexible as required by the custom product, and each generic department and its facilities are used intermittently as needed by the custom orders. The physical arrangement the departments by generic type is often called a "job shop" be cause it is designed to accomodate the needs of individual job offers.

Of course, a productive system of considerable significance in our society that is designed to deal with custom products is the project system.

Product-Focused Systems

By contrast, the nature of the demand on the productive system that produces high-volume, standardized produts results in continuous use of the facilities. Also, the material flow may be continuous, as in petroleum refining, or approaching continuous flow, as with automoble fabrication and assembly. Because of the high-volume requirements of such systems, speial processing equipment and entire dedicated producing systems can be justified as a productive system strategy. Processing is adapted completely to the product. Individial processes are physically arranged in the sequence required, and the entire system is integrated for a single purpose, like one gian machine. Thus, continuous systems have a produt focus. Under these extreme conditions of high demand for standardized products, the production process in integrated and makes use of of mechanization and automation to achieve standardization and low ost. Inventories of standardized products may be an important element of production as well as marketing strategy.

Between the two extremes of process-focussed (intermittent demand) and product focussed (continuous demand) systems, we have systems that must deal with low-volume multiple produts and relatively high-volume multiple products.

The low-volume multiple-product situaton usually involves a process-focussed system like that shown in Fig., but no products are produced in ***batches***. This allows certain economies of scale in comparison to the job shop system, which is designed to deal with custom products.

The high-volume multiple-product situation is likely to employ a mixed prodution strategy that combines both the process-focusses and product-focusses systems. In manufacturing, parts fabrication is often organised on a batch-intermittent basis and final assembly is organized on a line or continuous basis. Because parts fabrication output volume may be substantial but not large enough to justify the continuous use of facilitiess, parts are produced in economical batches, and the resulting inventories proide an important producing.

PRODUCTION TO-STOCK OR TO-ORDER

Now, we consider those products that *could* be produced either to stock or to order; that is, a decision is possible. We might decide to produce only to-order for important reasons, even though it would be possible to produce to stock. For example, a to-order policy might offer product design flexibility to customers, it might minimize the risk associated with carrying inventories, it might allow a close control of quality, and so on.

On the other hand, we might decide to adopt a to-stock policy for the same type of produt for equally valid reasons; for example, to offer better service in terms of availability, to reduce variable costs, and to increase market share by making share by making items available off-the-shelf when customers have the urge to buy.

The choice between a to-order to to-stock inventory policy does not necessarily depend on whether a product-focussed or a process-focussed physiccal system has been adopted. For example, one might think that the auto industry, which uses a product-focussed system, would certainly be a to-stock producer. But this has not been the case. Each auto is produced for a specific order from a customer or a dealer who has specificed the options desired.

Therefore, we have the possibility of two types of systems, product-focussesd or process-focusssed, in combination with two possible finished goods inventory policies, to stock or to order, as shown in figure below with examples.

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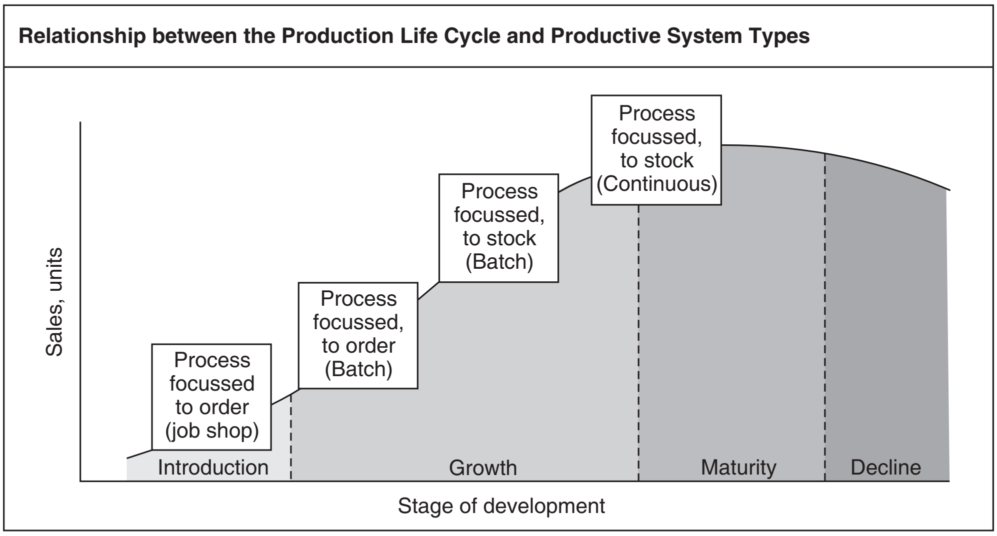

Fig. 2.2. PLC and productive systems

TYPE OF OPERATION

The degree of standardization and the *volume of output* of a produt or a servicce influene the way production is organized.

- **Continuous processing**
  1. Mass prodution.
  2. Volume prodution.
- **Intermittent processing**
  1. Batch processing.
  2. Job shop processing.
- **Project**
- **Automation**

	Job Shop	*Batch*	*Repetition/ Assembly*	*Conference*
Description	Customized goods or services	Semi-standardized goods or services	Standardized goods or services	Highy standardized goods or services
Examples of Process manufacturing service	Machine shop Beauty shop Barber shop	Bakery Classroom	Assembly line Cafeteria line	Steel mill, paper mill, etc. Control heating system

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Examples of goods services	Specially tools Hair styling	Cookies Education	Automobiles Car wash	Steel, paper, flour, sugar Heating, air conditioning
Volume	Low	Low-moderate	High	Very high
Output variety	Very high	Moderate	Low	Very low
Equipment flexibility	Very high	Moderate	Low	Very low
Advantages	Able to handle a wide variety of work	Flexibility	Low unit cost, high volume, efficient	Very efficient very high volume
Disadvantages	Slow, high cost per unit, complex planning and scheduling	Moderate cost per unit, moderate scheduling complexity	Low flexibility high cost of down time	Veru rigid, lack of variety costly to change, very high cost of down time

Product Variety	High	Moderate	Low	Very low
Equipment flexibility	High	Moderate	Low	Very low
Low volume	Job shop			
Moderate volume		Batch		
High volume			Repetitive assembly	
Very high volume				Continuous flow

Sources: Adopted from Rober H Hoyes one Srepher C Wheelwright Link Manufacturing Producer and Process, its cycles, Review on Feb 1979, pp. 135–40 and Irwin Operations Management V deb series.

TYPICAL PRODUCTION SYSTEM

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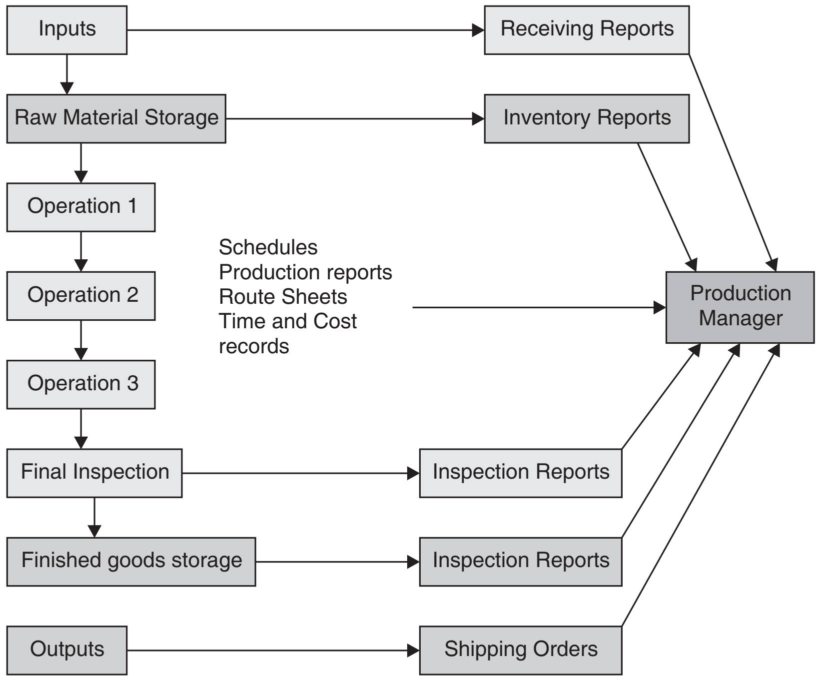

CONTINUOUS PRODUCTION

In this system the items are produced for the stocks and for the specific orders before manufacturing to stock, a sales forecast is made to estimate likely demand of the product. A master schedule is prepared according to the past orders.

In this type of manufacturing system, production is arried out in large lot sizes, **FIFO** is followed

It is of two type

1. Mass Production
2. Process Production.

Mass Production

- Items prodtued in large Quantity
- Production is made to stock not made to order.
- One type of product is produced at a time.

For example, Cars, Scooters etc.

Process Production

- Similar to mass production.
- Volume of produconi is very high.
- Used to manufacture those items whose demand is very high and continuous.

For example, Petroleum products, brand of medicines, plastics industries.

Single raw material is transformed to different products.

Like crude oil is transformed to kerosene, gasoline etc.

NOTES

INTERMITTENT SYSTEM

In this sytem, the goods are manufactured specially to fulfill orders made by the customers rather than for stock. Production facilities are flexible enough to hande wide variety of product and sizes.

It can be use to manufacture those products where the basic nature of the inputs change in design of product and production process requires continuous adjustments.

For example, Hospitals, General office etc.

Characteristics:

- Most product are produed in small quantities.
- Process layout followed.
- Workload generally unbalanced.
- In process inventory large.

Further classified into two categories:

1. Job Production
2. Batch Production

Job Production

Job or make complete production of single complete unit by one operator or group of operator.

For example, Bridge building, damn construction, ship building.

Here whole project is considered as one operation.

Characteristics:

- Whole project is taken as a single operation.
- Work is completed on each product before passing on to the next.
- High capital Investment.
- High unit cost of production.
- Preferred by heavy machinery manufacturers.

Batch Production

Production schedules are formed on the basis of demand forecasts. The items are processed in batches. In this system new batch is considered for production when work for the previous batch is finished.

For example, chemical industry, electronics instrument.

Any product is divided into parts or operations and each operations is to be completed throughout the batch before next operation is undertaken.

Intermittent	*Continuous*
Made to order	Made to stock
Production process flexible	Not flexible
Equipment use for limited time	Regular use of equipment
Wide range of products can be manufactured	Single product can be manufactured
Low capital investment	High capital investment
High cost of productoin	Low cost
Low accuracy	High accuracy
Change in location easy	Change in locaiton difficult.

For production or services with life cycles, a manager must know when to shft one type of processes to the next.

SUMMARY

- A **custom product** is not available from inventory because it is one of a kind. The emphases in the custom product strategy are on uniqueness, dependability of on-time delivery, quality, and flexibility to change the production process in accordancce with changing customer preferences.
- Standardized products of this type are available from inventory. They are "off-the-shell" products because each unit is identical and the nature of demand is such that availability and cost are important elements of competitive strategy.
- A productive system for custom products must be flexible. It must have the ability to produce according to customer or client specifications.
- Physical facilites are organized around the nature of the processes, and personnel are specialized by generc process type.
- The nature of the demand on the productuve system results in intermittent demand for the system's facilities and each component flows from one processes to the next intermttenly.
- By contrast, the nature of the demand on the productive system that produces high-volume, standardized produts results in continuous use of the facilities.
- *The degree of standardization* and the *volume of output* of a produt or a service influene the way production is organized.

QUESTIONS

1. What is a custom product? What are standardized products?
2. What are process focussed systems? What are product focussed systems?
3. What are the characteristics of mass production?
4. What type of products are product in process production?
5. Explain in the method of continuous production.
6. What are production scheduless formed on the basis of demand forecasts?
7. What is the relation between Production life cycle and Productive sytem types?
8. What is intermittant system? Explain job production.
9. When is whole project taken as a single operation?
10. What is Batch Production?

3. PLANT LOCATION AND LAYOUT

NOTES

STRUCTURE

- Work Break Down Structure (WBDS)
- Process Design
- Plant Location
- Plant Layout

Project leaders seldom get better until they know how to do it right. Project is only a one time set of activities that has definite beginning and ending points in time.

It is some *Unique Entity* that occurs just once having a significant and specific period of time to perform and is directed towards some major output.

It is a way of life that calls for the coordination of numerous and diversified activities that are all interrelated. All projects inspite of their unique entity share a set of few basic characteristics which are as below:

(*a*) A number of sequential activities make up the project.

(*b*) The various activities are interrelated in terms of precedence concurrance and succession.

(*c*) Every project has some definite starting and completion dates.

(*d*) Each activity in the project has specific start date and completion date.

(*e*) All projects have a combination of critical and non-critical activities.

A project starts with statement of work to be carried out. This underlines the objectives to be achieved, which is to be done and a proposed schedule specifying the start and finish dates. The project is further sub-divided into a number of tasks and sub-tasks to be performed/carried out. By one group of the organisation within a period of less than a year sub-tasks may further be sub-divided into meaningful pieces.

In a project a work package is a group of activities combined together so that these can be conveniently assigned to a single organisational unit of the system. The package decides:

(*i*) What is to be done?

(*ii*) When it is to be started and finished?

(*iii*) Budget constraints etc.

Specific events to be attained at various points of times and measures of performance. This ensures all organisational units of project.

(*i*) Working independently

(*ii*) Make these manageable in size

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(*iii*) Authority to carry out the program

(*iv*) Monitor and measure/evaluate the level of performance

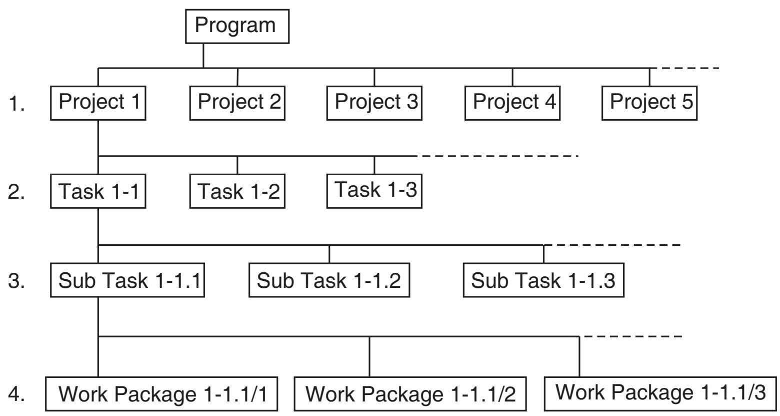
(*v*) Assess and arrange the necessary resources at various levels and stages.

Project management can be defined as *planning, directing and controlling resources to meet the technical, cost and time constraints of any project*.

WORK BREAK DOWN STRUCTURE (WBDS)

It defines the hierarchy of project tasks, subtasks and work packages. Completion of one or more work packages results in the completion of a subtask, completion of one or more subtasks results in the completion of a task; and finally the completion of all tasks is required to complete the project. This can be represented as following:

Level



Note. Similar chain of activities are associated with project 2, 3, 4, 5 and so on.

Essentials for the good WBDS are as below:

(*a*) Allow the elements to work independently

(*b*) Make them manageable in size

(*c*) Give authority to carry out the programme

(*d*) Monitor and measure the programme

(*e*) Provide the required resources.

Organizational Structure

Before the starting of project, the senior management must decide among the organizational structures, which will be used to the project to the parent firm.

There are basically following three types of organizational structure:

(*i*) Pure project (*ii*) Functional project

(*iii*) Matrix

Pure Project

These are those projects where a self contained team works full time on the project.

Salient Features:

(*a*) The project manager is blessed with full responsibility and authority of the project.

(*b*) The total team associated to the project is answerable to the project manager.

(*c*) Line of communication is quite small.

(*d*) Decisions are made quickly.

(*e*) Due to self contained in nature this enjoy the team pride, motivation and commitment to the task assigned.

(*f*) Duplication of the resonances as these are not shared among the projects and organisation as a whole.

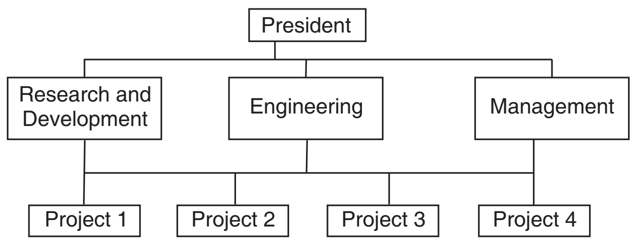
(*g*) Less familisation with the parent organisation hence, organisation's policies, practices, goals and objectives are not followed.

(*h*) Due to smaller in size, the latest development in terms technology/ies are not available.

(*i*) At times the people working don't feel the belongingness to the organisation hence life after project is not certain and leads to uncommitted.

Functional Projects

In this form of project the organisation spectrum is functional means the project is very much within the parent organisation.



Salient Features:

(*a*) A team member can work on several projects at a time.

(*b*) Technical expertise can be maintained as people are associated with the parent organisation.

(*c*) Objectives, plans, policies, goals etc. are well cleared to the people as these have been in the organisation.

(*d*) No duplication of resources because project is well within the parent organisation.

(*e*) Experts create synergistic effect to the project.

(*f*) Those aspects of the project which are not directly related to the functional areas get short changed.

(*g*) Motivation level is very low.

(*h*) Needs of the clients are treated as secondary.

Matrix Project

It is a mixture of pure as well as functional project structure. In this type a proper blending of pure and financial project is done to suit the requirements of the particular organisation.

Each project utilizes people from different functional areas. The project manager decides what tasks and when they will be performed but the functional manager control which people and technologies are used.

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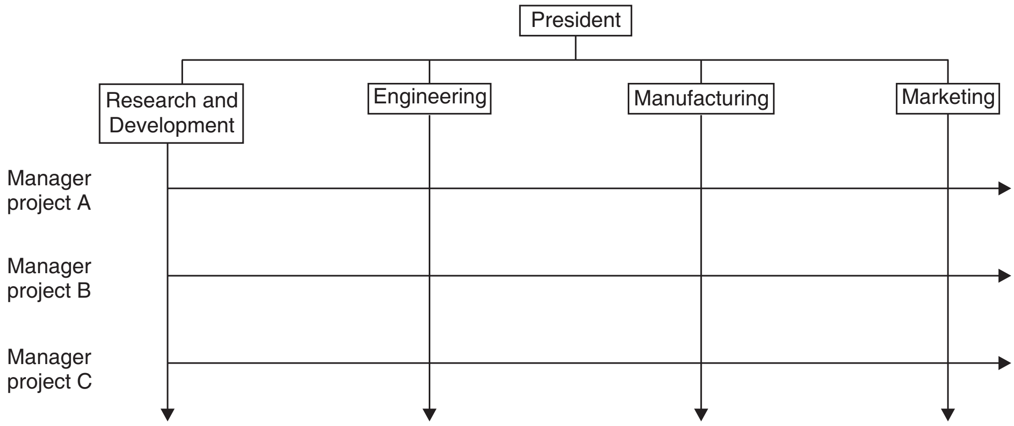


Salient Features:

(*a*) It enjoys the best possible communication among the functional divisions.

(*b*) The project manager is sole responsible for successful completion of the project.

(*c*) Optimum utilization of resources, it also avoids the duplication of resources.

(*d*) Organisations plans, policies, goods, objective etc., are known to the people who are present now in project from the functional areas thereby awareness goes to the new people in the project and are being followed.

(*e*) Team members from the functional areas know that they can be back after completion of the project hence a kind of security prevails in the project. Others also know that if the project is completed within the specified time and other norms they can also be absorbed in the organisation.

(*f*) All times, there are disputes due to two bosses are from the project *i.e.,* project manager and other from the functional area.

(*g*) Sometime this fails because of incompetence of project manager.

(*h*) Optimum utilization of resources at times create problem of giving more emphasis of one's task either in project or functional area.

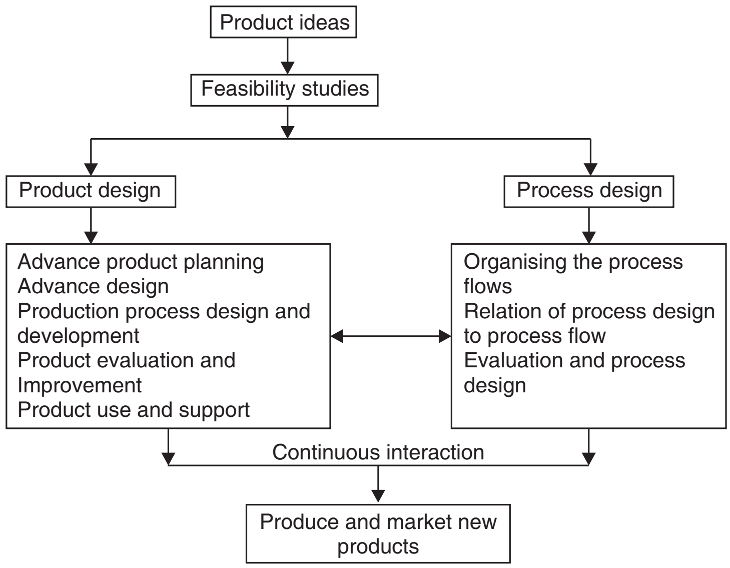
PROCESS DESIGN

New products are not realities until they are manufactured. Process design is necessary to manufacture new products. Process design means the complete delineation and description of specific steps in the production process and the linkages among the steps that will enable the production system to produce products of the desired quality, in the required quantity at the time, customers want them and at the budgeted cost.

Process planning is intense for new products, but replanning can also occur as capacity needs change, business or market conditions change, technologically superior machines become available or as other changes occur.

Relationship between Product Design and Process Design

The design or redesign of products and the design or redesign of production processes are interrelated.



There is continuous interaction between the two activities. On the surface, it looks as though, production process needs to be designed to accommodate the product design and that the product must be designed on the basis of producibility. But more importantly, continuous interaction means product design influenced by design of production process. Similarly, production process design is influenced and changed by design of product.

Note. Key decisions relating to process design relates to organising the process flows, relating process design to process flow and evaluating the process.

Organising Process Flows

There are five types of distinguished process. These are:

(*a*) Project (*b*) Job shop

(*c*) Batch assembly (*d*) Line

(*e*) Continuous.

Each one is more or less suited to different product/market situations and has unique operating characteristics, problems and challenges.

Project

It deals with one of a kind products that are tailored to the unique requirements of each customer. A construction company with its many kind and sizes of projects, is an example.

Since the product cannot be standard, the conversion process must be flexible in its equipment capabilities, human skills and procedures. The convervion process features problem solving, teamwork and coordinated design and production of unique products.

Job-Shop Process

It is most appropriate for manufactures of small batches of different products, each of which is custom designed and, hence, requires its own unique set of processing steps, or routing through the production process.

e.g., Printing press illustrates job-shop technology.

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Each product uses only a small portion of the shop's human resources and general purpose equipment.

Note. 1. With a large number of different jobs, elaborate job-tracking and control systems are used.

2. Much time is spent in waiting for access to equipment.

3. Some equipment is overloaded while the other equipment is idle, depending upon the mix of jobs at hand.

Batch Technology

This is a step ahead from job-shop process in terms of product standardisation, but it is not as standardised as the assembly line process.

With the wide range of products in a batch, several are produced repeatedly and that to in large volumes. These few dominant products differentiate batch facilities from job shops, however, no produt is sufficiently dominated to warrant dedicated equipment and process. Consequently, like job-shops, batch facilities produce a wide variety of products in a wide variety of volumes.

Note. The system must be flexible for the low volume/high variety products, but the higher volume products can be processed differently. *e.g.,* producing some batches for stocking rather than the customer order.

Assembly Line Technology

It is also known as simple line technology. It is for facilities that produce a narrow range of standardised products. *e.g.,* Laundry appliances.

Since the product design are relatively stable, specialised equipment, human skills and management systems can be developed and dedicated to the limited range of products and volumes. Beyond this range, the system is rigid.

Continuous Flow Technology

This technology is most appropriate in the case of chemical plants and oil refineries etc., where materials and products are produced in continuous, endless flows, rather than in batches of discrete units.

The product is highly standardised, as all are of the manufacturing procedures, the sequence of product build up, materials and equipment.

This technology affords high volume, around-the-clock operations with capital intensive and specialised automation.

Process planning is concerned with planning the conversion or transformation processes needed to convert the materials into finished products. A production process is a series of manufacturing operations performed at work stations to achieve the design specifications of the planned output. A vast number of different operations and various kinds of equipments and machines may be required to produce a complex product.

Process planning consists of two parts namely

(*a*) Process design (*b*) Operations design.

Process design is concerned with the overall sequences of operations required to achieve the product specifications. It specifies the type of work stations that are to be used, the machines and equipments necessary and quantities in which each is required.

The sequence of operations in the manufacturing process is determined by:

(*i*) The nature of the product (*ii*) The materials used

(*iii*) The quantities being produced

(*iv*) The existing physical layout of the plant.

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Framework for Process Design

The design of transformation process required answers to several questions given below:

1. What are the characteristics of the product or service being supplied or offered to customers?
2. What is the expected volume of output?
3. What kinds of equipment or machinery are available?
4. Must the equipment or machinery be custom built?
5. What is the cost of equipment and machinery needed?
6. What types of labour skills are available, in what quantities and at what wage rates?
7. How much money can be spent on the manufacturing process?
8. Should the process be capital intensive or labour intensive?
9. Should the components or parts be made or purchased?
10. How best to handle materials?

Systems Approach to Process Planning and Design

A. Inputs

(*a*) *Product/Service Information*—It includes product/service demand, prices/volumes, competitive environment, customer needs/wants and desired product characteristics.

(*b*) *Production System Information*—It includes resource availability, production economics, available techonologies and techonologies that can be acquired and predominant strengths and weaknesses of the firm.

(*c*) *Operation Strategy*—Includes positioning strategy, competitive strategy, focus of factory/organisation and service facilities and allocation of resources.

B. Conversion Process

(*a*) Selection of the type of process coordinated with open actions strategies.

(*b*) Vertical integration studies consists of study of vendor capabilities, acquisitions decision, make or by decisions.

(*c*) *Process/Product Studies*—It consists of major/minor technological steps, product simplification, standardization and product design for producibility.

(*d*) *Equipment Studies*—Regarding level of automations, linkage of machines, equipment selection and tooling.

(*e*) *Production Procedure Studies*—Includes production sequence, material specifications and personnel requirements.

(*f*) *Facilities Studies*—Regarding building designs and layout of facilities etc.

C. Output

(*a*) *Technological Processes*—Design of specific processes and linkage among processes.

(*b*) *Facilities*—Building design, layout of facilities and selection of equipments.

(*c*) *Personnel Estimates*—Skill level requirements, number of employees, training and retaining requirements and supervisions requirements.

Scope of Process Design

Design of manufacturing process starts with the receipt of product specifications and ends with the final plan for the manufacturing *i.e.,* manufacture of the product. The steps involved in process design are:

(*i*) A careful review of the product design and product specifications to ensure the economical manufacture is feasible.

(*ii*) Determination of the methods of manufacture that will result in the optimum manufacturing cost.

(*iii*) Selection or development and procurement of all machines, tools, jigs and fixtures, material handling equipments and machine accessories required for the manufacture of the product at the required quantity level and at the rate of production.

(*iv*) Layout of the production area and auxillary spaces and installation of the manufacturing facilities.

(*v*) Planning for and establishing the necessary control of materials, machines and man power to ensure the effective utilisation of the manufacturing facility for the economical production of the product.

Factors affecting Process Design

The basic factors affect the design of manufacturing process are:

(*a*) The volume or quantity of the product to be manufactured

(*b*) The required quality of the product

(*c*) The equipment that is available or that can be procured for the manufacture of the product.

Major factors affecting process design decisions are as below:

(*i*) Nature of product/service demand.

(*ii*) Degree of vertical integration.

(*iii*) Product/service and volume flexibility.

(*iv*) Degree of automation.

(*v*) Level of product/service quality.

(*vi*) Degree of customer contact.

Types of Process Designs

The basic type of production system and the finished goods inventory policy to be used must be decided at the earliest stage of process planning.

The common type of production systems are:

(*a*) Product-focused production system.

(*b*) Process-focused production system.

(*c*) Group technology/cellular manufacturing system.

(*a*) ***Product-Focused Production System:*** In this type of production processing, the production departments are organised according to the type of product/service being produced. All production operations required to produce a product/service are grouped into one production department or work centre.

Note. 1. It is also known as line flow production or continuous production.

2. The product tend to follow along direct lines paths and in continuous production the products tend to proceed through production departments without stopping.

(*b*) ***Process-Focused Production System:*** This is a form of production system in which, production operations are grouped according to the type of process. In other words, all production operations having similar technological processes are grouped together to form a production department.

Note. It is also known as intermittent production system or job-shops or batch production system.

(*c*) ***Group Techonology (GT)/Cellular Manufacturing (CM) Systems:*** It is the latest form of production system and in this the product or components being manufactured are placed in families or groups and separate manufacturing cells are used to manufacture these groups.

This is used to develop a hybrid between product focused and process focused production system. It enables production of a variety of parts in small batches to achieve economics of line-flow production without product standardization cellular manufacturing is a subset of group technology concept. A close grouping of equipments for processing a sequence of operations in multiple units of a part or a family of parts is called as manufacturing cell.

Note. 1. Use of manufacturing cells reduces the distances moved by parts between machines.

2. Parts do not have to be moved in large batches to reduce the transportation cost.

3. Parts are processed one by one through processing steps thereby reducing the work in progress (WIP) inventory and the manufacting cycle time or through part time.

PLANT LOCATION

It may be understood as the function of determining where the plant should be located for maximum operating economy and effectiveness. 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.

Unscientific and unplanned industrialisation is harmful not only to the industrial unit but as to the social and economic structure of the country as a whole. This encouraged a large number of industrialists to follow a more scientific and logical approach towards the selection of site for establishing their industries.

The degree of significance for the selection of location for any enterprise mainly depends on its size and nature. Sometimes, the nature of the product itself suggests some suitable location. A small scale industry mainly selects the site where in accordance with its capacity the local market for the product is available. It can easily shift to other place when there is any change in the market. But for large scale industries requiring huge amount of investment there are many considerations other than the local demand in the selection of proper plant location. These plants cannot be easily shifted to other place and an error of judgement in the selection of site can be very expensive to the organisation.

The need for the selection of location may arise under any of the following conditions:

(*a*) When the business is newly started.

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(*b*) The existing business unit has outgrown its original facilities and expansion is not possible, hence new location has to be searched.

(*c*) The volume of business or the extent of market necessitates the establishment of branches.

(*d*) A lease expires and landlord does not renew the lease.

(*e*) Other social or economical reasons for *e.g.*, inadequate labour supply, shifting of market etc.

Steps in Location

While choosing a plant location in a systematic approach following steps are taken:

(*i*) Within the country or outside.

(*ii*) Selection of the region.

(*iii*) Selection of the locality or community.

(*iv*) Selection of the exact site.

The selection of a particular region out of the many natural regions of a country the following factors are to be kept in mind:

(*a*) Availability of raw materials. (*b*) Nearness to the market.

(*c*) Availability of power. (*d*) Transport facilities.

(*e*) Suitability of climate. (*f*) Government policy.

(*g*) Competition between states.

Selecting a particular locality or community is influenced by the following factors:

(*a*) Availability of labour required for the particular industry.

(*b*) Civic amenities for workers.

(*c*) Existence of complementary and competing industries.

(*d*) Finance and research facilities.

(*e*) Availability of water and fire-fighting facilities.

(*f*) Local taxes and restrictions.

(*g*) Momentum to an early start.

(*h*) Personal factors.

Selection of an exact site in a chosen locality is the fourth step and is influenced by the followings:

(*a*) Soil, size and topography. (*b*) Disposal of waste.

(*c*) Environment.

Note. National decision must be taken keeping in view:

(*i*) Political stability export or import, (*ii*) Currency and exchange rates

(*iii*) Cultural and economic peculiarities (*iv*) Natural environment.

Location Models

Various models are available which help identify a new ideal location. Following are a few most popular models:

(*a*) Factor Rating Method. (*b*) Point Rating Method.

(*c*) Break-Even Analysis. (*d*) Quantitative Factor Analysis.

Factor Rating Method

In this method, factor ratings are used to evaluate alternative locations. Following steps are involved:

1. List the most relevant factors in the location decision.
2. Rate each factor according to its relative importance *i.e.*, a factor rating is given to each factor, based on its importance, the higher the ratings the more important is the factor.
3. Rate each location according to its merits on each factor.
4. Compute the product of ratings by multiplying the factor rating by the location rating for each factor.
5. Compute the sum of the product of ratings for each location.

Decision: Select the location alternative which has the maximum sum of the product ratings as the choice.

This method has following advantages:

(*a*) Simplicity which facilitates communication about why one location/site is better than other.

(*b*) Enables bringing diverse locational considerations into the evaluation process.

(*c*) Faster consistency of judgement about location alternatives.

e.g.,

Factors	*Factor Ratings*	*Location rating*			*Product of rating*		
		A	*B*	*C*	*A*	*B*	*C*
1. Adequacy of water supply	4	6	1	3	24	4	12
2. Availability of power supply	4	7	3	1	28	12	4
3. Access to rail and air transportation	2	8	2	2	16	4	4
4. Proximity to supplier	5	6	9	8	30	45	40
5. Proximity to customers/ market	5	4	10	9	20	50	45
6. Quality of educational system *i.e.,* labour/workers	4	1	4	4	4	16	16
7. Receptivity of community	3	2	6	5	6	18	30
8. Suitability of labour skill	3	3	5	7	9	15	21
9. Suitability of climate	3	5	8	6	15	24	18
10. Tax advantage	3	10	7	10	30	21	30
			Total	–	**182**	**209**	**220**

From the above calculation it is revealed that out of three sites/locations *i.e.,* A, B, C, 'C' is the most suitable location as its score is highest among the three. A has the score of 182, B has score of 209 and C has the score of 220.

Point Rating Method

In selecting a site or location, companies have several objectives, but not all are of equal importance. The relative weightage assigned to each objective or to each location

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factor may be represented by the number of points a perfect site would receive in each category.

Each potential site is then evaluated with respect to every factor a company is looking for and points are assigned for each factor. The site with the highest total number of points is considered superior to other sites.

If two alternative potential locations are formed to be equally alternative by comparing the costs (based on tangible factors) then, these two locations may further be evaluated based on intangible factor using the same method.

Advantages

1. In this method, relative importance of tangible cost factors are significant compared to intangible factors.
2. Points are usually assigned to only intangible factors.
3. An evaluation is made to determine whether the difference between the intangible scores is worth the difference, between the tangible costs of the competion locations.

Disadvantages

1. High score in any factor can overcome a low score in any other factor.
2. Some factors are considered as important or essential, any site that does not have at least a specified number of points for those essential factors will be included from other consideration.

e.g.,

Factors	*Max. possible points*	*Points assigned to locations*		
		A	*B*	*C*
1. Adequate water supply	100	100	75	100
2. Future availability of fuel	350	300	300	250
3. Living conditions	150	150	125	150
4. Pollution control/regulation	250	200	250	250
5. Site topology	100	50	100	100
6. Transport flexibility and growth	200	100	150	200
7. Labour availability	250	200	250	250
	Total	**1100**	**1250**	**1100**

In the above example the calculation reveals that site A has got a score of 1100, site B-1250 and site C-1100. Hence as per the above method the best location is 'site B'.

Break-Even Analysis (Locationwise)

In comparing several potential locations on an economic basis *e.g.,* tangible factors, the only revenues and costs that need to be considered are the ones that vary from one location to another. If revenue per unit is the same, regardless of where the goods is produced the total revenues can be eliminated from consideration. An economic comparison of locations can be made by identifying the fixed costs and variable costs and plotting the break even analysis on a graph for each location.

This graphical approach can easily identify the range of annual production volume over which a location is preferable.

Following steps are involved in this method:

(*a*) Determine all relevant costs that vary with each location

(*b*) Categorize the costs for each location into annual fixed costs (FC) and variable cost per unit (VC) and calculate the total cost (TC) for the desired volume of production per annum, for each location.

(*c*) Plot the total costs associated with each location on a single chart or graph of annual cost versus annual production volume.

(*d*) Select the locations with the lowest total annual cost (TC) at the expected production volume per annum (Q).

Note. 1. If revenues vary from one location to another then comparison of locations should be made on the basis of profits at each location.

2. Profit = Total revenue – Total cost.

e.g.,

A company which is planning to produce a product, whose selling price in the market is ₹ 100/unit. The expected production/planned product per annum is 2000 units. Determine the range of annual volume of production for which, each of the location A, B and C would be most economical.

Location	*FC/year*	*VC/units*
A	₹ 25,000	₹ 50
B	₹ 50,000	₹ 25
C	₹ 80,000	₹ 15

$$Q = 2000 \text{ units}$$

$$TC = (FC) + (VC) \times Q.$$

For location A, $TC_A = 25,000 + 50 \times 2000 = 25000 + 1,00,000 = 1,25,000$ ₹

For location B, $TC_B = 50,000 + 25 \times 2000 = 50,000 + 50,000 = 1,00,000$ ₹

For location C, $TC_C = 80,000 + 15 \times 2000 = 80,000 + 30,000 = 1,10,000$ ₹

From the above calculation it reveals that the site B is most economical among A, B, C sites for a production 2000 units/annum.

To determine the range of annual volumes of production at which each of the three locations would become most economical, it is necessary to determine the break-even volumes either by graphical or analytical method.

Analytical Method

(*a*) To determine the B/E volume between location A and B the total cost of producing the B/E quantity say Q_{AB} at each of location A and B are equated.

$$25,000 + 50\, Q_{AB} = 50,000 + 25\, Q_{AB}.$$

$$50\, Q_{AB} - 25\, Q_{AB} = 50,000 - 25000$$

$$25\, Q_{AB} = 25000,\ \ Q_{AB} = 2500/25 = 1,000 \text{ units.}$$

(*b*) To determine the B/E volume between location B and C the total cost for producing the B/E quantity say.

$$25\, Q_{BC} + 50000 = 80000 + 15\, Q_{BC}$$

$$25\, Q_{BC} - 15Q_{BC} = 80,000 - 50,000$$

$$10\, Q_{BC} = 30,000,\ \ Q_{BC} = 30,000/10 = 3,000 \text{ units.}$$

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Qualitative Factor Analysis Method

If economic criteria are not sufficiently influential to decide the location alternatives, a system of weighted score might be useful in making a plant location decision. It is known as qualitative factor analysis. Following are the steps:

(*a*) Develop a list of relevant factors.

(*b*) Assign a weight to each factor to indicate its relative importance.

Note. Weights may total upto 1.00.

(*c*) Assign a common scale to each factor (say 0 to 100) and designate any minimum point to be scored by any location.

(*d*) Score each potential location according to the designated scale and multiply the scores by the weights to arrive at the weighted scores.

(*e*) Total the points for each location and choose the location with the maximum points.

e.g., ABC manufacturing company is planning to opening its new venture, for which it is evaluating from locations. The weighted and relevant scores are as below. Using these scores develop a qualitative factor comparison for the locations.

Relevant factors	*Assigned weight*	*Scores for locations*			
		α	β	γ	δ
1. Production cost	0.35	50	40	60	30
2. Raw material supply	0.25	70	80	80	60
3. Labour availability	0.20	60	70	60	50
4. Cost of living	0.05	80	70	40	80
5. Environment	0.05	50	60	70	90
6. Markets	0.10	70	90	80	50
	1.00				

Solution.

Factors	*Weighted score for locations*			
	α	β	γ	δ
Production cost	17.5	14.0	21.0	10.5
Raw material supply	17.5	20.0	20.0	15.5
Labour availability	12.0	14.0	12.0	10.0
Cost of living	4.0	3.5	2.0	4.0
Environment	2.5	3.0	3.5	4.5
Market	7.0	9.0	8.0	5.0
Total	**60.5**	**63.5**	**66.5**	**49.0**

From the above it reveals that site/location 'γ' is most preferred because of its highlist weighted score.

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PLANT LAYOUT

Once a decision about location of the plant has been taken the next important problem before the management is to plan suitable layout for the plant.

When a new plant is erected, the question of the placement of machinery at different places, the location of stores, inspection cabins, tool rooms, maintenance wings, plating shops, heat treatment chambers, toilets, canteens, trolleys, cranes and other handling equipments, receive a priority consideration. This is so because, the efficiency of the production flow depends, largely on how well the various machines, production facilities and employee amenities are located in a plant. In a properly laid out plant, the movement of materials, from the raw material stage to the end product stage is smooth and rapid, the movement is generally in a forward direction the materials do not criss-cross, or go backward and forward for further operations. Moreover production bottlenecks and delays are few, and materials handling costs are reduced. Such arrangements constitute the subject matter of a plant layout.

Efficiency and performance of good machines and sturdy building depend to a great extent on the layout of a plant. Plant layout is the method of allocating machines and equipment, various production processes and other necessary services involved in transformation process of a product with the available space of the factory so as to perform various operations in most efficient and convenient manner providing output of high quality and minimum cost.

"*Layout identically involves the allocation of space and the arrangement of equipment in such a manner that overall operating costs are minimised*".—**James Lundy.**

In other words, plant layout is an effort to arrange machines and equipment, and other services within a predesigned building ensuring steady, smooth and economical flow of materials.

Planning the layout of a plant is a continuous process as there are always chances of making improvements over the existing arrangement specially with shifts in the policies of management of techinques of production.

The disposition of the various parts of a plant along with all the equipment used is known as **plant layout**. It should be so designed that the plant functions most effectively.

Layout problems are common to all kinds of organisations. A retailer must arrange his counter, display of items etc. Office management must position desk tables etc. in such a way that it facilitates the flow of work. A manufacturing organisation must position its machinery and other equipment so as to achieve smooth flow of products through their factories.

A good layout results in comfort convenience, safety, efficiency, compactness and profits. A poor layout results in congestion, waste, frustration and inefficiency.

Development of a good layout depends on a series of decisions already taken on location, capacity facility, manufacturing methods and material handling.

Thus after plant location the proper design of plant layout is most significant for smooth functioning and success of the organisation.

It begins with plant location and continues through three further levels as:

(*a*) The layout of departments within site

(*b*) Layout of items within the department

(*c*) Layout of individual work places.

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Stages of plant Layout: Plant layout process in an enterprise involves the following stages :

(*i*) Product demand
(*ii*) Production requirements
(*iii*) Components and parts analysis
(*iv*) Work methods and measurements
(*v*) Machine requirements
(*vi*) Handling and movement requirements
(*vii*) Space requirements.

Objectives of Layout: An efficient layout can be instrumental in the accomplishment of the following objectives.

1. Provides enough production capacity.
2. Reduce material handling costs.
3. Reduce congestion that impedes the movement of people or material.
4. Reduce hazards to personnel.
5. Utilize labour efficiently.
6. Increase employee morale.
7. Reduce accidents.
8. Utilize available space efficiently and effectively.
9. Provide for volume and product flexibility.
10. Provide case of supervision.
11. Facilitate coordination and face-to-face communication where appropriate.
12. Provide for employee safety and health.
13. Allow case of maintenance.
14. Allow high machine/equipment utilization.
15. Improve productivity.

Features of a Good Layout

The layout of a plant can be planned in a number of ways, but a good layout should passess some basic characteristics as:

(*i*) There should be sufficient space for the workers as well as for the equipment to perform their functions. This will ensure smooth and continuous flow of production process.

(*ii*) Must provide adequate safety and security to workers against accidents of injury *e.g.*, provision of fire fighting equipment, first aid boxes etc.

(*iii*) Sufficient grang-way space for materials, workers and semi-finished goods. This leads to increase in efficiency.

(*iv*) Arrangement of machines and equipment should be such that minimum material handling is necessary for low cost processing.

(*v*) Stores for in process material should be provided at some convenient place *i.e.,* not far from the place of operations.

(*vi*) Supervision, coordination and control of activity should be effectively and easily executed.

(*vii*) There should be sufficient scope for making adjustments and modifications whenever any need arises *i.e.,* layout should be flexible.

Factors Influencing Layout

The pattern of layout varies from industry to industry, location to location and plant to plant. Different types of layout are in use and the selection of a particular type to suit the requirements of a plant depends on a number of factors.

Primarily the layout of a plant is influenced by the relationship among materials, machines and men. Other factors such as the type of product, type of workers, type of industry and management policies also influence the layout.

Some of the important factors are as below:

(*a*) Materials (*b*) Product
(*c*) Workers (*d*) Machinery
(*e*) Type of industry (*f*) Location
(*g*) Managerial Policies.

Materials

Materials influence plant layout, it means that there is a need to provide for the storage and movement of raw materials in a plant until they are converted into finished products. Buying of raw materials must be economic. If these are seasonal, have to purchased and stored properly their movement through production centres must be efficient for manual or mechanical operations or chemical processing. This all needs proper place for storage and materials movement or materials handling equipment. These involve initial investment as well as recurring costs. The type and size of storage as also the type of materials, equipment, cranes, trolley and pipelines depends on:

(*i*) Type of raw materials used (*ii*) Availability of materials.

Note. 1. It is essential that a plant layout should be planned after bearing in mind the particular handling or moving equipment which may be required in the manufacturing process.

2. The usual way to taking the raw material factor into account is to draw flow charts to visualise the paths of materials flow or movements, and then to eliminate cross-covers, long distance and back tracking. The best path is thus determined around which, the layout is planned.

Product

Layout is designed with the ultimate purpose of producing a product. The type of product can be different and its position in relation to the plant location influence the layout. During the process of production either the product moves from one work station to another to be converted to finished product or it remain stationary. Thus, the position of the product in relation to other factor of production deserves consideration in planning the plant layout.

The sales demand also exercises some influence on the plant layout. The sales demand for a product determines the volume of production and therefore the quality and size of the equipment, the area of the storage space, and other facilities which, in turn determine the type of layout. A product with a relatively inelastic demand should be produced on a mass scale by using specialised equipment in contrast to a luxury article which is produced on a small scale with less specialised equipment. Hence, plant layout should begin with the product.

Note. A plant layout must be the expression of a purpose, which is efficient and effective production of a product or product line. The purpose then distates that the point at which the analyst for layout must start with the product to be produced.

Workers

The layout designer should also consider the type, position and requirements of employees.

If women workers are employed, the layout must be planned after keeping in mind their particular requirements.

The position of employees, that is whether they remain stationary or moving, also influences the layout.

Note. 1. Employee facilities, such as health and related services, feeding and related services, locker rooms and public facilities influence the layout.

2. Employee safety too must receive due consideration.

Machinery

The type of product, the volume of its production, the type of process and management policy determines the size and type of the machine to be installed which, in turn, influence the plant layout.

Production is the combination and manipulation of men, materials and machines. These elements may be combined in various ratios and in various ways in the cause of the production activity. The ratio in which, these elements are used depends on their relative costs and on the production processes selected.

Note. 1. Before laying out a plant, it is necessary to determine which of these elements are to be stationary or fixed as to location in the plant and which will be mobile during the process of production.

Following are the various alternatives available in determining which factor to move:

(*a*) To move the product and the workers from one work station to other workstation.

(*b*) To move the product from one work station to another keeping the workers and machine stationary.

(*c*) To move the machine and worker to the product, which is held stationary.

2. The layout or arrangemnt of machines should be planned to suit the alternative used in a plant.

Type of Industry

Type of industry and method of manufacturing process too influence the plant layout significantly.

From this point of view, the industries can be classified as:

(*a*) Synthetic (*b*) Analytical
(*c*) Conditioning (*d*) Extractive.

- A synthetic industry is also called the assembling industry which involves the production of a product by the use of various elements.
- An analytical industry converts raw materials into various elements or constituent parts.
- A conditioning industry involves a change in form or physical properties
- Extrative industries involve the separation of one element from another.

Each of the above types of industries may be further classified into two types:

(*a*) Intermittent industries (*b*) Continuous industries.

Above classification is based on the method of manufacture.

- Intermittent industries manufacture different components on different machines and assemble them to get the end product.
- Continuous industries uninterruptedly produce one or two products of a standardised nature.

Note. While planning the layout, it has to be kept in mind about the type of industry and method of manufacturing process.

Location

The site selection for the plant location influences the layout in many ways. Such as:

(*a*) The size and the terrain of the site determine the type of building which in turn influences the layout.

(*b*) Location of the plant determines the mode of transportation depending upon the distances from the source of raw materials and market to the plant. The layout plan should provide for the exact type of transportation required.

(*c*) A plant location may be determined in part by the fuel requirements of the concern. The plant layout must provide sufficient place for the fuel storage.

(*d*) The demand for future expansion influences the plant layout. In case of urban area expansion is possible in the increase in storeys. The number of storeys determine the type of materials handling equipment which would be required and which in turn influences the plant layout.

Managerial Policies

Management policies significantly influence plant layout. Following are some important management policies:

(*a*) The volume of the production and provision for expansion

(*b*) The extent of automation

(*c*) Making or buying a particular product/component

(*d*) Desire for rapid delivery of goods to customers

(*e*) Purchasing policy

(*f*) Personnel policies.

It is obvious that many top management policies determine the plant layout objectives and the scope of the plant activities. The layout engineer must have a clear and complete understanding of those top management policies that have a bearing on plant layout objectives.

Principles of Layout

While accepting the selected layout, the layout engineer should be guided by certain principles. The layout selected in conformity with layout principles should be an ideal one. These principles are:

(*i*) Principle of minimum travel (*ii*) Principle of sequence

(*iii*) Principle of usage (*iv*) Principle of compactness

(*v*) Principle of safety and satisfaction (*vi*) Principle of flexibility

(*vii*) Principle of minimum investment.

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(*i*) **Principle of Minimum Travel—**Men and materials should travel the shortest distance between operations so as to avoid wastage of labour, time and minimise the cost of material handling.

(*ii*) **Principle of Sequence—**Machinery and operations should be arranged in a sequential order.

This principle is best achieved in product layout, and efforts should be made to have it adopted in the process layout.

(*iii*) **Principle of Usage—**Every foot of available space should be effectively utilised. This principle should receive top consideration in towns and cities where land is costly.

(*iv*) **Principle of Compactness—**There should be a harmonious fusion of all the relevant factors so that the final layout looks well integrated and compact.

(*v*) **Principle of Safety and Satisfaction—**The layout should contain built in provisions for safety of the workmen. It should also be planned on the basis of the comfort and convenience of the workmen so that they feel satisfied.

(*vi*) **Principle of Flexibility—**A layout should permit revisions with the least difficulty and at minimum cost.

(*vii*) **Principle of Minimum Investment—**The layout should result in savings in fixed capital investment, not by avoiding installation of the necessary facilities but by an intensive use of available facilities.

Types 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. Following are the methods of grouping or the types of layout:

(*a*) Process layout or functional layout or jobs shop layout.

(*b*) Product layout or line processing layout or flow line layout.

(*c*) Fixed position layout or static layout.

(*d*) Cellular manufacturing layout or group technology layout.

(*e*) Combination layout or hybrid layout.

(*a*) **Process Layout:** It is also known as functional layout or job-shop layout, in this layout more emphasis is given to specialisation or functional homogeniety on various components of the system.

<table>
<tr><th>Receiving</th><th colspan="2">Service</th><th>Shipping</th></tr>
<tr><td rowspan="2">Lathe</td><td>Milling</td><td>Surface Finishing</td><td>Packing</td></tr>
<tr><td>WIP</td><td>Assembly</td><td>Inspection</td></tr>
<tr><td colspan="4">Office</td></tr>
</table>

All operations of similar nature are grouped together in the same department or part of the factory. Here machines performing same type of operations are installed at one place *i.e.,* plant is grouped according to functions in different sections like milling, moulding, packaging etc.

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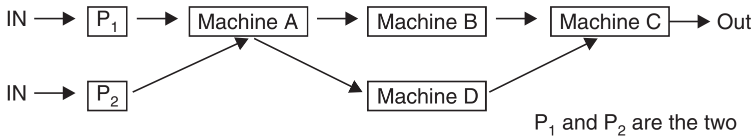
Note. This type of layout is most appropriate for intermittent *i.e.,* Job and Batch type of manufacturing systems where small quantities of a large range of products are to be manufactured.



Advantages

There are numerous advantages of this type, the important ones are as below:

1. In the case of output of smaller quantities and with varying specifications this layout is most appropriate.
2. In each specialisation section, workers expert in the specific operations can be used *i.e.,* scope for more skilled labour leads to better quality in production.
3. Each production unit of the system works independently and is not affected by the happenings in another section of the plant.
4. Provides cohesiveness and enable individual bonus schemes.
5. **Wide Flexibility in Production Facilities—**The system is more flexible to adjust modifications and changes in production strategies. Work can be done on a short notice with much time spent on production planning and scheduling.
6. **Effective Supervision—**Supervision and inspection work can be independently and efficiently carried out by each department. The worker in each section frequently becomes very adopt and specialised in maintenance and repair of equipment specification and inspection requirement. There is also saving of time in inspection and control operations.
7. Machine breakdown does not distrupt production schedule. In this layout machine breakdown does not immoblise the entire production process. If there is a breakdown of any machine in the same section. In case the department is already working at high capacity, minor modifications in scheduling can readily be made to perform more urgent jobs.
8. **Lower Capital Investments—** The production facilities can be utilised to greater capacity with less duplication of machines. The equipment is highly productive and profitable. Overloading of any department can be done by increasing the working hours, routing the work to other machines or by sub-contracting.
9. **Lower Proportion of Fixed Costs to Total Costs—**At peak production level the amount of labour utilised in proportion to capital utilised is high in comparison to product layout. When the decline in demand and plant operations is at a low capacity then smaller labour force can keep the system running full time how capital investment makes smaller overhead charges for idle plant. Also the risk on investment is reduced as the facilities are more flexible and are less subjected to obsolescence.

Disadvantages

1. **More Material Handling—**As there is no definite channel through which all work can flow, hence too much movement of semi-finished goods from one

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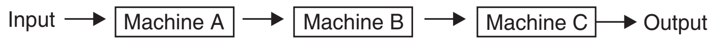
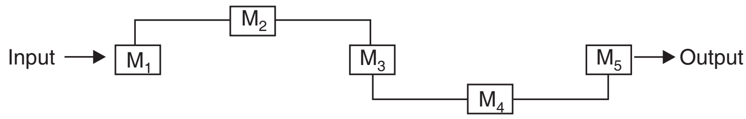
place to another inside the plant, thus enhancing the chances of material waste and higher costs of material handling. In the absence of any definite channel for material flow material handling does not readily land itself to mechanisation and elimination of manual labour. There are situations where work in progress may return to the same department more than once for processing.

2. **Longer Processing Time**—The speed of the various operations in the system is likely to be low as more time is required for material handling, transportation and inspection. The total processing in process layout is greater than that required for processing the same work in product layout.
3. **Requires Substantial Production Planning and Control**—With increase in the size of the plant and the variety of operations it can perform, the functions of co-ordination of various processes and operations becomes diffcult and complicated. The routing and scheduling is more cumbersome and time consuming. The responsibility for production is divided among many departmental supervisors, making accountability for the work progress more difficult. Each order has different list of materials and specifications needing separate routing and scheduling sheets.
4. **Require more Floor Space**—A larger proportion of the floor space is required for service activities in comparison to the total plant area devoted to actual production operation. There is need for more space between work stations due to aisles, storage and inspection.
5. **Inspection is more Frequent and Costlier**—Since each department performs score specialised operations, inspection is necessary before the work goes to next operation in another department. Strict departmental responsibility for the quality of the work done by it is the main reason for thorough inspection in each department.
6. **Requires Highly Skilled Labour Creating Difficulty in Labour Procurement**—Workers should be trained to operate a number of general purpose machines doing variety of work and performing many specialised operations. Due to complex and versatile labour is required.
7. Machine loading is quite high.
8. Buffer stock is essential.
9. High investment in raw materials and WIP (Work-in-progress).
10. Work in progress or stocks of semi-finished goods may be accumulated.

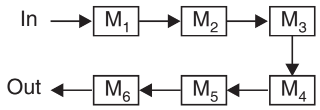
(*b*) **Product Layout:** It is also known as line processing layout or flow line layout. In this type, the position of a particular machine/equipment is determined at some definite stage or place where the machine is required to perform some operations from a sequence of operations designed to manufacture the product it is assumed that materials are transformed into product through a series of integrated operations arranged in a ordered sequence. The position and order in the sequence for a machine performing particular operation is fixed. Once a machine is in line it cannot perform any operation, which is not designated in the sequence of operations. This layout can be of following shapes.



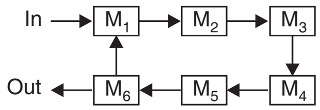
Line Layout



'S' shape layout



'U' shape layout



Circular or 'O' shape layout

Equipment/machines are arranged according to the needs of the product and in the same sequence as the operations are necessary for manufacture.

There is a continuous flow of material during the production process from start to finish. This type of layout is used for continuous type of manufacturing system, producing items of the same type on mass scale. *e.g.*, textile, sugar, petroleum, paper and pulp etc.

Manufacturing of a large quantity of standardised products is the primary requisite to the line production upon which the product layout is based. In its each workstation must employ machines/equipment of approximately equal capacitor in order to achieve good equipment utilization balance. *e.g.*, flour mills, sugar refineries, cement plants, rolling mills. Many companies involved in special/job lot work as well as manufacture of standardised products in fairly large quantities adopt straight—line production methods.

Advantages

Important advantages are as below:

1. Ensures smooth and regular flow of materials and finished goods.
2. Provides economy in materials and labour by minimising waste.
3. **Short Processing Time**—Since travel, storage and inspection occurs less frequently, time and opportunity for delay in operations are minimised. Due to shortening of processing time the stock of finished goods and raw materials be held for shorter periods, which lead to reduction in investment on working capital and provides high return rate on investment.
4. **Reduces Material Handling**—In this system, there are direct channels of materials flow, short distances between operations, lesser back-tracking etc. This reduces proportion of material handling requirements. Low cost mechanical transport system introduces labour savings. Thus savings from low cost materials handling is one of the primary advantage of product handling and of product layout.

5. **Low Cost Labour Procurement and Lesser Training Requirement—** One can use special purpose automatic or semi-automatic machines. Greater specialisation of jobs results in highly proficient operations at each work centre. Sub-division and simplification of operations on the production line reduces the total time required to train the employee. There is maximum use of unskilled and semi-skilled labour.
6. **Lesser Inspection—**A limited amount of end inspection supplemented by spot-scheduling or patrolling inspection is usually sufficient. This leads to low cost quality control.
7. **Smaller Floor Area per Unit of Product—**There are not many storage spaces and inspection stations. The concentration of manufacturing facilities and the high output in product layout results in a smaller floor area per unit of product *i.e.,* with better and efficient processing conditions the output increases.
8. **Easy Production Control—**Due to standardised operations, routing and scheduling is to be done in the beginning only. This facilitates production planning and control problem.

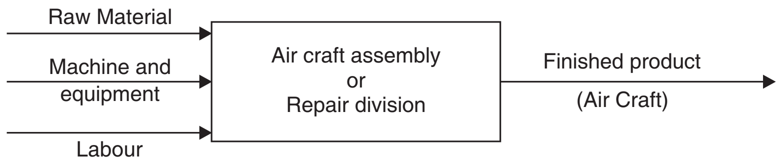
   A steady flow of production at a predetermined rate and at a known cost can be easily ensured.
9. Minimum need for the buffer stock.

Disadvantages

1. **Product Layout is of Inflexible Nature**—The facilities are designed to perform special operations. The machines cannot be interchanged either in capacity or with regard to any other operations. This results in frequent interruption, expansion change over and more changes of technological obsolescence. In other words the system cannot easily adjust to some modifications in the production process.
2. **Vulnerability to Production Line Shut Down**—If any machine or equipment in production line breaks down the whole production line is immoblised. The reason is that various operations in this system are integrated and coordinated to such a fine degree that considerable machine idleness results if one ore more machines in the system is behind schedule. Such interruption can be due to absentism, poor production scheduling etc.
3. **Supervision is more Difficult**—The system requires more specialised and skilled supervision. The supervision/foreman has to supervise wide range of diversified activities for which they should have thorough knowledge of various machines set ups, kinds of workdone, operating speeds, and feeds, maintenance, loading and scheduling requirements etc. A supervisor under product layout is more prone to neglect one or other of the responsibilities.
4. **Requires Heavy Capital Investment**—In this system there is unavoidable duplication of facilities, which increases the capital investment and risks. A product layout is generally characterised by the combination of high proportion of capital investment relative to labour. High capital investment leads to high over head changes, which may be a burden on the firm in lean periods.

(*c*) **Fixed Position Layout:** 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 components remains in a fixed location and tools, machinery and men as well as other pieces of material 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 usually very bulky.



This kind of layout is also called as fixed location layout, and usually followed in these organisations where products are bulky. Such as—locomotives, ships, boilers, air crafts, generators, construction of building, brick kiln etc.

Advantages

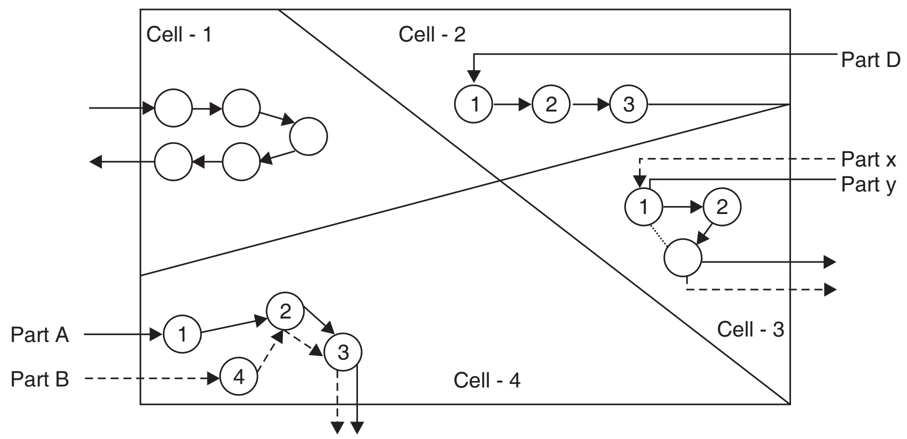
(*i*) Men and machines can be used for a wide variety of operations producing different products.

(*ii*) The investment on layout is very less.

(*iii*) The worker identifies himself with the product and takes pride in it when the work is completed.

(*iv*) The high cost of and difficulty in transporting a bulky product is avoided.

(*d*) **Cellular Manufacturing (CM) Layout:** In this type of layout machines are grouped into cells and the cells function some what like product layout within a larger shop or process layout. Each cell in the CM layout is formed to produce a single parts family-a few parts, all with common characteristics, which means that they require the same machines and have similar machine settings.

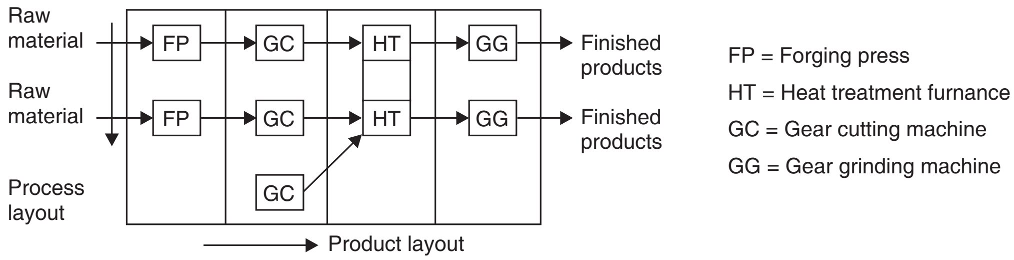


O production operation → Product or material flow

(*e*) **Combined Layout**: The application of the principles of product layout, process layout or fixed location layout in their strict meanings is difficult to come across. A combination of the product and process layout with an emphasis on either, is noticed in most industrial establishments. Plants are never laid out in either pure form. It is possible to have both types of layout in an efficiently combined form if the products manufactured are some what similar and not complex.

NOTES

In plants involving the fabrication of parts and assembly fabrication tends to employ the process layout, while the assembly areas often employ the product layout. In soap manufacturing plants, the machinery manufacturing is arranged on the product-line principle; but ancillary services such as heating, the manufacturing of glycerine, the power house, the water treatment plants are arranged on a functional basis.



Importance of Layout

The importance of a layout would be better appreciated if one understands the influence of an efficient layout on the manufacturing function. Operating efficiencies, such as economics in the cost of handling materials, minimisation of production delays and avoidance of bottlenecks—all these depends on a proper layout.

A ideally laid out plant reduces manufacturing costs through reduced materials handling, reduced personnel and equipment requirements and reduced in—process inventory.

The objectives or advantages of an ideal layout are as below:

(*a*) Economics in handling
(*b*) Effective use of available area
(*c*) Minimisation of production delays
(*d*) Improved quality control
(*e*) Minimum equipment investment
(*f*) Avoidance of bottlenecks
(*g*) Better production control
(*h*) Better supervision
(*i*) Improved utilisation of labour
(*j*) Improved employee morale
(*k*) Avoidance of unnecessary and costly change.

Economics in Handling—Nearly 30–40% of the manufacturing costs is accounted for, by materials handling. Every effort should, therefore, be made to cut down on this cost. Long distance movements should be avoided and specific handling operations must be eliminated. A cynic may say that the cheapest way to handle materials is not to handle them at all. But, in a factory materials have to be handled and therefore, the answer to the question how best to avoid handling depends on layout.

Effective Use of Available Area—Every inch of the plant area is valuable, specially in industrial/urban areas. Efforts should therefore be made to make use of the available area by planning the layout properly. Some steps for achieving this end are—locations of equipment and services in order that they may perform multiple functions, developments of up-to-date work areas and operation job assignments for a full utilisation of the labour force.

Minimisation of Production Delays—Repeat orders and new customers will be the result of prompt execution of orders. Every management should try to keep to the delivery schedules. Often, the dead lines dates for delivery of production orders are a bug-a-boo to the management.

Plant layout is a significant factor in the timely execution of orders. An ideal layout eliminates such causes of delays as shortage of space, long distance movements of materials, spoiled work and contributes to the speady execution of orders.

Improved Quality Control—Timely execution of orders will be meaningful when the quality of the output is not below expectations. To ensure quality, inspection should be conducted at different stages of manufacture. An ideal layout provides for inspection to better quality control.

Minimum Equipment Investment—Investment on equipment can be minimised by planned machine balance and location, minimum handling distances, by the installation of general purpose machines and by planned machine loading. A good plant layout provides all these advantages.

Avoidance of Bottlenecks—Bottlenecks refer to any place in a production process where materials tend to pile up or produced at rates of speed, less rapid than the previous or subsequent operations. Bottlenecks are caused by inadequate machine capacity inadequate storage space or low speed on the part of the operations. The results of bottlenecks are delayed in production schedules, congestion, accidents and wastage of floor area. All these may be overcome with an efficient layout.

Better Production Control—Production control is concerned with the production of a product of the right time and at seasonable cost. A good plant layout is a requisite of good production control and provides the plant control officers with a systematic basis upon which to build organisations and procedures.

Better Supervision—A good plant layout ensures better supervision in following two ways :

(*i*) Determining the number of workers to be handled by a supervisor.

(*ii*) Enabling the supervisor to get a full view of the entire plant at one glance.

A good plant layout is, therefore, the first step in good supervision.

Improved Utilisation of Labour—Labour is paid for every hour it spends in the factory. The efficiency of a management lies in utilising the time for productive purpose. A good plant layout is one of the factors in effective utilisation of labour. It makes possible individual operations, the process and flow of materials handling in such a way that the time of each worker is effectively spent on productive operations.

Improved Employee Morale—Employee morale is achieved when workers are cheerful and confident. This state of mental condition is vital to the success of any organisation. Morale depends on:

(*i*) Better working condition (*ii*) Better employee facilities

(*iii*) Reduced number of accidents (*iv*) Increased earnings

Plant layout has a bearing on all these.

Avoidance of Unnecessary and Costly Changes—A planned layout avoids frequent changes which are different and costly. The incorporation of flexibility elements in the layout would help in the avoidance of revisions.

Layout Planning

What so ever designs and installs of a layout, there is no readymade method for preparing it. The process of preparing a layout is an art as well as a service, inspite of the advances made in the use of layouts. The final layout will be a consummation of many trials, errors and compromises. Which emerges out of trails and errors, may not be the best.

NOTES

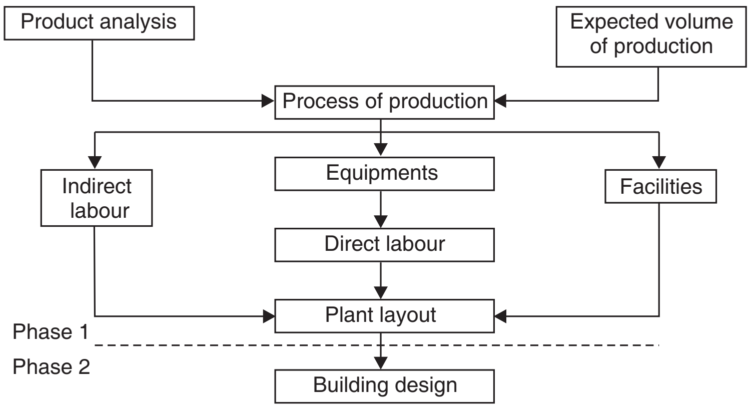
To make the final layout as perfect as possible, the layout personnel would do well to proceed step by step in the process of layout planning. These steps are as below:

Broadly the layouts are divided into the phases as—phase 1, 2, 3,...

Subsequently these phases are sub-divided into the various following steps:

1. Product Analysis
2. Expected volume of production
3. Process of production
4. Requirement of equipments
5. Requirement of facilities
6. Requirement of indirect labour
7. Requirement of direct labour
8. Blue print of plant layout
9. Building design.

The layout procedure might start with an analysis of the product to be manufactured and the expected volume of its production. An analysis of the product includes a study of make or buy etc., and the stages at which they should be assembled to obtain the end product. The volume of production is estimated in terms of market and management policies.



For a given product, at a stated volume of production, a most appropriate process must be determined. Process that is determined is also like other factors is not permanent as the volume of production increases the production process also changes. Consumer demands are changed cause change in the product. Technological developments change the equipment/machines.

The process which is decided upon, determines the type of equipment that would be needed to manufacture a given product at a given volume. The equipment requirements of a company vary with its methods of grouping machines or the type of layout , the main consideration being an increasing use of machines and not of labour. The equipment, which is selected, determines the number of workers that will be required.

These days with the latest development of technology the production processes are usually machine oriented instead of labour oriented. This not only helps in more production but also reduces cost, better quality as well as less labour oriented problems. The number of labours can be reduced with more mechanisation but it can be fully dispersed with.

Product and volume have led to a process which dictates the type of equipment which would be acquired and which in turn would require operators. But operators require the services of indirect labour of material handler, maintenance staff, quality control staff and production supervisors. etc. The arrangement of all these facilities and personnel constitutes the plant layout. Once the plant layout is designed, the layout engineer often engages the services of an architect or the construction division of the company to design the system.

SUMMARY

- Project leaders seldom get better until they know how to do it right. Project is only a one time set of activities that has definite beginning and ending points in time.
- A project starts with statement of work to be carried out. This underlines the objectives to be achieved, which is to be done and a proposed schedule specifying the start and finish dates. The project is further sub-divided into a number of tasks and sub-tasks to be performed/carried out. By one group of the organisation within a period of less than a year sub-tasks may further be sub-divided into meaningful pieces.
- In a project a work package is a group of activities combined together so that these can be conveniently assigned to a single organisational unit of the system.
- It defines the hierarchy of project tasks, subtasks and work packages. Completion of one or more work packages results in the completion of a subtask, completion of one or more subtasks results in the completion of a task; and finally the completion of all tasks is required to complete the project.
- Before the starting of project, the senior management must decide among the organizational structures, which will be used to the project to the parent firm.
- There are basically following three types of organizational structure: (*i*) Pure project (*ii*) Functional project (*iii*) Matrix.
- **Pure Project.** These are those projects where a self contained team works full time on the project.
- **Functional Projects.** In this form of project the organisation spectrum is functional means the project is very much within the parent organisation.
- **Matrix Project.** It is a mixture of pure as well as functional project structure. In this type a proper blending of pure and financial project is done to suit the requirements of the particular organisation.
- New products are not realities until they are manufactured. Process design is necessary to manufacture new products. Process design means the complete delineation and description of specific steps in the production process and the linkages among the steps that will enable the production system to produce products of the desired quality, in the required quantity at the time, customers want them and at the budgeted cost.
- There are five types of distinguished process: (*a*) Project, (*b*) Job shop, (*c*) Batch assembly, (*d*) Line, (*e*) Continuous.
- It may be understood as the function of determining where the plant should be located for maximum operating economy and effectiveness. 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.

NOTES

- Once a decision about location of the plant has been taken the next important problem before the management is to plan suitable layout for the plant.

QUESTIONS

1. What is a workbreakdown structure?
2. What is an organisational structure?
3. Explain pure project and functional project and matrix project?
4. What is a process design?
5. Explain the relationship between product design and process design.
6. Explain the organising process flows.
7. Explain the organising approach to process planning and design.
8. What do you understand by plant location.
9. Explain plant layout.
10. What is the importance of layout?

4. INVENTORY MANAGEMENT

NOTES

STRUCTURE

- Inventory Concepts
- Two Forms of Demand
- Inventory Systems
- Inventory Costs
- Variables Used in Inventory Models
- Assumptions of Basic EOQ Model
- Gradual Replacement Model
- Concept of Quantity Discount
- Lead Time in Deterministic Models
- ABC Analysis
- Material Requirement Planning
- Benefits of MRP

Summary

Inventory management answers two questions

- How much to order?
- How much to order?

Inventory is stores of goods and stocks, including raw material, work in progress, finished products or supplies. In manufacturing, items in inventory are called stock keeping items, held at a storage or stock point.

In simple words inventory in Stock of items held to meet future demand.

INVENTORY CONCEPTS

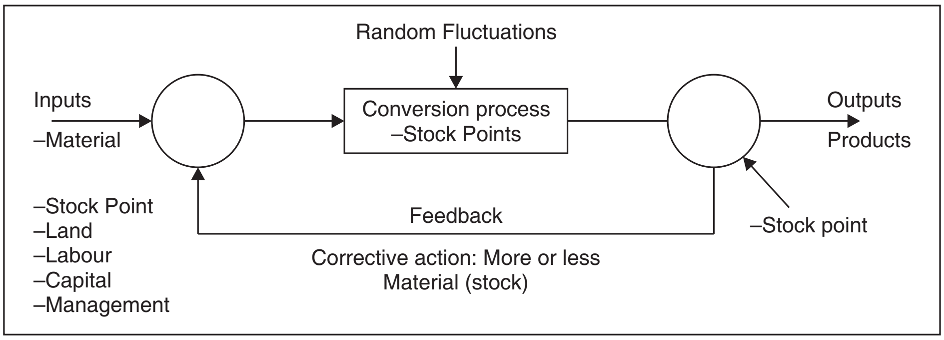


Fig. 4.1. Inventory process

NOTES

Types of Inventory

- Raw materials
- Purchased parts and supplies
- Labour
- In process (partially completed) products
- Component parts
- Working capital
- Tools, machinery, and equipment
- Finished goods

Reasons to Hold Inventory

- Meet unexpected demand
- Smooth seasonal or cyclical demand
- Take advantage of price discounts
- Hedge against price discounts
- Quantity discounts.

TWO FORMS OF DEMAND

Dependent Demand

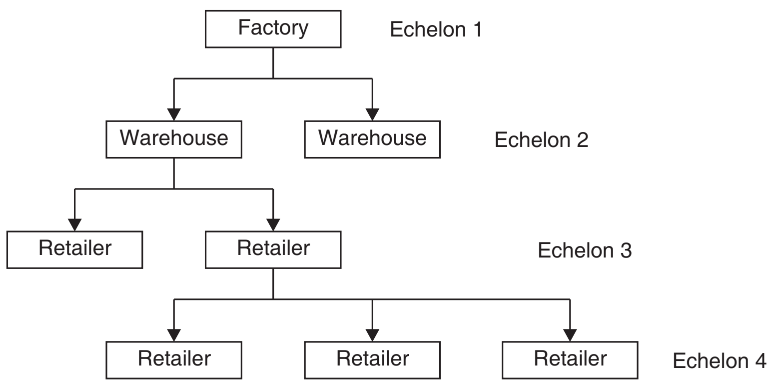
It is the demand for the items used to produce final products.

Independent

It is the demand for the items used to produce final products.

Some important terms used in inventory control are as follows:

1. *Buffer stock*: Inventories to protect against the effects of usual product demand and uncertain lead time.
2. *Lead Time*: The time passing between ordering and receiving goods.
3. *Multi Echelon Inventories*: The products are stocked at various levels-Factory, warehouse, retailer, customer in a distribution system.



4. *Reorder Point*: The inventory level at which stock should be reordered.
5. *Order Quantity*: The amount of stock that should be reordered.

NOTES

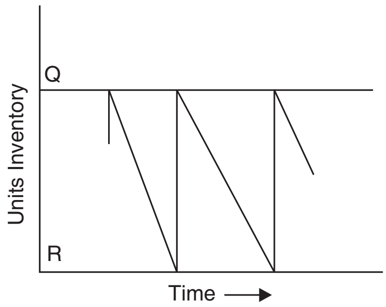
INVENTORY SYSTEMS

Q/R Inventory System

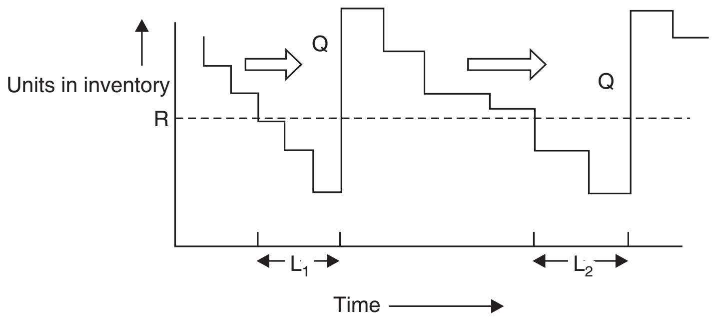
Features

- Constant Usage rate.
- Economic Order Quantity (EOQ) is fixed.
- Reorder Point R is fixed.
- Lead time = 0

Q/R system with usage rate fixed



Q/R System with usage rate variable:



Periodic Inventory System–Based on Periodic Review

AP system uses a fixed time period for review and varies the quantity of the order

The inventory Position (IP) is reviewed every T time periods

An order is placed for a quantity *q* which is equal to:

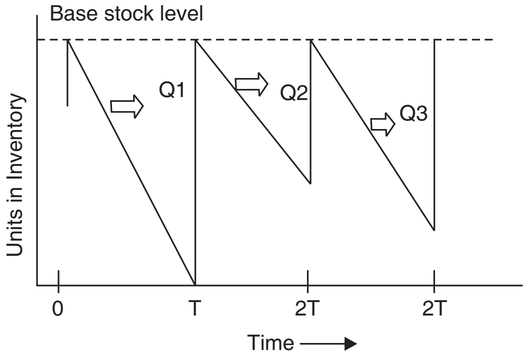
q = Q – IP where Q is the target inventory (desired inventory position just after an order is placed)

Inventory position is calculated the same way as n the Q system

Features

- *Reorder points and order quantities vary.*
- *Stocks are replenished up to a fixed base stock level after a fixed time period has passed.*
- *Lead Time = 0*

NOTES



INVENTORY COSTS

Cost of them: The cost or value of the item is usually its purchase price the amount paid to the supplier for the item. Transportation, receiving or inspection may be included as part of the cost of the item.

Carrying or Holding Cost

Carrying cost are the cost of maintaining the inventory warehouse and protecting the inventoried items. Typical costs are insurance, security, warehose rental, light, taxes and losses due to spoilage or breakage.

Ordering Cost

Cost of placing a purchase order or setup costs if item is manufactured at the facility. These include costs of postage, telephone calls to the vendor etc.

Shortage Cost/Stock Out Cost

Temporary or permanent loss of sales when deman cannot be met

VARIABLES USED IN INVENTORY MODELS

- D = Total annual demand (In units)
- Q = Quantity Ordered (in units)
- Q* = Economic Order Quantity (EOQ) in units
- R = Reorder point (in units)
- L = Lead Time (in time units)
- S = Ordering cost/order
- C = Cost of the individual item
- I = Carrying cost per unit carried, expressed as a % of unit cost C.
- DL = Demand during lead time
- TC = Total annual relevant cost
- TC* = Minimum total annual relevant cost

NOTES

Mainly there are two types of inventory models.

1. Deterministic Inventory Model – Certain Demand
2. Stochastic Inventory Model – Uncertain Demand

We are here dealing with only deterministic inventory model. There are of two types:

1. Basic EOQ Model
2. Gradual repalcement model.

ASSUMPTIONS OF BASIC EOQ MODEL

- Demand is constant and known with certainity
- No shortages are allowed
- Lead time for the receipt of orders is constant and independent of demand,
- The order quantity is received all at once
- Cost per unit is constant.

Mathematical Formulation

Total cost (TC) = Purchasing Cost + Ordering cost

+ Carrying cost + Stock out cost ...(1)

Purchasing cost = C * D

Ordering cost = Cost per order * No of order = S * D/Q

Carrying cost = Cost of carrying one unit * Average number of unit held per year.

For any one cycle

Average inventory per cycle = (Maximum Inventory + Minimum Inventory)/2

Average inventory = (Q + 0)/2

Substituting the above in equation (*i*)

TC = CD + SD/Q + ICQ/2 ...(*ii*)

Stock out cost being 0.

Our objective is to find out the quality for which the total cost (TC) is minimum.

So differentiating equation (*ii*) w.r.t. Q and putting d TC/d Q = 0. We get

$Q^* = \sqrt{2}$ DS/IC

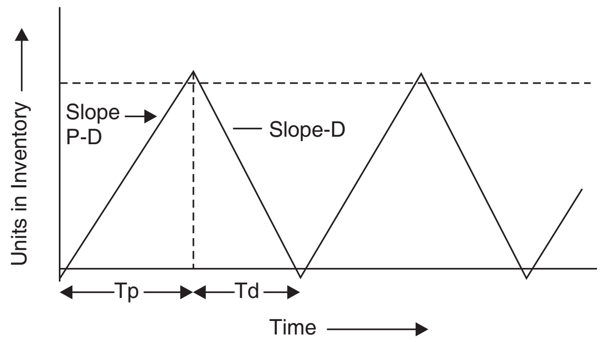
GRADUAL REPLACEMENT MODEL

Assumptions:

- Demand is constant and known with certainty
- No shortages are allowed
- Lead time for the receipt or orders is constant and independent of demand,
- The order quantity is not received all at once
- Cost per unit is constant.

NOTES

Mathematical Formulation



Sometimes part of the order is delivered instantaneously but rest of the order is sent over time. When the order is placed, the supplied, begins producing units which are supplied continuously to the purchaser. While these units are being added to the inventory (causing it to grow), other units are being aken out of inventory (causing it to diminish)

P = Replenishment rate *i.e.*, rate at which inventory is being added.

d = Withdrawal rate *i.e.,* rate at which inventory is being consumed.

During time Tp, the slope of inventory accumulation is not vertical, as it was in basic EOQ model. This is the case because the entire order is not received at a time.

Since P > d during time T_p inventory is consumed as well as built up and this situation continues until the initial order quantity Q has been produced and delivered.

During time T_d order is being consumed only.

Maximum inventory at any point of time would be less than or equal to $Q_{max} < Q$

Total Cost (TC) = Purchasing Cost + Ordering Cost
+ Carrying Cost + Stockout Cost ...(4)

Purchasing Cost = C * D

Ordering Cost = Cost per order * No. of order = S * D/Q

Carrying Cost = Cost of Carrying one unit
* Average number of units held per year

For any one cycle:

Average inventory = $(Q_{max} + 0)/2$

Carrying Cost = IC $Q_{max}/2$

Since stock out cost is zero so:

$$TC = CD + SD/Q + IC\ Q_{max}/2$$

As evident from above figure

$$Q_{max} = (P - d) * T_p$$

Since $T_p = Q/P$ so $Q_{max} = (P - d) * Q/P$

Since our objective is to find the quantity for which total cost is minimum. So

Differentiating eq. (*iii*) w.r.t Q and putting *d* TC/d Q = 0 we get:

$$Q^* = (2DS/IC) * P/P - d$$

CONCEPT OF QUANTITY DISCOUNT

Sometimes Manufacturer encounters a situation when he has more than one price offers at his disposal.

The different price slabs are available for a same raw material depending upon the quantity ordered. As the quantity ordered increases price per unit decreases.

The objective is to find the quantity ordered in way that total cost is minimum.

The above quantity would be called Economic order quantity.

LEAD TIME IN DETERMINISTIC MODELS

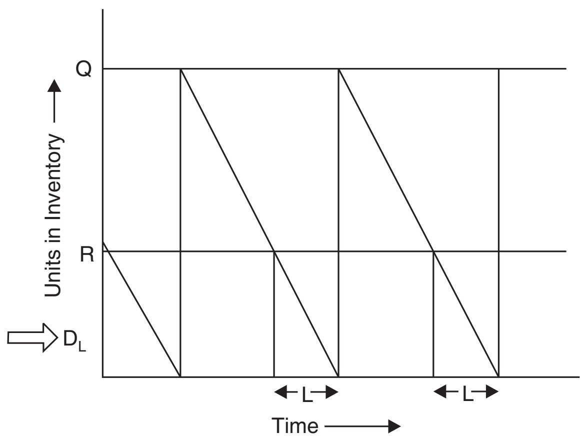
Deterministic models can easily be adjusted for lead times known with certainity. The reorder point is calculated:

R* = Buffer Stock + Demand during lead time

$= O + D_L = 0 + $ (Lead time) (Demand/unit time)

$= L\, d_L$

The reorder point is now set and shown in figure. At R*, an order will be placed for Q* units, which will arrive L units of time later. During the time between ordering and arrival d_L units per time unit, D_L in total will be demanded, and inventory will be reduced accordingly.



Inventory Planning Uncertainty

Terms: Used

Continuous DDLT Distributions: Probability distribution of all possible demand during lead time (DDLT) values where DDLT is continuous random variable. In other words DDLT can take any value continuously between the extreme DDLT values of distribution.

DDLT Distribution Parameters: Measures that describe the DDLT distributions. For example

EDDLT – Expected demand during lead time is the mean of DDLT distribution

NOTES

σ_{DDLT} : Standard deviation of the demand during lead time, the measure of how the DDLT values are dispersed about their mean.

Demand Per Day (d) Distribution Parameters:

$\overline{LT}$ – Mean Lead Time

σ_{LT} – Standard deviation Lead Time, the measure of how the LT values are dispersed about their mean.

EDDLT = LT(d)

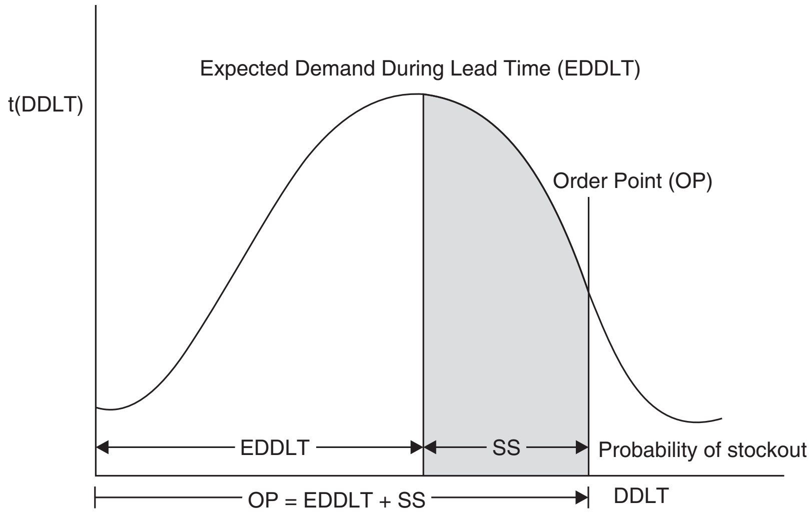
$\sigma_{DDLT} = \sqrt{LT(\sigma_d^2)}$

Optimal Safety Level: The amount of safety stock level, which is the Order Point (OP) minus the Expected Demand During Lead Tmei (EDDLT), that balances the expected long costs and expected short costs during lead time.

Service Level: The probabililty that a stock out will not occur during lead time. For example 90% service level means that there is a 10% probabilty that all the orders cannot be filled from inventory during the lead time.

Risk of Stockout: It is complement of service level

Relationship Among DDLT, EDDLT, SS, OP and Probability of Stockouts for Each Order Cycle



ABC ANALYSIS

ABC stands for "Always Better Control".

For better and more economc control of items in inventory the items should be classified accordingly to their significance or priority for reordering.

Economy is control can be obtained by paying little attention on those items which usually costs less to absorb the lost due to waste than to keep a record. E.g. paper clips, rubber band etc.

NOTES

The inventory is categorized as:

1. Items are functionally critical to the operations, no matter how little they cost.
2. Items that are important because their usage value is high.
3. Items having average usage value.
4. Items which have low usage value.

In ABC analysis the items are categorized in three main components:

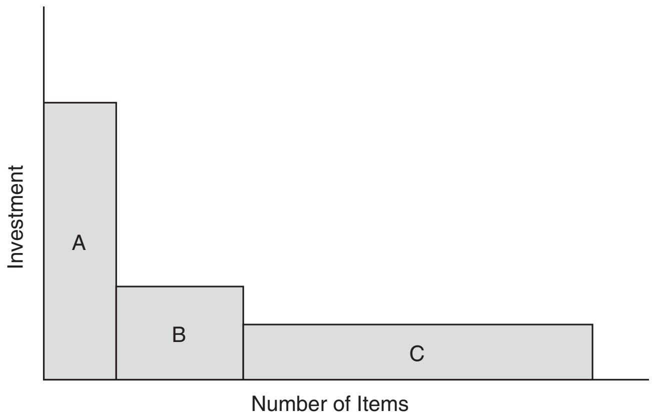
(*i*) More costly and valuable items are classified as **Class A.** These are large investment items but not much in items i.e., vital few say 10% of the items account for 75% of the total capital invested inventory.

(*ii*) Average usage value items are classified as **Class B.** About 15% of the items in an inventory account for 15% of the total investment. These items are less important than A class items but are costly enough to have more attention on their use.

(*iii*) Low usage value items are put in **Class C.** About 75% of the inventory items account for only 10% of the invested capital.

The objective of such classification is to separate out the group C which is large in number and which may potentially require a large amount of record keeping and attention but which is relatively unimportant from the point of view of keeping inventory investment at a reasonable level.

The diagram below shows ABC classification of Inventory



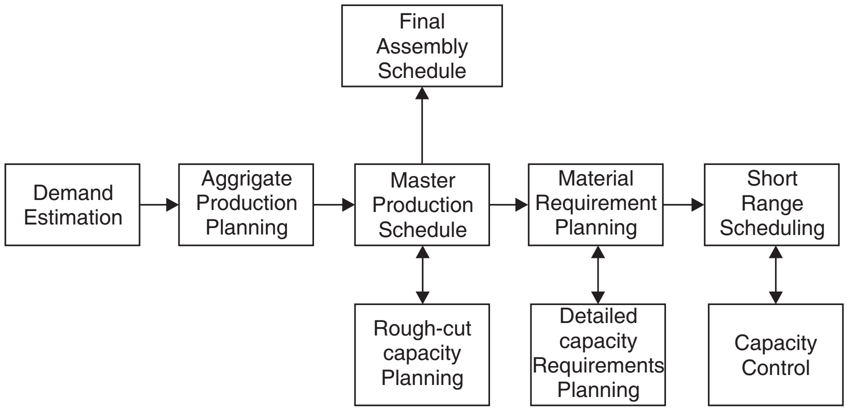
MATERIAL REQUIREMENT PLANNING

MRP is a computational technique that converts Master Schedule (MS) for end products into Detailed Schedule (DS) for raw material. The DS identifies the quantities of each raw material and component items. It also tells which item must be ordered and delivered so as to meet the master schedule for final product.

The purpose of MRP is to ensure that materials and components are available in the right quantity and at right time.

NOTES

Figure below shows the role of MRP.



Functions

- Control of Inventory levels.
- Assignment of priorities for components (depending upon their delivery date).
- Determinatoni of capacity requirement at a detailed level.

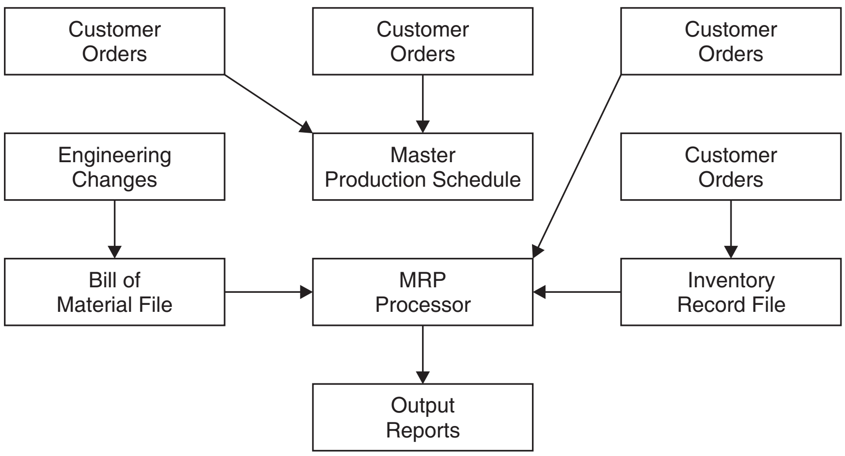
Inputs to the MRP

MRP converts the *Master Productin schedule* (MPS) into DS for raw materials and components. For MRP to perform its functions, it must operate on the data contained in the MS.

The 3 inputs to MRP are

- The MPS and their order data.
- The Bill of Material (BOM) file, which defines product structure.
- The inventory record (IR) file.

Figure below shows the flow of data into MRP processor and its conversion into useful reports.



Master Production Schedule (MPS)

The MS is based on an accurate estimate of demand for the firms products, together with a realistic assessment for its production capacity.

NOTES

The MPS as shown below is list of what end products are to be produced, how many of each product is to be produced and when the products are likely to ready for shipment.

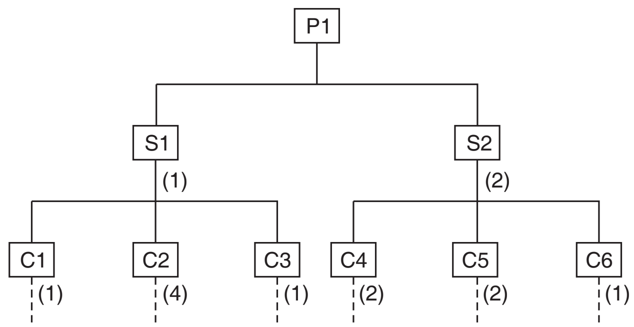
Week Number		6	7	8	9	10
Product P1			50			95
Product P1		40	60	90		
Etc.						

Bill of Materials (BOM) File

In order to compute the raw material and component requirement for the end products listed in mS, the product structure must be known.

This is specified by BOM which is a list of components parts and sub assemblies that make up each product. Putting al these assembly lists together, we have the BOM file.

Figure below shows structure of assembled product. It shows subassembly S1 is parent of components C1, C2 and C3. Product P1 is the parent of sub assemblies S1 and S2. The sub assembly S1 contains 4 of components C2 and one each of components C1 and C3.



Inventory Record File (IRF)

A definition of lead time for the raw material, components and assemblies must be established in IR file. It contains information on the current and future inventory status of each component.

BENEFITS OF MRP

- Reduction in inventory.
- Improved customer service.
- Better machine utilization.
- Greater Productivity.
- Quicker response to change in demand.

NOTES

SOLVED PROBLEMS

Problem 4.1. *If the annual demand for a product is 350,000 units, then the annual arrying cost rate is 25 percent of the cost of the unit; the product costs ₹ 14.75 per unit to purchase, and each time the product is ordered the related ordering cost is ₹ 53.00.*

(*a*) *What is the EOQ?*

(*b*) *What is the TSC at the EOQ?*

(*c*) *How much would the TSC increase if the order quantity must be 2,500 units because of a standard shippin-container size?*

Solution. D = 350,000 units per year

S = ₹ 53 per order

IC = .25(14.75) = ₹ 3.6875 carrying cost per year per unit held

$$EOQ = \sqrt{\frac{2DS}{IC}} = \sqrt{\frac{2(350,000)(53)}{.25(14.75)}} = 3,171.9 \text{ or } 3,172 \text{ units}$$

$$\begin{aligned} TSC &= ICQ/2 + SD/Q \\ &= .25(14.75)\ (3172)/2 + 53(350,000)/3172 \\ &= 5,848.375 + 5,848.045 \\ &= ₹\ 11,696.42 \end{aligned}$$

$$\begin{aligned} TSC &= ICQ/2 + SD/Q \\ &= .25(14.75)\ (2500/2) + 53(350,000)/2500 \\ &= 4,609.38 + 7,420.00 \\ &= ₹\ 12,029.38 \end{aligned}$$

So TSC would increase by (12,029.38 – 11,696.42) = ₹ 332.96

Problem 4.2. *The information systems department of a local university buys paper for its copier machine frequently. Andrea Web, the office manager, would like to determine the best quantity to order each time an order is placed. She has estimated that the ordering cost is ₹ 12 each time an order is placed. The monthly demand for paper is 135 reams (500 sheets to a ream). The cost of paper is ₹ 6.50 per ream, and the carrying cost is 25 percent of the paper cost per month. How many reams should be ordered at a time, and what is the expected average inventory level for copier paper?*

Solution. D = 13 reams per month

S = ₹ 12 per order

IC = 0.25(6.50) = ₹ 1.625 carrying cost per month unit held

$$EOQ = \sqrt{\frac{2DS}{IC}}$$

$$= \sqrt{\frac{2(135)(12)}{.25(6.50)}} = 44.65 \text{ or } 45 \text{ reams}$$

Average inventory level = Q/2 = 45/2 = 22.5 reams

NOTES

Problem 4.3. *State Bank of Inda orders cash from the RBI to meet daily transaction needs. Shyam Lal, the operations manager, estimates that ₹ 5,000,000 in cash will be needed next month. He has estimated that the cost to order, receive, and store each shipment of cash from the RBI will be ₹ 675 per shipment, SBI is open for business 250 days each year. The bank's related carrying cost for cash is 0.65 percent per month. (That is, each Rupee r held in the bank's vault costs 0.0065 per month in foregone profits).*

(*a*) *How much should Shyan order from the SBI each time a cash order is placed?*

(*b*) *What is the expected total annual carrying costs plus ordering cost?*

(*c*) *How many working days should one shipment of cash last SBI?*

Solution. D = ₹ 5,000,000 per month

S = ₹ 675 per order

IC = .0065(1.00) = ₹ 0.0065 carrying cost per month Re held

(D and C are both given in months)

$$EOQ = \sqrt{\frac{2DS}{IC}} = \sqrt{\frac{2(5{,}000{,}000)(675)}{.0065(1.00)}}$$

= ₹ 1,019,049.33

TSC = 12(ICQ/2 + SD/Q)

= 12(.0065) (1.00) (1,019,049.33)/2 + 12(675) (5,000,000)/1,019,049.33

= 39,742.92 + 39,742.92

= ₹ 79,485.84

250[Q/12D] = 250[1,019,049.33/(12*5,000,000)] = 4.25 working days

Problem 4.4. *The peace Care Hospital uses about 3,500 boxes of sterile bandages per month. The annual carrying cost rate is ₹ 2.90 per box per year. A typical box of sterile bandages costs ₹ 14.50 to purchase. The ordering cost is ₹ 25 each time an order is placed, regardless of the order quantity. There is a storage space for at most 1,500 boxes of bandages at any time. The hospital operates 365 days per year. Peace care Hospital would like to use the EOQ model.*

(*a*) *How many boxes of sterile bandages should be ordered each time an order is placed?*

(*b*) *How many orders per year should be expected?*

(*c*) *What is the expected TSC per year?*

(*d*) *How many days should one order last, on average?*

Solution. D = 12(3,500) = 42,000 boxes per year

S = ₹ 25 per order

IC = ₹ 2.90 carrying cost per year per box held

$$EOQ = \sqrt{\frac{2DS}{IC}} = \sqrt{\frac{2(42{,}000)(25)}{2.90}}$$

= 850.96 or 851 boxes

NOTES

D/Q = 42,000/851 = 49.35 orders per year

TSC = ICQ/2 + SD/Q

= 2.90(851)/2 + 25(42,000)/851

= 1,233.95 + 1,233.84

= ₹ 2,467.79

Order will last for

365(Q/D) = 365(851/142,000) = 7.4 days

Problem 4.5. *The production rate of final assembly is 2,400 digital video discs (DVDs) per day. After DVDs are assembled, they go directly to finished-goods inventory. Customer demand averages 1,300 DVDs per day, or about 352,000 per year. It costs ₹ 700 to set up the assembly line for the DVDs, the cost per DVD is ₹ 2.30, and the carrying cost rate is 30 percent of product cost per year.*

(*a*) *How many DVDs should be in a production batch at final assembly?*

(*b*) *What is the annual TSC at the EOQ?*

Solution. D = 325,000 DVDs per year

S = ₹ 700 per batch

IC = .30(2.30) = ₹ 0.69 carrying cost per year per box held

p = 2,400 DVDs per day production rate

d = 1,300 DVDs per day demand rate

$$EOQ = \sqrt{\frac{2DSp}{IC(p-d)}} = \sqrt{\frac{2(325{,}000)(700)(2400)}{.30(2.30)(2400-1300)}}$$

= 37,930.66 or 37,931 units

TSC = ICQ(p – d)/[2p] + SD/Q

= .30(2.30) (37,931) (2400 – 1300)/[2(2400)]

+ 700(325,000)37,931

= 5,997.84 + 5,997.73

= ₹ 11,995.57

Problem 4.6. *Mathura Oil Refinery buys crude oil on a long-term supply contract for ₹ 38 per barrel. When shipments of crude oil are made to the refinery, they arrie at the rate of 12,000 barrels per day. Mathura Oil uses the oil at a rate of 5,000 barrels per day and plans to purchase 600,000 barrels of crude oil next year. If the carrying cost is 30 percent of acquisition cost per unit per year and the ordering cost is ₹ 11,600 per order:*

(*a*) *What is the EOQ for the crude oil?*

(*b*) *What is the TSC at the EOQ?*

(*c*) *How many days worth of demand are supported by each order of crude oil?*

(*d*) *How much needed storage capacity is expected for the crude oil?*

Solution. D = 600,000 barrels per year

S = ₹ 11,600 per order

IC = .30(38.00) = ₹ 11.4 carrying cost per year barrel held

p = 12,000 barrels per day supply rate

d = 5,000 barrels per day demand rate

NOTES

$$EOQ = \sqrt{\frac{2DSp}{IC(p-d)}} = \sqrt{\frac{2(600{,}000)(11{,}600)(12{,}000)}{.30(38.00)(12{,}000-5{,}000)}}$$

= 45,752 barrels

TSC = ICQ(p – d)/[2p] + SD/Q

= .30(38.00) (45,752) (12,000 – 5,000)/[2(12,000)]
+ 11,600(600,000)/45,752

= 152,125.40 + 152,124.50

= ₹ 304,249.90

No of days.

Q/d = 45,752/5,000 = 9.15 days

maximum inventory = (p – d)Q/p = (12,000 – 5,000) (45,752)/12,000 = 26,688.7

Problem 4.7. *Clips Inc., sells discounted office supplies over the Internet. One popular product sold is legal-size notepads, which are ordered by many law firms. Clip supplies offers the following quantity discount structure, based on how many dozen notepads are ordered: 1–19 dozen. ₹ 21.95 per dozen; 20–99, ₹ 19.95 per dozen; 100–199, ₹ 18.95 per dozen; 200+, ₹ 17.95 per dozen. The ABC law firm would like to decide how many legal notepads to order using the EOQ model for quantity discounts. Its ordering cost is ₹ 35 per order, its anticipated need in the coming year is for 1,500 dozen notepads, and itss annaul carrying cost rate is 40 percent of acquisition cost.*

(*a*) *How many dozen notepads should ABC order each time?*

(*b*) *What would be the resulting total inventory cost per year (ordering plus carrying plus materials)?*

(*c*) *How many order/year should be expected?*

(*d*) *What is the expected maximum inventory level of notepads?*

(*e*) *If ABC has only enough storage space for 150 dozen notepads, how many should it order each time?*

Solution. D = 1,500 dozen per year

S = ₹ 35 per order

IC = 40(ac) carrying cost per year dozen held

First, compute the EOQ at each acquisition cost level:

$$EOQ = \sqrt{2DS/I[C_i]}$$

For ac_1 = ₹ 21.95:

$$EOQ_1 = \sqrt{2(1500)(35)/[.40(21.95)]} = 109.36 \text{ or } 109 \text{ dozen} \quad \text{(infeasible)}$$

For ac_2 = ₹ 19.95:

$$EOQ_2 = \sqrt{2(1500)(35)/[.40(19.95)]} = 114.71 \text{ or } 115 \text{ dozen} \quad \text{(infeasible)}$$

For ac_3 = ₹ 18.95:

$$EOQ_3 = \sqrt{2(1500)(35)/[.40(18.95)]} = 117.70 \text{ or } 118 \text{ dozen} \quad \text{(feasible)}$$

For ac_4 = ₹ 17.95:

$$EOQ_4 = \sqrt{2(1500)(35)/[.40(17.95)]} = 120.93 \text{ or } 121 \text{ dozen} \quad \text{(infeasible)}$$

NOTES

Next, check the total inventory cost for 118 dozen @ ₹ 18.95 and for 200 dozen @ ₹ 17.95:

TC = ICQ/2 + SD/Q + D(ac)

For 118 dozen @ ₹ 18.95

TC = .40(18.95) (118)/2 + 35(1500)/118 + 1500(18.95)
= 447.22 + 444.92 + 28,425.00
= ₹ 29,317.14

For 200 dozen @ ₹ 17.95

TC = .40(17.95) (200)/2 + 35(1500)/200 + 1500(17.95)
= 718.00 + 262.50 + 26,925.00
= ₹ 27,905.50

AB should order 200 dozen at acost of ₹ 17.95 for each dozen

TC = ₹ 27,905.50

orders per year:

D/Q = 1,500/200 = 7.5 orders per year

maximum inventory level of notepads Q = 200 dozen

If the maximum inventory level cannot exceed 150 dozen, then the cost ₹ 17.95 per Dozen would not be allowed since 200 dozen cannot be stored.

In this case the best order quantity would be 118 dozen at ₹ 18.95 per dozen.

Problem 4.8. *A grocery store orders paper grocery bags from a distributor. The store uses about 2,300 cases of bags per year, and its ordering cost is ₹ 65 per order. The store's carrying cost rate is 35 percent of acquisition cost. The distributor has the following pricing structure for cases of bags: 1–49 cases, ₹ 129.95 per case; 50–249, ₹ 127.95 per case; 250–999, ₹ 126.95 per case; 1000+, ₹ 125.95 per case.*

(*a*) *How many cases of bags should the store order each time?*

(*b*) *What would be the resulting total inventory cost per year (ordering plus carrying plus materials)?*

(*c*) *How many orders per year should be expected?*

(*d*) *What is the expected maximum inventory level of paper bags (in cases)?*

(*e*) *If the store has only enough storage space for 200 cases of bags, how many should in order each time?*

Solution. D = 2,300 cases per year
S = ₹ 65 per order
C = .35(ac) carrying cost per year per case held

First, compute the EOQ at each acquisition cost level:

$$EOQ_i = \sqrt{2DS/[IC_i]}$$

For ac_1 = ₹ 129.95:

$$EOQ_1 = \sqrt{2(2300)(65)/[.35(129.95)]} = 81.08 \text{ or } 81 \text{ cases} \quad \text{(infeasible)}$$

For ac_2 = ₹ 127.95:

$$EOQ_2 = \sqrt{2(2300)(65)/[.35(127.95)]} = 81.71 \text{ or } 82 \text{ cases} \quad \text{(feasible)}$$

For ac_3 = ₹ 126.95:

$$EOQ_3 = \sqrt{2(2300)(65)/[.35(126.95)]} = 82.03 \text{ or } 82 \text{ cases} \quad \text{(infeasible)}$$

For ac_4 = ₹ 125.95:

$$EOQ_4 = \sqrt{2(2300)(65)/[.35(125.95)]} = 82.36 \text{ or } 82 \text{ cases} \quad \text{(infeasible)}$$

Next, check the total inventory cost for 82 cases @ 127.95, for 250 casess @ ₹ 126.95, and for 100 cases @ ₹ 125.95

TC = ICQ/2 + SD/Q + D(ac)

For 82 cases @ ₹ 127.95:

TC = .35(127.95) (82)/2 + 65(2300)/82 + 2300(127.95)

= 1,836.08 + 1,823.17 + 294,285.00

= ₹ 297,944.25

For 250 cases @ ₹ 126.95:

TC = .35(126.95) (250)/2 + 65(2300)/250 + 2300(126.95)

= 5,554.06 + 598 + 291,985.00

= ₹ 298,137.06

For 1000 cases @ ₹ 125.95:

TC = .35(125.95) (1000)/2 + 65(2300)/1000 + 2300(125.95)

= 22,041.25 + 149.50 + 289,685.00

= ₹ 311,875.75

Problem 4.9. *An auto dealership has experienced the following historical demands during lead tmes for Ford half-ton pickup trucks.*

Actual DDLT	*# of Occurrences*	*Actual DDLT*	*# of Occurrences*
7	2	12	6
8	6	13	11
9	4	14	9
10	8	15	3
11	7	16	1

This data covers the dealership's past 57 orders to Ford. The replenishment lead time is five days to receive an order of trucks.

(*a*) *Compute the order point using a 90 percent service level.*

(*b*) *Compute the expected demand during lead time.*

(*c*) *What is the effective level of safety stock resulting from this order point?*

NOTES

Solution. First prepare a cumulative distribuution of DDLT:

Actual DDLT	*# of Occurrences*	*Probability*	*Cumulative Probability*	
7	2	0.0351	0.0351	
8	6	0.1053	0.1404	
9	4	0.0702	0.2105	
10	8	0.1404	0.3509	
11	7	0.1228	0.4737	
12	6	0.1053	0.5789	
13	11	0.1930	0.7719	
14	9	0.1579	0.9298	← at least 90%
15	3	0.0526	0.9825	
16	1	0.0175	1.0000	
	57	1.0000		

The order point should be set at 14 trucks to expect at least a 90 percent service level.

To compute the expected demand during lead time (EDDLT)

$$\text{EDDLLT} = \Sigma[(\text{actual DDLT level}) \times (\text{probability})]$$

$$\text{EDDLLT} = 7(.0351) + 8(.1053) + 9(.0702) + 10(.1404) + 11(.1228)] + 12(.1053) + 13(.1930) + 14(.1579) + 15(.0526) + 16(.0175)$$

$$\text{EDDLT} = 11.53 \text{ trucks}$$

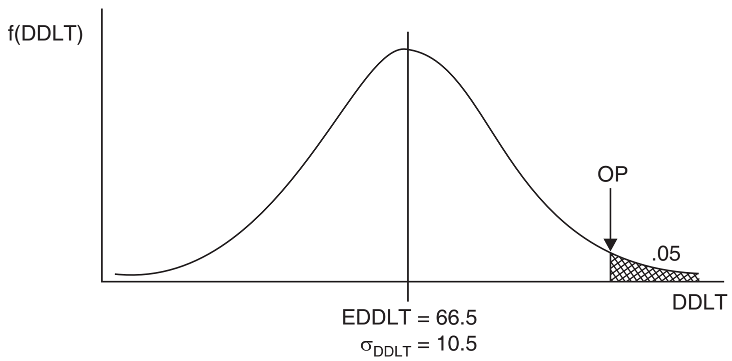
$$\text{OP} = \text{EDDLT} + \text{SS}$$

$$\text{SS} = \text{OP} - \text{EDDLT} = 14 - 11.53 = 2.47$$

Problem 4.10. *If EDDLT = 65.5 units, σ_{DDLT} = 10.5 units, DDLT is normally distributed, and service level is 95 percent:*

(*a*) *What is the order point?* (*b*) *What is the safety stock level?*

Solution.



Z at 95% service level = 1.64

$$\text{OP} = \text{EDDLT} + Z(\sigma\text{DDLT})$$

$$= 65.5 + 1.64(10.5) = 65.5 + 17.22$$

$$= 82.72 \text{ units}$$

NOTES

The safety stock level is

$$SS = OP - EDDLT$$
$$= 82.72 - 65.5$$
$$= 17.22 \text{ units}$$

Problem 4.11. *A part used to repair machines has a normally distributed monthly demand with a mean of 65.0 and a standard deviation of 5.2. If lead time is so predictable that it can be considered a constant 0.25 month and the service level is 90 percent:*

(*a*) *What is the order point?*

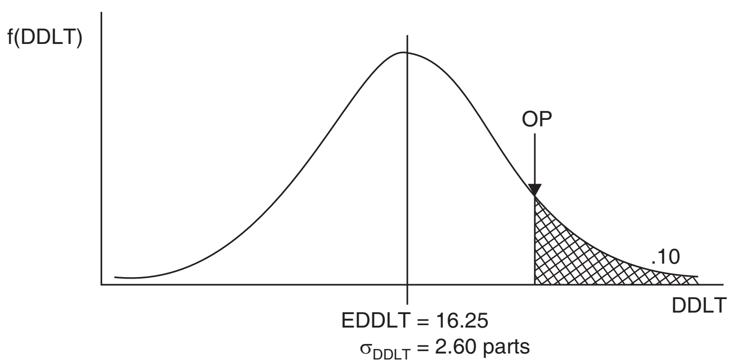
(*b*) *What is the safety stock level?*

Solution. $EDDLT = (\text{lead time}) \times (\text{monthly demand})$

$$= LT(d) = .25(65) = 16.25 \text{ partd}$$

$$\sigma_{DDLT} = \sqrt{LT(\sigma_d)^2} = \sqrt{.25(5.2)^2} = 2.60 \text{ parts}$$

This graph depicts the DDLT



$$OP = EDDLT + Z(\sigma_{DDLT}) = (16.25 + 1.28(2.60) = 19.58 \text{ parts}$$

The safety stock level is

$$SS = OP - EDDLT$$
$$= 19.58 - 16.25$$
$$= 3.33 \text{ parts}$$

Problem 4.12. *If j = 30 percent and EDDLT = 740 units:*

(*a*) *Compute the safety stock using the percentage of EDDLT method.*

(*b*) *Compute the order point using the percentage of EDDLT method.*

(*c*) *Compute the safety stock using the square root of EDDLT method.*

(*d*) *Compute the order point using the square root of EDDLT method.*

Solution.

j = 30 percent, and EDDLT = 740 unit

(*a*) The safety stock using the percentage of EDDLT method is

$$SS = j(EDDLT) = .30(740) = 222 \text{ units}$$

(*b*) The order point using the percentage of EDDLT method is

$$OP = EDDLT + SS = 740 + 222 = 962 \text{ units}$$

NOTES

(*c*) The safety stock using the square root of EDDLT method is

$$SS = \sqrt{EDDLT} = \sqrt{740} = 27.2 \text{ or } 27 \text{ units}$$

(*d*) The order point using the square root of EDDLT method is

$$OP = EDDLT + SS = 740 + 27 = 767 \text{ units}$$

Problem 4.13. *The maintenance manager of a local manufacturing company wants to decide on a safety stock level and order point for a machine lubricating oil used by many of the company's machines. The typical usage of lubricating oil is 65-quarts per week. The oil is ordered from a company in Assam and the replenishment lead time is 2.6 weeks to receive a shipment of oil. The company's policy is to carry 40 percent of EDDLT as safety stock for consumable supplies.*

(*a*) *What is the expected demand during lead time for this lubricating oil?*

(*b*) *How many quarts of oil should be carried as safety stock?*

(*c*) *How many quarts of oil should be left when a replenishment order is placed?*

Solution.

(*a*) EDDLT = (lead time) × (weekly demand) = LT(d) = 2.6(65) = 169 quarts

(*b*) safety stock SS = j(EDDLT) = .40(169) = 67.6 or 68 quarts

(*c*) OP = EDDLT + SS = 169 + 68 = 237 quarts

Problem 4.14. *A company wants to use a fixed order period for ordering a particular inventory item that is purchased for ₹ 180 per unit. The annual demand for the product s 15,000 units. The ordering cost is ₹ 800 per order. The annual carrying cost rate is 35 percent of the acquisition cost. The expected demand during lead time is 20 units, and the upper inventory targe iss 700 units.*

(*a*) *How often should the product be ordered?*

(*b*) *What is the annual told inventory cost that should be expected?*

(*c*) *If the company is going to place an order now and the current inventory level is 248 units, what should be the order quantity?*

Solution.

(*a*)

$$D = 15{,}000 \text{ units per year}$$

$$S = ₹\ 800 \text{ per order}$$

$$IC = .35(180) = ₹\ 63 \text{ carrying cost per year per unit held}$$

$$T = \sqrt{\frac{2S}{IDS}} = \sqrt{\frac{2(80)}{15{,}000\,(.35)\,(180)}} = .04115 \text{ years}$$

(.04115 years) + (365 days/year) = 15.02 days

(*b*)

$$\begin{aligned} TSC &= ICDT/2 + S/T \\ &= .35(180)\ (15{,}000)\ (.04115)/2 + 800/.04115 \\ &= 19{,}443.38 + 19{,}441.07 \\ &= ₹\ 38{,}884.45 \end{aligned}$$

(*c*)

$$\begin{aligned} Q &= (\text{upper inventory target}) - (\text{inventory level}) + (\text{EDDLT}) \\ &= 700 - 248 + 200 \\ &= 652 \text{ units} \end{aligned}$$

SUMMARY

NOTES

- **Dependent Demand**

  It is the demand for the items used to produce final products.

  Independent

  It is the demand for the items used to produce final products.

  Some important terms used in inventory control are as follows:

  1. *Buffer stock*: Inventories to protect against the effects of usual product demand and uncertain lead time.
  2. *Lead Time*: The time passing between ordering and receiving goods.
- *Cost of them*: The cost or value of the item is usually its purchase price the amount paid to the supplier for the item. Transportation, receiving or inspection may be included as part of the cost of the item.
- MRP is a computational technique that converts Master Schedule (MS) for end products into Detailed Schedule (DS) for raw material. The DS identifies the quantities of each raw material and component items. It also tells which item must be ordered and delivered so as to meet the master schedule for final product.
- The MS is based on an accurate estimate of demand for the firms products, together with a realistic assessment for its production capacity.
- In order to compute the raw material and component requirement for the end products listed in mS, the product structure must be known.

QUESTIONS

1. What are the reasons to hold Inventory?
2. What are the two forms of Demand?
3. What is a buffer stock? What is lead time?
4. What is Gradual Replacement Model?
5. What is the concept of Quantity discount?
6. What is lead time in Deterministic Models?
7. What is ABC Analysis?
8. Explain Material Requirement Planning?
9. Discuss the inputs of MRP.
10. What is Master Production Schedule?

NOTES

5. PRODUCTION/OPERATIONS PLANNING AND CONTROL

STRUCTURE

- Factors Determining Production Planning Procedures
- Volume of Production
- Nature of Production Processes

Various activities involved in production/operations planning are designing the product, determining the equipment and capacity requirements, designing the layout of physical facilities and materials handling system, determining the sequence of operations and the nature of the operations to be performed along with time requirements *i.e.,* standard times and specifying certain production quantity and quality levels.

The objective of production planning is to provide a physical system together with a set of operating guidelines for efficient conversion of raw materials, human skills and other inputs into finished products.

FACTORS DETERMINING PRODUCTION PLANNING PROCEDURES

Production planning may begin with a product idea and a plan for the design of the product and the entire production/operating system to manufacture the product. It also includes the task of planning for the manufacturing of a modified version of an existing product using the existing facilities. The wide difference between planning procedures in one company/organisation and another is primarily due to the differences in the economic and technological conditions under which the firm operates.

The three major factors determining production planning procedures are as below:

1. Volume of production
2. Nature of production processes
3. Nature of operations.

Volume of Production

The amount and intensity of production planning is determined by the volume and character of the operations and the nature of the manufacturing processes. Production planning is expected to reduce manufacturing costs. The planning of production in case of custom order job shop is limited to planning for purchase of raw materials and

NOTES

components, determination of work centres which have the capacity of manufacturing the product. In high volume operation extensive production planning is necessary in planning for the design of both the product and the production processes in order to achieve substantial cost reduction when a large number of products are produced.

Nature of Production Processes

In job shop, the production planning may be informal and the development of work methods is left to the individual workman who is highly skilled. In high volume production, many product designers, equipment designers, process engineers and method engineers, are involved and they put enormous amount of effort in designing the product and the manufacturing processes.

Nature of Operations

Detailed production planning is required for repetitive operations *e.g.,* production of continuous production of a single standardized product.

The variants in manufacturing approach are:

(*a*) Manufacturing to order which may or may not be repeated at regular intervals.

(*b*) Manufacturing for stock and sell (under repetitive batch or mass production) *e.g.,* manufacturing of automobiles, watches etc.

(*c*) Manufacturing for stock and sell (under continuous process manufacturing) *e.g.,* chemical and food products, soaps, synthetic yarns etc.

The degree to which production planning is carried varies with the nature of the process.

Production Planning System

There are two interrelated sub-systems in the production planning system as below:

(*i*) Product Planning System (*ii*) Process Planning System.

PRODUCTION CONTROL

It is the updating and revising procedures, where according to the requirements of implementation, the labour assignments, machine assignments, job priorities, line speeds, productions routes etc., may revise. It is basically a correcting mechanism which goes on throughout the implementation process of the already drawn up production plan and schedule.

"Production control is essentially the control of quantity in manufacturing"—**Bethed, Walter, Smith** and **Stackman.**

"Production control is defined as the task of coordinating manufacturing activities in accordance with manufacturing plans so that pre-conceived schedules can be attained with maximum economy and efficiency"—**William Voris.**

"It is a directive agency which regulates for an orderly flow of materials and co-ordination of the different production operations, following the scientific produce of its principles viz. planning, routing, scheduling, dispatching and inspecting and taking the objective of producing the right quality in the right quantity, at the right time and at a minimum cost"—**British Standard Institute.**

"The highest efficiency in production is obtained by manufacturing the required quantity of product, of the required quality, at the required time by the best and cheapest methods"—**Alford** and **Borngs.**

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Functions of Production Control

The important functions of production control are as below:

(*i*) To provide for the production of parts, assemblies and products of required quality and quantity at the required time.

(*ii*) To coordinate, monitor and feedback to manufacturing management, the results of the production activities, analysing and interpreting their significance and taking corrective actions if necessary.

(*iii*) To provide for optimum utilisation of all resources.

(*iv*) To achieve the broad objectives of low cost production and reliable customer service.

Advantages

Advantages can be divided into following two types:

1. Improvement of profit
2. Competitive advantage

1. **Improvement of Profit:**

   (*a*) Maintenance of a balanced inventory of materials, parts, WIP and finished goods

   (*b*) Balanced and stabilized production

   (*c*) Maximum utilisation of equipment, tooling, manpower and manufacturing and storage space.

   (*d*) Minimum investment in inventory

   (*e*) Reduction in indirect costs

   (*f*) Reduction in set up costs

   (*g*) Reduction in scrap *i.e.,* wastage and rework costs

   (*h*) Reduction in inventory costs.

2. **Competitive Advantage:**

   (*a*) Reliable delivery to customers

   (*b*) Shortened delivery schedules to customers

   (*c*) Lower production costs and greater pricing flexibility

   (*d*) Orderly planning and marketing of new or improved products.

Elements of Production Control

The important elements of production control are as below:

(*i*) Control of planning
(*ii*) Control of materials
(*iii*) Control of tooling
(*iv*) Control of manufacturing capacity
(*v*) Control of activities
(*vi*) Control of quantity
(*vii*) Control of material handling
(*viii*) Control of due dates
(*ix*) Control of information.

Control of Planning: Assure receipt of latest forecast data from sales and production planning, bill of materials data from product engineering and routing information from process engineering.

Control of Materials: Control of inventory and providing for issue of materials to the shop and movement of materials within the shop.

Control of Tooling: Check the availability of tooling and provide for issue of tools to shop departments from tool cribs.

Control of Manufacturing Capacity: Determine the availability of equipments and manpower capacities and issue realistic production schedules and provide a means of recording completed production.

Control of Activities: Release order and information at assigned times.

Control of Quantity: Follow up of progress of production in order to ensure that the required quantities are processed at each production step and to ensure that corrective action is initiated where, work fails to pass each stage of inspection.

Control of Material Handling: Release orders for movement of work to ensure availability of materials as required at each stage of the operation.

Control of Due Dates: Check the relation of actual and planned schedules and determine the cause of delay or stoppages that interfere with weekly schedules of work assigned to each machine or work centre.

Control of Information: Distribute timely information and reports showing deviations from plans so that corrective action can be taken and provide data on production performance measurements for future planning.

Factors Determining Production Control Procedures

Factors determining production control procedures can be grouped into following:

1. Nature of production
2. Complexity of operations
3. Magnitude of operations.

Nature of Production: Manufacturing firms are classified as intermittent, continuous or composite production firms, depending on the length of processing time without set up changes.

Production control procedure is comparatively simpler in the continuous flow process operation than in intermittent, multi-operation production as resulting is standardised, quality control is highly developed and planning for raw materials, finished goods investing levels and markets is extremely important. Hence, production control function is generally embodied in the process itself.

In case of intermittent, multi-operation production, found in manufacture of hand tools, toys, automobile spares etc., a great variety of material is used in many ways and for many purposes. The products consist of a large number of parts and sub-assemblies. The production control procedures become complex and sophisticated in order to ensure proper sequence of operation and performing these operations at right time and the right place.

A large number of manufacturing plants include both intermittent and continuous processes and are classified as composite or combination operations. Such a plant may have sub-assembly departments making parts in a continuous operations, while the final assembly department works on an intermittent basis.

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Complexity of Operation: Usually, the complexity of production planning and control function increases with the increase in the variety of operations. Factors affecting the complexity of production control procedures are:

(*a*) Number of ultimate parts in the end product

(*b*) Number of different operations on each part

(*c*) Extent to which processes are dependent on the completion of previous operations

(*d*) Variations in production rates of machine used in the process

(*e*) Number of discrete parts and sub-assemblies

(*f*) Degree to which customer's orders with specific delivery dates occurs

(*g*) Receipt of many small lot orders.

Magnitude of operations: The size of operation (*i.e.,* time taken to complete an operation), the distance travelled by the parts from operations to operation are important in establishing proper production control procedures. Generally, the need is greater for centralised production control organisation and for formal procedures as the size of the operation increases and the dependent operations are more physically separated.

PRODUCT CONTROL SYSTEM

It consists of a group of procedural elements that operates as a whole, to fulfil the functions of product control.

Elements of production control system are as under:

1. Means of setting the system in motion such as production orders
2. Methods to determine the lead time for production
3. Methods to control and monitor production operations including means to:
   (*a*) Determine what and where work is to be done
   (*b*) Determine when work is to be done
   (*c*) Issue orders to production shops and ensure that work is completed.
4. Techniques for measuring and recording data on machine utilisation, scrap and indirect labour that can serve as a basis for manufacturing action leading to optimum utilisation of facilities and low cost operations.
5. An information system for display, recording and retrieval as well as processing and flow of data.

Production Planning/Operations Planning and Control

Production planning and control function essentially consist of planning production in a manufacturing organisation before actual production activities start and exercising control activities to ensure that the planned production is realised in terms of quantity, quality, delivery schedule and the cost of production.

Objectives of Production Planning and Control

1. To deliver quality goods in required quantities to the customers in the required delivery schedule—to achieve maximum customer satisfaction and minimum possible cost.
2. To ensure maximum utilisation of all resources.
3. To ensure production of quality products.
4. To minimise the product throughput time or production/manufacturing cycle time.
5. To maintain optimum levels of inventory.
6. To maintain flexibility in manufacturing operations.
7. To coordinate between labour and machines and various supporting departments.
8. To plan for plant capacities for future requirements.
9. To remove bottlenecks at all stages of production and to solve problems related to production.
10. To ensure effective cost reduction and cost control.
11. To produce effective results for least total cost.
12. To prepare production schedules and ensure that promised delivery dates are met.
13. To establish routes and schedules for work that will ensure optimum utilisation of materials, labour and equipments and machines and to provide the means for ensuring the operation of the plant in accordance with these plans.
14. The ultimate objective is to contribute to the profit of the enterprise.

Stages of Production Planning and Control Functions

There are basically three stages in the production planning and control functions. These are as below:

(*a*) Planning *i.e.,* choosing the best course of action among several alternatives.

(*b*) Operations *i.e.,* execution as per plan.

(*c*) Control *i.e.,* maintaining the performance by comparing the actual results with performance standards set and taking appropriate corrective action if necessary to reduce variation.

Scope of Production Planning and Control

The scope of production planning and control is very vast.

Usually it encompasses the following areas:

(*i*) Materials	(*ii*) Methods
(*iii*) Machines and equipments	(*iv*) Manpower
(*v*) Routing	(*vi*) Estimating
(*vii*) Loading and scheduling	(*viii*) Dispatching
(*ix*) Expediting	(*x*) Inspection
(*xi*) Evaluating	(*xii*) Cost control.

NOTES

Materials: Planning for procurement of raw materials components and spare parts in the right quantities and specifications at the right time from the right service at the right price. Purchasing, storage, inventory control standardisation, variety reduction, value analysis and inspection are the other associated with materials.

Methods: Choosing the best method of processing from several alternatives. It also includes determining the best sequence of operations (process plans) and planning for tooling, jigs and fixtures etc.

Machines and Equipments: Manufacturing methods are related to production facilities available in the production system. It involves facilities planning, capacity planning allocation and utilization of plant and equipments, machines etc.

It also involves equipments replacement policy, maintenance policy and maintenance schedules, tools manufacture and maintenance of tools etc.

Manpower: Planning for manpower *i.e.,* labour, supervisor and managerial levels, having appropriate skills and expertise.

Routing: Determining the flow of work, material handling in the plant and sequence of operations or processing steps. This is related to considerations of appropriate stop layout and plant layout, temporary storage locations for raw materials, components and semifinished goods and of materials handling system.

Estimating: Establishing operations times leading to fixation of performance standards both for the workers and machines.

Loading and Scheduling: Machine loading is allocation of jobs to machines in conjunction with routing and with due consideration for capacity of machines and priority for jobs in order to utilise the machines to the maximum possible extent.

Scheduling ensures that parts, sub-assemblies and finished products are completed as per the requirement of delivery dates. It provides a time table of manufacturing activities. It ensures a balanced load on all work centres and ensures even flow of work through the manufacturing facilities.

Dispatching: This is concerned with the execution of the planning functions. It gives necessary authority to start a particular work which has already been planned under routing and scheduling functions. Dispatching is the release of orders and instructions for the starting of production in accordance with the route sheets and schedule charts.

Expediting: Means chasing, follow up or progressive which is done after the dispatching function. It keeps a close liasion with scheduling in order to provide an efficient feedback and prompt review of targets and schedules.

Inspection: This function is related to maintenance of quality in production and of evaluating the efficiency of the processes, methods and labour so that improvements can be made to achieve the quality standards set by product design.

Evaluating: The objective of evaluation is to improve performance. Performance of machine, processes and labour is evaluated to improve the same.

Cost Control: Manufacturing cost is controlled by wastage reduction, value analysis, inventory control and efficient utilisation of all resources.

Principles of Production Planning and Control—(PPC)

1. Type of production determines the kind of production planning and the control system needed.

2. Number of parts involved in the product affects expenses of operating PPC department.
3. Complexity of PPC denominator for all scheduling activities.
4. Time is a common denominator for all scheduling activities.
5. Size of the plant has relatively little to do with the type of PPC system needed.
6. PPC permits managements by exception.
7. Cost control should be a by-product of the PPC function.
8. "The highest efficiency in production is obtained by manufacturing the required quantity of a product, of the required quantity, at the required time by the best and cheapest method"-PPC is a tool to coordinate all manufacturing activities in a production/operating system.

Phases in Production Planning and Control Function

Production Planning and Control functions can be divided in following three phases:

(*a*) Planning phase (*b*) Action phase

(*c*) Control phase.

(*a*) **Planning Phase:** This phase can be sub-divided into the following:

(*i*) Preplanning phase

(*ii*) Active phase.

(*i*) Preplanning activity involves product planning and development demand forecasting, resource planning, facilities planning, plant planning, plant location and plant layout etc.

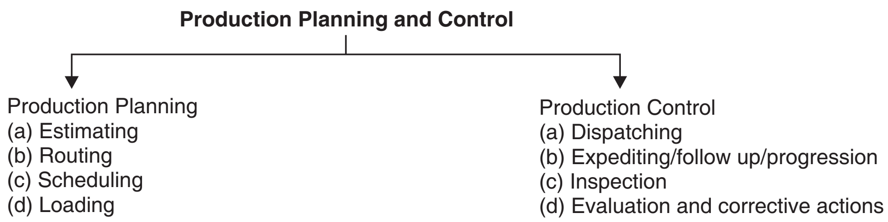
(*ii*) Active planning involves planning for quantity, determination of product, mix, routing, scheduling, material planning, process planning, capacity planning and tool planning.

(*b*) **Action Phase:** Execution or implementation phase includes the dispatching and progressing function.

(*c*) **Control Phase:** It includes status reporting, material control, tool control, inventory control, quality control, labour O/P control and cost control.

Main Functions of Production Planning and Control Department

The various functions of production planning and control department can be broadly classified as below:



Estimating: It involves deciding the quantity of products to be produced and cost involved in it on the basis of sales forecast.

Estimating manpower, machine capacity and material require to meet the planned production targets are the key activities before budgeting for resources.

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Routing: This is the process of determining the sequence of operations to be performed in the production process. Routing determines what work must done, where and how ?

Routing information is provided by product or process engineering function and it is useful to prepare machine loading charts and schedules.

Route sheet is a document which provides information and instruction for converting the raw materials into finished parts or products. It defines each step of the production operation and lays down the precise path or route through which the product will flow during the conversion process.

Routes sheet contains following information:

(*i*) Operations required and their desired sequence.

(*ii*) Machine or equipment to be used for each operation.

(*iii*) Estimated set up time and operation time/piece (standard time).

(*iv*) Tools, jigs and fixtures required for the operations.

(*v*) Detailed drawings of parts, sub-assemblies and final assemblies.

(*vi*) Specification, dimensions, tolerances, surface finished and quality standards to be achieved.

(*vii*) Cutting speed, feed, depth of cut etc., to be used on machine tools for the operations to be carried on.

(*viii*) Inspection procedure and metrology tools required for inspection.

(*ix*) Packing and handling instruction during the movement of parts and sub-assemblies through the operation stages.

Scheduling: It involves fixing priorities for each job and determining the starting time and finishing time for each operations, the starting dates and finishing dates for each part, sub-assembly and final assembly. Scheduling lays down a time table for production, indicating the total time required for the manufacture of a product and also the time required for carrying out the operations for each part on each machine or equipment.

Objectives of Scheduling

(*a*) To prevent unbalanced use of time among work centres and departments.

(*b*) To utilise labour such that the output is produced within established lead time or cycle time so as to deliver the products in time and complete production at minimum total cost.

Loading: Facility loading means loading of facility or work centre and deciding, which jobs to be assigned to which work centre or machine. Loading is the process of conventing operation schedule into practice. Machine loading is the process of assigning specific jobs to machines, men or work centres based on relative priorities and capacity utilisation.

A machine loading chart also called as *Gantt Chart* is prepared showing the planned utilisation of men and machines by allocating the tools to machines or workers as per priority sequencing established at the time of scheduling.

Loading ensures maximum possible utilisation of productive facilities and avoids bottlenecks in production. It is important to avoid either over loading or under loading the facilities, work centres or machines to ensure maximum utilization of resources.

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Dispatching: It may be defined as setting production activities in motion through the release of orders and instructions in accordance with the previously planned time schedules and routing.

Dispatching also provides a means for comparing actual progress with planned production progress. It includes:

(*i*) Providing the movement of raw materials from stores to the first operation and from one operation to the next operations fill all the operations are carried out.

(*ii*) Collecting tools, jigs and fixtures from tool stores and issuing them to the user department or worker.

(*iii*) Issuing job orders authorising operations in accordance with dates and times as indicated in schedules or machine loading charts.

(*iv*) Issue of drawings, specifications, route, cards, material requisitions and tool requisitions to the user department.

(*v*) Obtaining inspection schedules and issuing them to the inspection section.

(*vi*) Internal materials handling and movement of materials to the inspection area after completing the operations, moving the materials to the next operation centre often inspection, and movement of completed parts to holding stores.

(*vii*) Returning jigs; fixtures and tools to stores after use.

Expediting/Follow-Up Progressing: It ensures that the work is carried out as per the plan and delivery schedules are met.

Progressing includes activities such as status reporting attending to bottlenecks or hold ups in production and removing the same, controlling variations or deviations from planned performance levels, following up and monitoring progress of work through all stages of production, coordinating with purchases, stores, tool room and maintenance departments and modifying the production plans and replan if necessary.

Need for expediting arises due to the following:

(*a*) delay in supply of materials

(*b*) excessive absenteeism

(*c*) changes in design specifications

(*d*) changes in delivery schedules initiated by customers

(*e*) breakdown of machines or tools, jigs and fixtures

(*f*) error in design drawings and process plans.

Levels of Production Planning

Production planning occurs at several levels in the organisation and covers different time horizones.

Planning can be classified as:

(*a*) Strategic planning (*b*) Tactical planning (*c*) Operational planning	On the basis of hierarchical level

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On the basis of time span of planning:

(*a*) Long range planning (*b*) Intermediate range planning

(*c*) Short range planning.

Strategic Planning: It is a process of thinking through the organisation's current mission and environment and then setting forth a guide for future decisions and results.

Strategic plans are usually long range plans done at the top management level. These are focused on product lines, divisions, factories, markets and other business units, span several years and reflect the operations strategy of the business. It also focus on the utilisation of production facilities in the long run to achieve business objectives. These involve commitment in term of capital investment, manufacturing process technology, product life etc. The factors to be taken into consideration in long range planning are investment, capacity of the firm, product life cycle, technology level, market requirements etc. These plans set in motion activities required to develop facilities and equipment, production processes and major sub-contractors.

Long range plans become constraints on how many products can be produced in the intermediate and short range plans.

Objective Laid Down by Long Range Planning

These are as below:

(*a*) Production levels (Number of units produced)

(*b*) Operating capacities

(*c*) Inventory policies

(*d*) Levels of manufacturing costs.

Tactical Planning: It is done over an intermediate term or medium range time horizone, by the middle level management. These plans focus on aggregate products rather than individual specific products. The time span is of 6 to 18 months and specify the employment plans, machinery and utility plans, the sub-contractor and materials supply plans and facility modification/expansion plans.

Operational Planning: It is done over a short range time span developed by junior level management. It is concerned with the utilisation of existing facilities rather than creation of new facilities. It involves proper utilisation of key resources such as raw materials, machine capacity, energy etc.

It takes into account, current customers orders, priorities material availability, absenteeism rate, cash flows etc, and it is designed to respond quickly to changes in production levels and market conditions.

Short range planning establishes short range schedules which specify the quantity of specific products to be produced in each week of the planning horizon which varies from a week to a few months.

Advantages

Production planning and control function is the nerve centre or heart of the production/operations management function. It coordinates all phases of the production/operation system. An efficient production planning and control function results in higher quality, better utilisation of resources, reduced inventories, reduced manufacturing cycle time, faster delivery, better customer service, lower production cost and lower capital investment and higher customer satisfaction.

Efficient and optimum utilisation of resources results in higher productivity and economy of production, timely delivery and right quality of goods/services at the right cost will improve customer satisfaction. Minimisation of breakdown of machines, plant and equipments minimises idle time of equipments and labour and ensures even flow of work through the plant facilities. Hence, improves employees discipline and morale in the organisation.

An efficient PPC system enables the firm to improve its sales turnover, market share and profitability and provides a competitive advantages for the firm due to balanced inventory levels and higher quality, flexibility and dependability and lower prices which are the performance factors for the firm.

Limitation of PPC

1. PPC function is based on certain assumption or forecasts of customer's demand, plant capacity, availability of materials, power etc. If these assumption go wrong the PPC becomes ineffective.
2. Employees may resist changes in production levels set as per production plans if such plans are rigid.
3. The production planning process is time consuming when it is necessary to carry out routing and scheduling functions for large and complex products consisting of a large number of parts going into the product.
4. PPC function becomes extremely difficult when the environmental factors change very rapidly such as technology, customer's taste regarding fashion or style of products needed, government policy and controls, change frequently, stoppages of power supply by electricity boards due to power cuts, break in supply chain due to natural calamities such as floods, earthquakes, war etc.

AGGREGATE PLANNING

Aggregate planning involves planning the best quantity to produce during time periods in the intermediate range horizon < 3 months>/1 year and planning the lowest cost method of providing the adjustable capacity to accommodate the production requirements. For manufacturing operations, aggregate planning involves planning work force size, production rate *i.e.,* work hours/week and inventory levels.

Objectives

1. To develop plans that are
   (*a*) Feasible (*b*) Optimal
2. To increase the range of alternatives of capacity use, that can be considered by the management of the firm.

Feasible: The plans should provide for the portion of demand that the firm intends to meet and should be within the financial and physical capacity of the firm.

Optimal: The firm should aim for plans which will ensure the resources which are used as wisely as possible and costs kept as low as possible.

Aggregate Production (output) Planning: It is the process of determining output levels (units) of product groups over the next 6 to 18 months period on a weekly or monthly basis. The plan indicates the overall level of output supporting the business plan.

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Aggregate Capacity Planning: It is the process of devising a plan for providing a production capacity scheme to support the intermediate range sales forecast.

As forecast demand becomes known in the form of customer orders, aggregate capacity plan may have to be revised upwards and downwards to avoid either overloaded or underloaded facilities.

Need for Aggregate Capacity Planning

1. It facilitates fully loaded facilities and minimises overloading and underloading and keeps production cost low.
2. Adequate production capacity is provided to meet expected aggregate demand.
3. Orderly and systematic transition of production capacity to meet the peaks and valleys of expected customers demand is facilitated.
4. In times of scarce production resources, getting the maximum output for the amount of resources is enhanced.
5. To manage change in production/operations management by planning for production resources that adopt to the changes in customer demands.

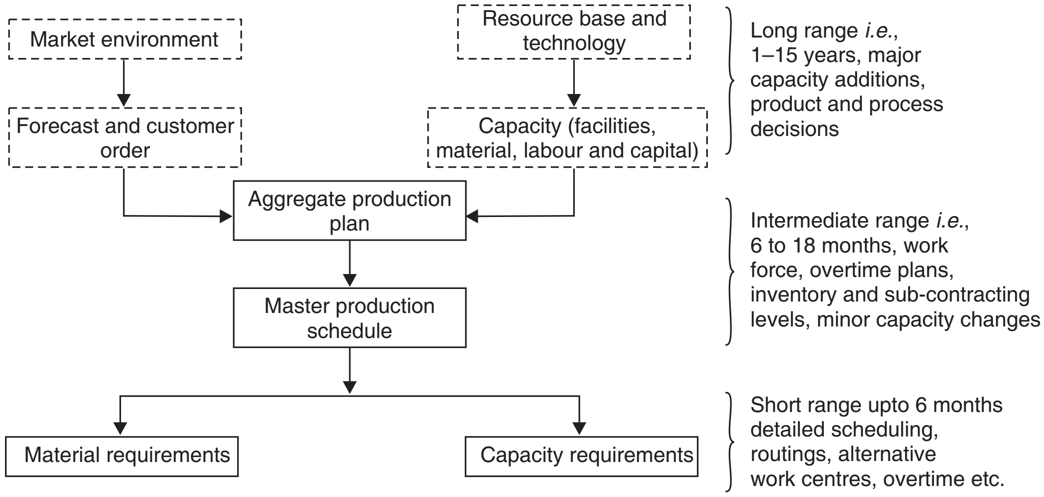
Steps in Aggregate Capacity Planning

1. Prepare the sales forecast for each product that indicates the quantities to be sold in each time period usually weeks, months or quarters over the planning horizon *i.e.,* 6–8 months.
2. Sum up the individual product or service forecast into one aggregate demand for the factory.
3. Transform the aggregate demand for each time period into labour, materials, machines and other elements of production capacity required to satisfy aggregate demand.
4. Develop alternative resource schemes for supplying the necessary production capacity to support the cummulative aggregate demand.
5. Select the capacity plan from among the alternatives considered that satisfy aggregate demand and best meets the objectives of the organisation.

Note. In case of intermediate aggregate capacity plan, the variables are to be manipulated to vary the production capacity from month to month.

The variables that may be manipulated to vary the production capacity from month to month are as below:

(*a*) size of the work force
(*b*) use of overtime or idle time
(*c*) use of inventories or back orders
(*d*) use of sub-contractors.
(*e*) leaving demand unfilled to buffer the difference between production capacity and variations in demand from month to month.



Flow chart of aggregate plan and Master production schedule.

Cost Associated with Aggregate Planning

The choices concerning aggregate production, workforce and inventory levels influence several relevant costs. These costs need to be identified and measured so that alternative aggregate plans can be evaluated on a total cost criterion.

Some of the cost that may be relevant are:

(*a*) Pay roll cost.

(*b*) Costs of overtime, second shift and sub-contracting.

(*c*) Costs of hiring and lay off of workers.

(*d*) Costs of excess inventory and backlog.

(*e*) Costs of production rate changes.

Approaches to Aggregate Planning

An aggregate plan takes into consideration the overall level of output and the capacity that is required to produce it. There are two basic approaches to estimating the capacity that will be required to produce an aggregation or grouping of a company's products

(*i*) Top down approach (*ii*) Bottom up approach.

Top Down Approach

It involves development of the entire plan by working only at the highest level of consolidation of products. It consolidates the products into an average products and then develops one overall plan. This plan is disaggregated to allocate capacity to product families and individual products.

Bottom Up Approach

It is also known as sub-plan consolidation approach. It involves development of plans for major products and product families at some lower level, within the product line. These sub-plans are then consolidated to arrive at the aggregate plan, which gives the overall output and the capacity required to produce it.

Bottom up approach is more widely used. This approach starts with plans for major products or product families and aggregates (sums) the impact, that these plans have on the capacity of the company. If the capacity requirements for individual plans, appear to sum up to a satisfactory overall use of the company's resources the plans are accepted to be implemented strategically. If not, some of the individual plans are revised to improve the overall impact of the aggregate plan. Individual plans are revised until a desirable aggregate plan is evolved.

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Top Down Aggregate Planning

With this approach, the desirable overall plan is developed for the periods in the planning horizon, with the plan for the first few periods being fairly firm. This approach rests on the assumption that if the proper amount of total capacity is available, the right amount of capacity for all of the parts will be available.

Aggregate plan for a top down approach is performed in terms of a pseudo-product which is a fictitious product that represents the average characteristics of the entire product line to be planned. However, difficulties may arise in disaggregation of the product mix varies overtime and the different products require different production resources.

Bottom Up Aggregate Planning

This is also known as resource requirement planning. At times is also called as rough-cut capacity planning and is used in conjunction with material requirement planning. Both capacity and materials must be available for products to be made and hence material plan need to be coordinated with a more detailed production plan.

SUMMARY

- Various activities involved in production/operations planning are designing the product, determining the equipment and capacity requirements, designing the layout of physical facilities and materials handling system, determining the sequence of operations and the nature of the operations to be performed along with time requirements.
- Production planning may begin with a product idea and a plan for the design of the product and the entire production/operating system to manufacture the product. It also includes the task of planning for the manufacturing of a modified version of an existing product using the existing facilities.
- The amount and intensity of production planning is determined by the volume and character of the operations and the nature of the manufacturing processes.
- It is the updating and revising procedures, where according to the requirements of implementation, the labour assignments, machine assignments, job priorities, line speeds, productions routes etc., may revise.

  "Production control is essentially the control of quantity in manufacturing" —**Bethed, Walter, Smith** and **Stackman.**
- Production planning and control function essentially consist of planning production in a manufacturing organisation before actual production activities start and exercising control activities to ensure that the planned production is realised in terms of quantity, quality, delivery schedule and the cost of production.
- **Cost Control:** Manufacturing cost is controlled by wastage reduction, value analysis, inventory control and efficient utilisation of all resources.
- **Estimating:** It involves deciding the quantity of products to be produced and cost involved in it on the basis of sales forecast.

- **Routing:** This is the process of determining the sequence of operations to be performed in the production process. Routing determines what work must done, where and how ?
- **Scheduling:** It involves fixing priorities for each job and determining the starting time and finishing time for each operations.
- **Strategic Planning:** It is a process of thinking through the organisation's current mission and environment and then setting forth a guide for future decisions and results.
- **Tactical Planning:** It is done over an intermediate term or medium range time horizone, by the middle level management.
- Aggregate planning involves planning the best quantity to produce during time periods in the intermediate range horizon < 3 months>/1 year and planning the lowest cost method of providing the adjustable capacity to accommodate the production requirements.

QUESTIONS

1. Explain the factors determing production planning procedures.
2. What is production control?
3. Explain production control system.
4. What is aggregate planning?
5. What are the two interrelated sub-systems in the production planning system?
6. What are the functions of production control?
7. What are the elements of production control?
8. How do we define control of planning and control of tooling?
9. What are factors determining production control procedures?
10. Explain the levels of production planning?

NOTES

6. QUALITY

STRUCTURE

- Components of Quality
- Acceptance Sampling Technique
- Total Quality Management
- Quality Audit
- Six sigma (6σ)
- International Standardisation Organisation

Quality is an important dimension of production and operations management. It is not enough to produce goods or services in the right quantity and at the right time. It is important to ensure that the goods and services produced are of right quality. The consumers of the final product of a company needs a certain quality of products of a quality appropriate to his/her needs. Without quality, the order dimensions of quantity and time have little relevance.

Quality can be defined in many ways. Out of which a few important ones are as below:

1. Quality is the performance of the product as per the commitment made by the producer to the consumers.
2. Quality is either a written or non-written commitment to a known or unknown consumer in the market. Since the market or the target market itself is decided by the company, that is to which type of consumer or customers to cater to, quality is a strategic marketing decision taken by the company itself at the outset. This concept may be broader by saying that the quality of products to be produced by a corporation is a corporate level decision. It is a decision based on various marketing considerations, production constraints, manpower or personnel constraints, and equipment or technology constraints. The decisions regarding quality are not really in the realm of one functional manager as this involves overall strategic decisions for the running of the business of a corporation.

Note. Commitment may be explict such as written contract or it may be implicit in terms of the expectation of the average consumer of the product.

Hence, Quality is defined as:

"*The sum of the attributes or properties that describe a product. These are generally expressed in terms of specific product characteristics such as length, width, colour, specific gravity and the like.*"

To be meaningful in an industrial sense, these characteristics must be quantitatively expressed in terms that can be objectively measured or observed.

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COMPONENTS OF QUALITY

Components of the quality can be classified into the following two:

1. Product features
2. Freedom from deficiencies.

Product Features: These have a major effect on sale income through market share, premium prices etc. In many industries, the total external customers population can be segmented by the level or grade of quality desired. Thus the spectrum of the customers leads to a demand for luxury hotels and budget hotels, to a demand for refrigerators with many special features as well as for those with basic cooling capabilities. Product features refers to the quality of design.

Note. Increasing the quality of the design generally leads to higher costs.

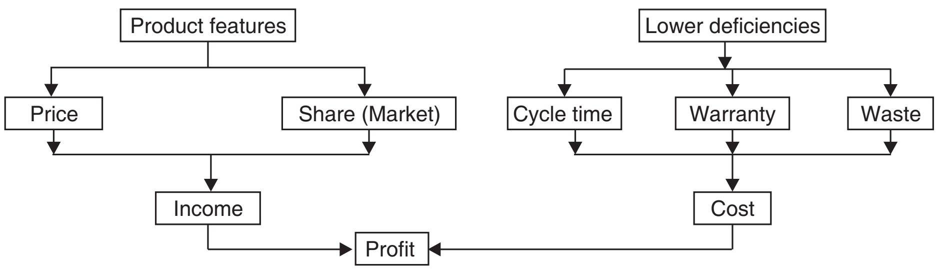
Product features includes: (Manufacturing industry)

(*a*) Performance
(*b*) Reliability
(*c*) Durability
(*d*) Serviceability
(*e*) Easy to operate
(*f*) Reputation
(*g*) Competition

Service industry:

(*a*) Accuracy
(*b*) Timeliness
(*c*) Completeness
(*d*) Friendliness and courtesy
(*e*) Anticipating customers need
(*f*) Knowledge of server
(*g*) Reputation.

Freedom from Deficiencies: It has a major effect on cost through reduction in scrap, rework complaints, and other results of deficiencies. Deficiencies are stated in different units for *e.g.*, errors, defects, failures, off specification etc. Freedom from deficiencies refers to quality of conformance. Increasing the quality of conformance usually results in lower costs. In addition higher conformance means fewer complaints and therefore increased customers satisfaction.



The need for quality needs no special emphasis. One benefit of quality is increased productivity. Better quality means reduced costs for repairs, instruction, scrap, rework and product warranties. Increased productivity results in better profits and builds customer loyalty.

Quality also results in sustained profits. Earning profit in one year and incurring loss the very next year will not speak light about an organisation. What is needed is sustained profit over a long period of time. This is possible when the organisation is able to maintain persistent quality for its products.

NOTES

Tools and Techniques for Quality Improvements

There are certain simple tools and techniques which can naturally be positioned within total quality management philosophy. Many of these tools can easily be utilised for everyday problem solving or for realsing opportunities, and can thus be effectively used to support the implementation of the methodology for quality management and improvement.

Following are the most popular and commonly used techniques:

(*i*) Affinity diagram
(*ii*) Bar charts/histogram
(*iii*) Block diagram
(*iv*) Brain storming
(*v*) Cause and effect analysis
(*vi*) Control chart

(*a*) Control charts for variables or $\overline{X}$-*R* chart (Mean-Range chart)

(*b*) Control charts for attributes

1. '*np*'-chart (number of defective charts for constant sample size *n*)
2. '*p*'-chart (fraction defective chart for varying sample size)
3. '*C*'-chart (number of defects chart for constant sample size)
4. '*U*'-chart (number of defects/unit chart for varying sample size).

(*vii*) Cost benefit analysis
(*viii*) Customers-supplier relationship checklist
(*ix*) Decision analysis
(*x*) Pereto analysis
(*xi*) Quality costing
(*xii*) Risk analysis
(*xiii*) Scatter diagrams.

Affinity Diagram

It is an organizing tool, useful in sorting out ideas generated through a brainstorming session. These are necessary when a large amount of information, ideas, opinions or issues have been collected in situations when a process needs defining, or customer requirements need identifying or when a problem needs solving.

The techniques organises the collected pieces of information into grouping based on the natural relationship that exist among them.

Note.

1. The maximum number of grouping is limited to 10
2. A single piece of information can constitute one independent group in its own right
3. A heading is created for each group, capturing its meaning.

This technique is useful in reducing an otherwise unmanageable amount of information into a smaller number of homogeneous groups, which are much easier to handle independently, priorities in order to significance or allocate to specific projects for further study or investigation.

Bar Chart/Gantt Chart

It is a graphical representation of discrete groups or categories of data, depicted in such a way that clear comparisons can easily be made.

It is frequently used to emphasis a point; this will dictate the way in which the chart is drawn.

Note. Chart is normally used to emphasis the variation and unevenness in data.

Using this information, further investigation could follow to determine why the variation was occuring. The items are usually ranked from high to low, with the lengths of the bars indicating the value or frequency that bar represents.

When the data are spread across a continuous range of values, a bar chart is equivalent to a histogram. With the equal group lengths the heights of the bars will also be proportional to the corresponding group frequencies. With unequal group lengths, the height of each bar should be chosen so that the area of the bar is proportional to the corresponding frequency. This can be achieved by defining the height as proportional to the ratio.

Group Frequency/Group Length

The ratio gives the density of the data values in the group that is the number of data values/unit of group length. The limiting value of this ratio, if the sample size keeps increasing and the group lengths keep decreasing is called the probability density function.

Block Diagram

If every activity, which is part of a process is represented by a block *i.e.,* box, and all blocks are connected by lines representing the interfaces between activities, a macrolevel view of the process is obtained, this is called a block diagram. The diagram traces the paths that any information, necessary actions or materials can take between the original input and the final output of the process, for each activity in the process, there is a determination of the output it produces, what other activities it feeds into, and, through the identification of special groups for particular work activities, there is also a determination of who performs the activity.

Brainstorming

It is an activity, which promotes group participation and teamwork, encourages creative thinking and stimulates the generation of as many ideas as possible in a short period of time.

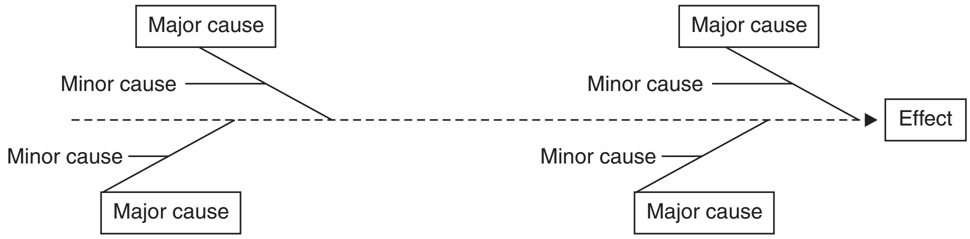
The participants in a brainstorming meeting are invited on the basis of their particular knowledge and experience, and are expected to contribute to the topic under discussion. An atmosphere is created where everybody feels free to express themselves. The production of random 'off' the top of the head ideas is encouraged, the emphasis is on quantity rather than quality. No criticism, expression of doubt as hasty judgement of the ideas is allowed until after the brainstorming session, this is crucial if the barriers to creative thinking are to be overcome.

Causes and Effect Analysis

This is a technique for identifying the most probable causes affecting problem, a condition or a project. It can help in analysis of cause and effect relationships and it can be used in conjunction with brainstorming.

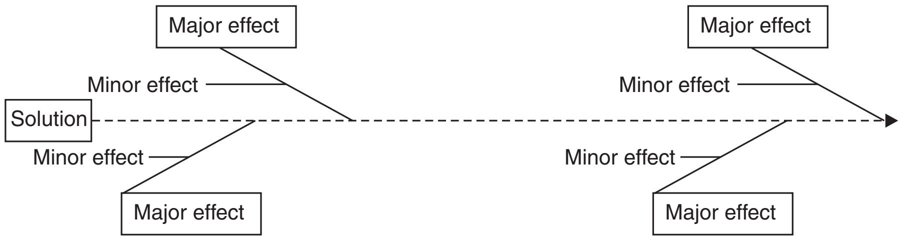
NOTES

The tool that is being used, the cause and effect diagram is a visually effective way of recording the possible causes of a particular effect. Examples of major categories of cause are methods, machines, manpower and materials. If a category of cause begins to dominate the diagram, it may be necessary to isolate that group on a separate diagram. The most likely causes can be circled to signify that they should be tackled first.



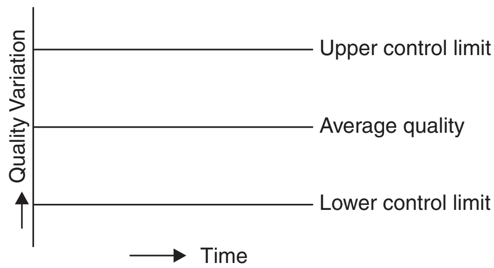
This diagram is also known as fishbone diagram, because of its appearance, or as the Ishihawa diagram on the name of founder **Prof. K. Ishihawa** of Japan. In Japan, it is an indispensible tool in Japanese management.

The cause and effect diagram is the image of the solution-effect diagram which helps to identifying the probable effect of a proposed solution on a project or problem. The procedure is similar to that used in cause and effect analysis.



Control Chart

A typical control chart consists of a central line corresponding to the average quality at which the process is to perform and two other lines corresponding to the upper and lower control limits, also called as tolerance limits. The vertical scales indicates the quality variations and the horizontal scale indicates time. Samples of product are taken at specified time intervals, quality checked, measured, averaged and plotted on the chart. If the values plotted are within the control limits, the processing is said to be under control. If the values move away from control limits, the process must be improved.



Note.

1. If the values are within the upper and lower control limits it is called process is under control.
2. If the values are beyond the upper and lower control limits it is called uncontrolled process.

Control charts are basically of two types:

(*i*) Control charts for variables (mean-range chart)

(*ii*) Control charts for attributes.

Note.

1. Usually two kinds of informations are available from control charts.
   (*a*) Whether the process is running under stable condition or not means whether the process is nder the state of statistical control or not.
   (*b*) Whether the process is meeting the desired quality standards or not.
2. If statistical control does not exist, it has to be established through technical control.

Control Charts for Variables (mean-range chart)

There are two charts viz x chart and R chart employed in analysing a variable data. There is no meaningful interpretation obtained if the $\bar{X}$ chart or 'R' chart are analysed individually. $\bar{X}$-R charts have to exist as a pair. Interpretation regarding the quality of the on-going process has to be done analysing both the charts simultaneously.

Following are the steps involved in the construction of $\bar{X}$ and $\bar{R}$ charts:

1. **Choice of Variable (x):** Choose the quality characteristic 'C' variable which gives maximum possible scope for cost reduction through control of the process. Also ensure that the quality characteristic can be measured quantitatively.
2. **Selection of Rational Sub-groups:** Rational sub-groups are homogeneous observations grouped into small groups.

Note. 1. Sample size varying from 3 to 20.

2. Sample size 4 or 5 being ideal.

3. **Choice of Frequency:** Frequency is the time interval between successive measurements of quality characteristics of sub-groups. Usually, it is determined as a% of the quantity of products measured or as a% of the total duration of the manufacturing process.
4. **Collection of K:** It is the number of sub-groups each of convenient sample size 'n'

Note. 1. Usually $K = 25$

2. n = 4-10.

5. **Calculation of Mean and Range:** For each sub-group calculate mean and range using the following formulae

$$\bar{X} = \Sigma x/n,\ R = X_{max} - X_{mini}$$

6. **Calculation of Average of Different Ranges for *K* Sub-groups:** With the help of following formula

$$\bar{R} = \Sigma R/K.$$

7. Compute central line ($\bar{R}$), upper control limit and lower control limit for Range chart using formulae.

$$\text{Central line } \bar{R} = \Sigma R/K.$$

$$UCL_R = D_4\bar{R}$$

$$LCL_R = D_3\bar{R}$$

where D_3 and D_4 are constants whose values depend on sample size n.

NOTES

8. **Testing Homogeneity:** Compare all individual range values for K sub-groups with the value of UCL_R and LCL_R.

Note.

1. If these individual range values fall in between the values of the UCL_R and LCL_R, all range values are said to be homogenous.
2. These sub-groups are known as rational sub-groups.

9. If the sub-groups are not homogeneous, remove those sample results which are out of the range limits *i.e.,* UCL_R and LCL_R then compute modified $\bar{R}$, modified UCL_R and LCL_R till homogeneity is obtained.
10. Calculate $\bar{\bar{X}}$ for the homogenised sub-group. K(let K,)

$$\bar{\bar{X}} = \frac{\Sigma\bar{X}}{K_1} = \frac{X_1 + X_2 + ... X_{K_1}}{K_1}$$

and compute upper control limit and lower control limit

$$ULC_R = \bar{\bar{X}} + A_z \bar{R}$$

$$LCL_R = \bar{\bar{X}} - A_z \bar{R}$$

11. **Test Homogeneity:** Compare all individual values of $\bar{X}$ for K_1 sub-groups with the values of $UCL_{\bar{X}}$ and $LCL_{\bar{X}}$

(*a*) If these individual values of $\bar{X}$ fall in between the values of $UCL_{\bar{X}}$ and $LCL_{\bar{X}}$ these values of $\bar{X}$ are homogeneous and K_1 sub-groups are known as rational sub-group.

12. If the above condition for homogeneity is not satisfied remove sample results for which $\bar{X}$ values fall outside the control limits and re-calculate the values of modified $\bar{\bar{X}}$, $UCL_{\bar{X}}$ and $LCL_{\bar{X}}$ till homogeneity is achieved.
13. Construct $\bar{X}$ chart and R chart for the rational sub-groups obtained after testing for homogeneity.

Fraction Defective Chart or '*p*'-Chart for Varying Sample Size

The data collected gives the sample size (n_1, n_2 ...... n_K) for K sub-groups, and values of numbers of defectives (c_1, c_2 ...... c_k) for K sub-groups. Fraction defective for each sub-group are calculated as

$$p_1 = c_1/n_1,\ p_2 = \frac{c_2}{n_2} \ ......\ p_K = \frac{c_k}{n_k}$$

Central line $\quad p = \frac{\Sigma p}{K} = \frac{p_1 + p_2 + p_K}{K}$

Upper control limit (UCL) for each sub-group

$$= p + 3\sqrt{p(1+p)/\text{sample size}}$$

Lower control limit (LCL) for each sub-group

$$= p - 3\sqrt{p(1-p)/\text{sample size}}$$

Note. Since sample size varies for each sub-group, there will be as many values of LCL and UCL as the number of values of sample size (*i.e.,* n_1, n_2 ...... n_k)

The chart is drawn as below:

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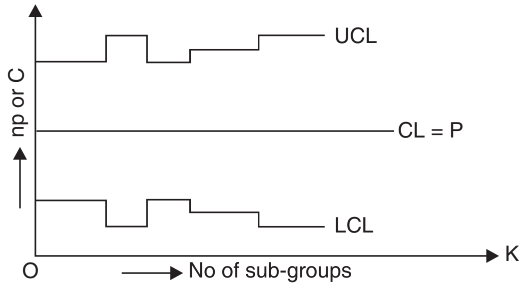


Number of Defects Chart or '*C*' Chart

The data regarding the number of defects existing in all the samples in each sub-groups are collected for '*K*' sub-groups each of sample size n. The number of defects per sub-groups are say C_1, C_2, ... C_K

Then

$$\text{Central line } (CL)_C = \frac{\Sigma C}{K} = \frac{C_1 + C_2 \ldots C_K}{K}$$

Upper control limit-UCL for each sub-group

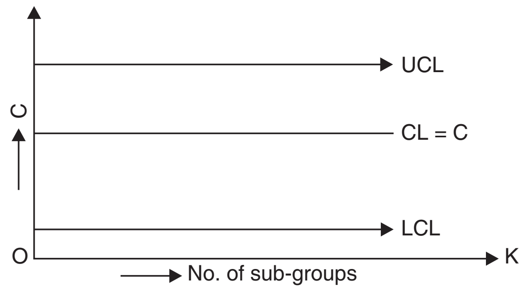
$$= \bar{C} - 3\sqrt{\bar{C}}$$

Lower control limit-LCL for each sub-group

$$= \bar{C} - 3\sqrt{\bar{C}}$$

Test for homogeneity is done by comparing the individual values of C_1, C_2 ... C_K with the control limit values and discarding, the sub-groups for which values of C fall beyond the limit values. For the remaining sub-groups, modified values of C, UCL and LCL are calculated till homogeneity is obtained.

The chart is drawn as below:



Number of Defects Per Unit for Varying Sample Size or 'U' Chart

Data regarding the sample size and the number of defects in all the samples in each sub-groups are collected for K sub-groups. Let C_1, C_2, ... C_K be the number of defects/sub-group for K sub-groups each having sample size varying from n_1 to n_K then

No. of defects/sub-group $\mu = \frac{C}{n}$ or $\frac{C}{\text{sample size}}$.

i.e., $\mu_1 = C_1/n_1,\ \mu_2 = C_2/n_2, \ldots\ldots \mu_k = C_K/n_K.$

NOTES

Central line (CL), $\bar{\mu} = \frac{\Sigma\mu}{K} = \frac{\mu_1 + \mu_2 \ldots\ldots \mu_K}{K}$

Upper Control Limit (UCL) for each sub-group

$$= \bar{\mu} + 3\sqrt{\bar{\mu}/\text{sample size}}.$$

Lower control limit (LCL) for each sub-group

$$= \bar{\mu} - 3\sqrt{\bar{\mu}/\text{sample size}}.$$

ACCEPTANCE SAMPLING TECHNIQUE

When 100% inspection is not practically possible because either it is too costly and time consuming or when inspection itself is of destructive in nature, sampling inspection is the best way of estimating the quality of incoming or outgoing lots.

Random sampling provides each element with an equal chance of being selected and permit logical inferences to be made about the lot *i.e.,* population or universe in statistical terms, quality on the basis of sample evidence.

Acceptance sampling inspection can be either sampling:

(*a*) by attributes (*b*) by variables

Sampling Plans for Attributes or Variables

Quality control inspectors are normally forced to resort to sampling inspection of lots because of the cost of 100% inspection and/or the destructive nature of inspection or testing which rules out 100% inspection.

Since the decision to accept or reject a lot must be made on the basis of sample evidence, hence subjected to risk of rejecting good lots or accepting bad lots.

Acceptance Sampling by Attributes

It involves entracting a random sample from the lot to determine whether to accept or reject the entire lot based on the quality of sample, or whether to subject the lot for 100% inspection and separate the good from the bad. This process may be used in inwards goods or receiving inspection for raw materials or bought-out components, in process inspection for semi-finished products and finished product inspection or final inspection. The sampling may be single sampling, double sampling or sequential sampling, depending on the sampling procedure and the number of samples drawn from a single lot for inspection.

Acceptance sampling plans have two important concepts as background when the characteristics being measured are attributes. These are as below:

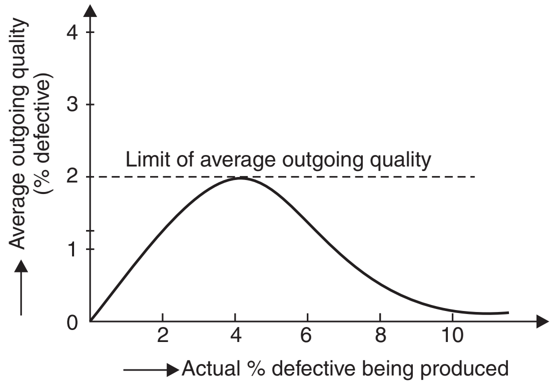
(*a*) Average outgoing quality curves (*b*) Operating characteristics curves.

NOTES

Average Outgoing Quality Curves

Acceptance sampling plans provides managers with the assurance that the average quality level or percentage defective actually going to customers will not exceed a certain limit.

It can be observed from the AOQ curve that as the actual % defective in a production process increases, initially the effect is for the lots to be passed even though the number of defectives has increased and the percentage of defectives going to the customer increases. If this trend increases, the acceptance plan begins to reject lots and when lots are rejected, the lots are usually inspected 100% and defective units are replaced by good ones. The net effect is to improve the average quality of the outgoing lots because the rejected lots that are ultimately accepted contain all non-defective units due to 100% inspection.



As the actual percentage of defectives increases, the average outgoing quality improves because more and more lots are rejected. At the extreme conditions, when all lots are rejected the percent defectives going to customers approach zero.

Note. The concept of AOQ curves show that acceptance plans protect an organisation through limiting the percentage of defective products that go to the customers.

Operating Characteristics Curve-'OC' Curves

With the acceptance sampling plans either of following can happen

(*a*) Good lot is accepted (*b*) Good lot is rejected

(*c*) Bad lot is rejected (*d*) Bad lot is accepted.

In the majority of cases good lot is acceptance and bad lot is rejected. On rare occasions bad lot may be accepted or good lot may be rejected.

Note.

1. When good lot is rejected, this error is known as type-I error
2. When bad lot is accepted this error is known as type-II error.

The operating characteristics curve describes an important feature of acceptance sampling plans. It shows how well an acceptance plan discriminates between good and bad lots.

From the above figure:

1. Good lot can be defined as any lot having less than 1% defectives.
2. This is called the acceptable quality level (AQL).
3. If there is 1% actual defective in a lot, the probability of accepting the lot should be as high as 95% and then the probability of rejecting a good lot is 5%.
4. The probability of rejecting a lot at A Q L quality is known as producer's risk *i.e.,* 'α'.
5. Bad lot can be defined as any lot having 5 % or more defectives.
6. This is known as lot tolerance% defective (LTPD).

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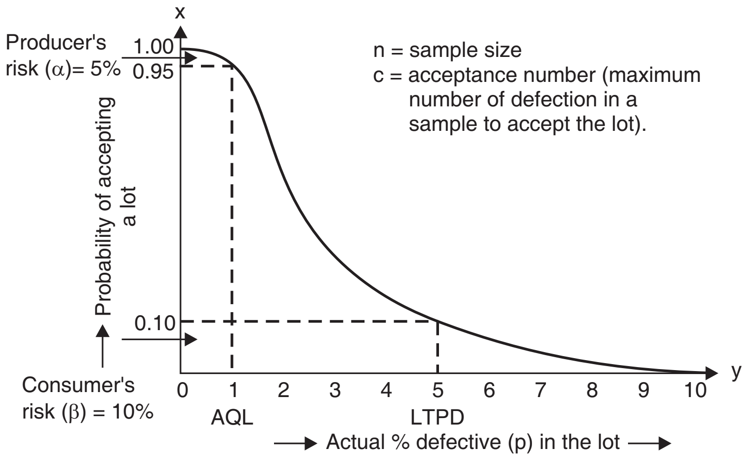


7. The probability of accepting a lot with 5% defectives should be as low as 10% called consumer's risk (β).
8. The probability of rejecting a lot with 5% defective or more is 90%.

Note. The degree to which a sample plan discriminates between good and bad lot is a function of the steepness of the OC curve.

Ideal OC Curve

If perfect discrimination is required between a good lot and a bad lot for *e.g.,* in a lot of a product of size N = 100 units, if the quality of defective units is less than 2%, the lot is to be accepted and if the quantity of defective is more than 2%, the lot is to be rejected. This kind of perfect discrimination is possible only by 100%, inspection and this OC curve is called as ideal OC curve.

However, in practice, 100% inspection is not feasible, the OC curve selected should ensure that as the lot quality decrease *i.e.,*% defective increases the probability of acceptance of such lots should decrease.

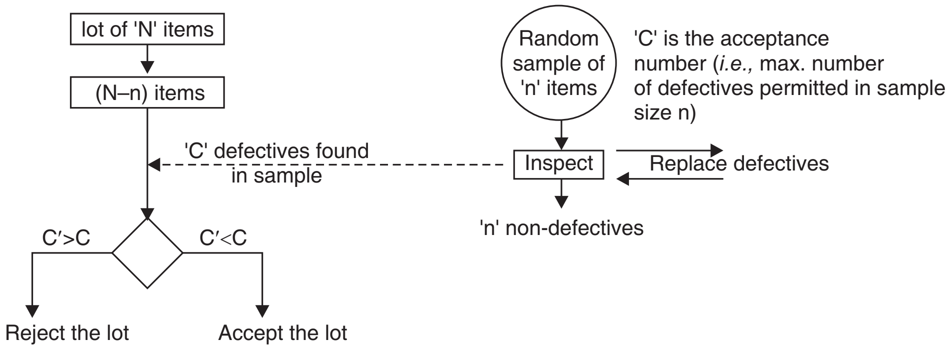
Types of Acceptance Sampling Plans

There are basically three types of acceptance sampling plans. These are as below:

1. Single sampling
2. Double sampling
3. Sequential sampling.

Single Sampling

A sampling plan for a single sample is specified by two numbers '*n*' and '*c*'. The number of items that should be included in a single random sample from the lot being inspected is the sample size '*n*'. The acceptance number '*C*' specifies the maximum number of defectives that may be permitted in the sample if the lot is to be accepted.



Note. If the number of defectives found in the sample is more than 'C', the entire lot will be rejected or 100% inspected.

NOTES

Double Sampling

In double sampling, one small sample is drawn initially. Two acceptance numbers C_1 and C_2 and $C_2 > C_1$ selected.

(1) If number of defectives C_1' in the first sample of size (n_1) is less than or equal to C_1 the lot is accepted.

$$C_1' \leq C_1 \rightarrow \text{accepted.}$$

(2) If number of defectives C_1' is greater than C_2 the lot is rejected.

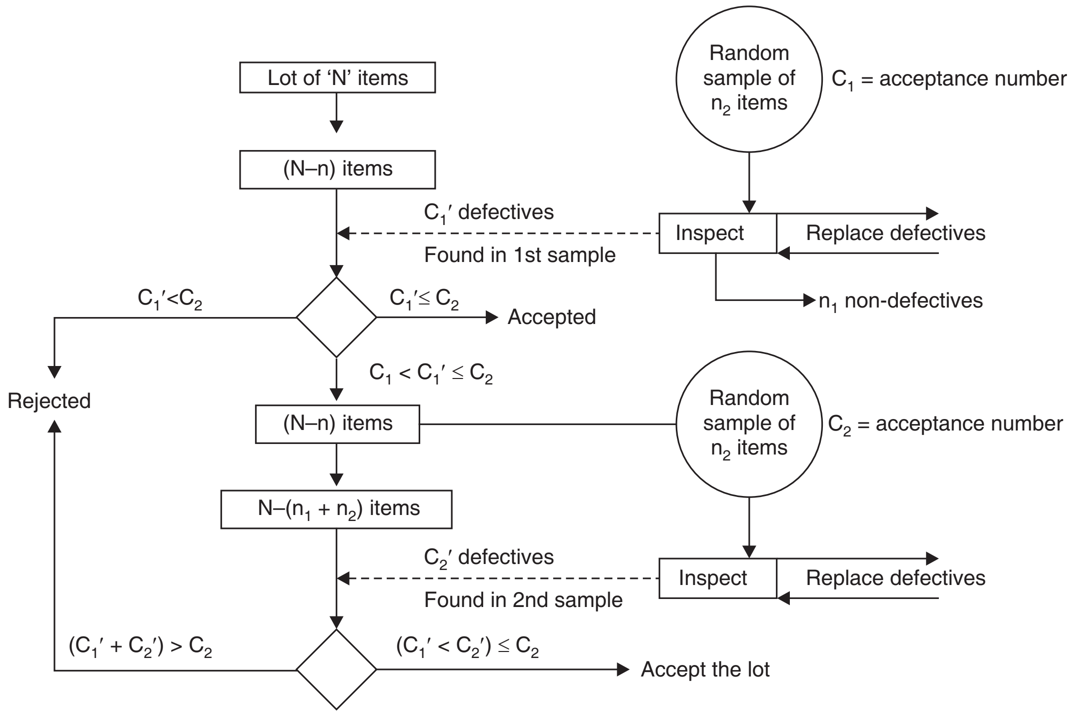
$$C_1' > C_2 \rightarrow \text{rejected}$$

(3) If the number of defectives (C_1') is more than C, but less than C_2, a second larger sample of size n_2 ($n_2 > n_1$) is taken and inspected.

(4) If the number of defectives in second sample is C_2', then the total number of defectives ($C_1' + C_2'$) from the two samples as compared with C_2.

(5) If $C_1' + C_2' > C_2 \rightarrow$ rejected

(6) If $C_1' + C_2' \leq C_2 \rightarrow$ accepted.



Sequential Sampling

In sequential sampling plan, units are randomly selected from the lot and tested one by one. After each one is tested a reject, accept or continuous sampling decision is made. This process continues until the lot is accepted or rejected.

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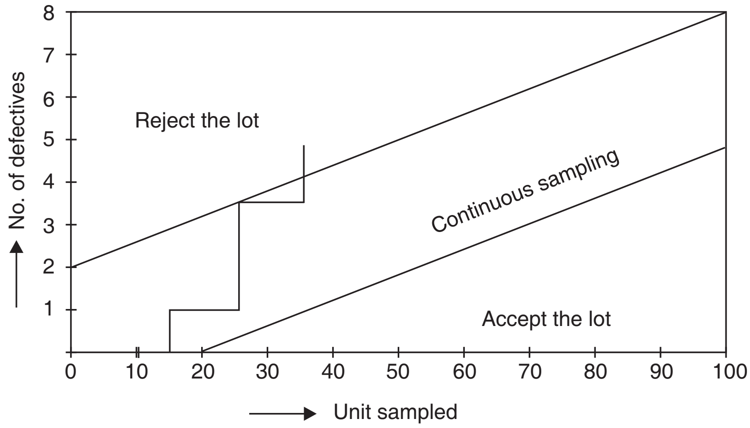

E.g.: When units are randomly drawn and inspected, the 1st defective is the 15th unit, which is in the continue sampling zone in the figure. If the 2nd defective is the 25th unit, which is again in continue zone. If 5th defective is at 35th unit which is in the reject lot zone hence lot is rejected.

TOTAL QUALITY MANAGEMENT

In the past the quality used to be considered as the by-product of the manufacturing system. Due to the variations in the process there use to be some defective parts or the finished products and if these so called defective parts/finished products lie with the permissible tolerance were send to the market otherwise back to the manufacturing system for the rework. Which not only increase cost but also delay in required quantity production. This whole approach is passive in nature, expensive and without guarantee of desired quality and quality in time. Secondly, quality maintaining and ensuring itself cannot be inspected into a product.

In the present scenario, a more enlightend approach to quality, emphasises building quality into the product by studying and improving activities that effect quality, from marketing through design to manufacturing came in existence and called as total quality management. This approach is an active approach and encompassing a company in operating philosophy and system for continuous improvement of quality. There is demand of co-operation from each individual of the company/organisation irrespective of level and department.

Note. TQM was first introduced in Japan after 2nd World War by the two American Economist *i.e.,* W.Edwards Deming and J.M. Juran, to rebuild the devasted economy.

Under the influence of these two men, the Japanese invested their money on designing, operations system that produced products with extremely small margins of errors and mistakes.

There are 14 principles of quality which were advocated by the **Deming.** These are as below :

(*a*) Create constancy of purpose towards improving products and services, allocating resources to provide for long large needs rather than short-run profitability.

(*b*) Adopt the new philosophy for economic stability by refusing to allow commonly accepted level of delay, mistakes, defective materials and workmanship.

(*c*) Cease dependence on mass inspection by requiring statistical evidence of built-in quality in both manufacturing and purchasing functions.

(*d*) Reduce the number of supplier for the same item by eliminating those, that do not quality with statistical evidence of quality. End the practice of awarding business solely on the basis of price.

(*e*) Search continuously for problems in the system to constantly improve processes.

(*f*) Institute modern methods of training to make better use of all employees.

(*g*) Focus supervision on helping people to do a better job. Ensure immediate action is taken on reports of defects, maintenance requirements, poor tools, in adequate operating definitions or other conditions detrimental to the products quality.

(*h*) Encourage effective two-way communication and other means to drive out fear throughout the organisation and help people work more productively.

(*i*) Break down barriers between departments by encouraging problem-solving through team work, combining the efforts of people from different areas such as research, design sales and production.

(*j*) Eliminate the use of numerical goals, posters and slogans for the workforce that task for new levels of productivity without providing methods.

(*k*) Remove all barriers that inhibit the worker's right to pride of workmanship.

(*l*) Institute a vigorous programme of education and re-training to keep up with changes in materials, methods, product design and machinery.

(*m*) Clearly define top managements permanent commitment to quality and productivity and its obligation to implement all these principles.

The job of quality management is not just advising a sampling plan for the acceptance/rejection of the incoming materials and controlling manufacturing process conditions, it is, in fact, a job at every step of the company's activity/activities.

Quality movement is more than just a series of awards and quality standards, the movement involves a total rethinking of how a business should be run. The term total quality management has been carried to describe a philosophy that makes quality values the driving force behind leadership, design, planning and improvement initiatives, like any other management process, quality management also has three main components *i.e.,*

(*i*) Planning/quality planning

(*ii*) Implementation/quality implementation

(*iii*) Monitoring and control/quality monitoring and quality control.

Quality Planning

It deals with following aspects:

1. To set quality objectives and targets and take into account customer's wants and the marketability of the products.

NOTES

2. To carry out pre-production process capability or quality deliver ability studies means to find out whether the company is capable of producing and marketing the products of certain quality.
3. To establish the relative importance of the quality characteristics and specifications, and communicate it to the production line people as well as to the vendors supplying the raw materials. Specifications and drawing per se, can never communicate what that particular specification stands for and why.
4. To look after various vendor quality control aspects such as examining new vendor facilities, their procedures and systems setting up of the vendor rating scales and periodic performance evaluation of the vendors.
5. To establish statistical control techniques, charts and sampling plans.
6. To establish training programmes for various personnel in the company so that quality consciousness gain a firm ground in the organisation.

Quality Implementation

The implementation part of quality management deals with:

1. Performing laboratory tests and analysis on the raw materials, finished products and the semifinished products for acceptance/rejection or for process control.
2. Maintaining quality control equipment *i.e.,* process, laboratory and inspection.
3. Advising and providing assistance for the clarification and solution of quality management problems in manufacture.

Quality Monitoring and Control

The quality monitoring and control functions deals with:

1. Appraising the quality plan vis-a-vis the problems of production and vendor quality. So that appropriate action is taken to correct the initial planning errors.
2. Appraising quality planning vis-a-vis the actual quality which has reached the customer and what the latters reaction is regarding the product quality, how such reaction can be set right by modification to the original quality plan.
3. In addition to performing quality audits, monitoring the costs of quality and providing such information to the quality-planners so that they take appropriate action for the future.

Cost of Quality

Quality management is not only concerned with maintaining the quality characteristics of a product but also with doing the same at the least cost. There are basically three categories of cost of quality.

(*a*) Costs of appraisal
(*b*) Costs of prevention
(*c*) Costs of failure.

Costs of Appraisal

This includes costs of inspection, testing and such checking operations are necessary to maintain the product quality. This includes the costs of implementation of quality and also the costs of monitoring and control.

Costs of Prevention

These are the costs of prevention of bad quality production. It also includes the costs of activity such as quality planning which tries to ensure the proper precautions have been taken to avoid wrong sampling plans being made or bad quality or raw materials entering into plant or improper methods and processes being followed in the plant.

Costs of Failure

Inspite of prevention and appraisal, there will still be losses due to rejections, rework, spoilage etc., to some extent. It also includes the costs of attending to customer complaints and providing product service, etc.

Quality Assurance

It is the activity of providing the evidence needed to establish confidence, among all concerned, that the quality-related activities are performed effectively.

According to **ISO-8402-1966** "*Quality assurance as related to a product or service; all these planned or systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality*".

Note. Quality assurance is often the title of a department which is concerned with many quality related activities such as quality planning, quality control, quality improvement, quality audit and reliability.

Many quality assurance activities provide protection against quality problems through early warnings of trouble ahead. The assurance comes from evidence *i.e.*, a set of facts. For simple products—the evidence is usually some form of inspection or testing of the product.

For complex products—the evidence is not only inspection and test data but also reviews of plans and audits of the execution of plans.

A family of assurance techniques is available to cover a wide variety of needs.

Following are the departmental activities provide assurance of quality:

(*a*) **Marketing:**

(*i*) Product evaluation by a test market controlled use of product

(*ii*) Product monitoring

(*iii*) Captive service activity

(*iv*) Special surveys

(*v*) Competitive evaluations.

(*b*) **Product Development:**

(*i*) Design review

(*ii*) Reliability analysis

(*iii*) Maintainability analysis

(*iv*) Safety analysis.

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(*c*) **Production:**

(*i*) Design review

(*ii*) Process capability analysis

(*iii*) Pre-production trail

(*iv*) Pre-production run

(*v*) Failure mode, effect and critically analysis for process

(*vi*) Review of manufacturing planning

(*vii*) Evaluation of proposed process control tools

(*viii*) Self control analysis

(*ix*) Audit of production quality.

(*d*) **Supplier Relation:**

(*i*) Qualification of supplier design

(*ii*) Qualification of supplier process

(*iii*) Evaluation of initial samples

(*iv*) Evaluation of 1st shipments.

(*e*) **Inspection and Test:**

(*i*) Inter laboratory test

(*ii*) Measuring inspector accuracy

(*f*) **Customer Services:**

(*i*) Audit of packing, storage and transportation

(*ii*) Evaluation of maintenance services.

QUALITY AUDIT

It is an independent review conducted to compare some aspect of quality performance with the standard set/laid down for that performance.

Note. 'Independent' means the person doing auditing has not direct or indirect involvement in the performance of that activity, hence the question of biasing is eliminated.

According to ISO 8402-1986 the quality audit is a systematic, independent examination and evaluation to determine whether quality activities and result comply with planned arrangements and whether these arrangements are implemented effectively and are suitable for achieving the desired objectives.

Quality audit is used as a tool to evaluate their quality performance along with the performance of their supplies, licenses, agents and other. The regulatory agencies use it to evaluate the performance of organisations.

Purpose of Quality Audit

Quality audit provides independent assurance that:

(*a*) Plans for attaining quality are such that, if followed the intended quality will, in fact, be attained.

(*b*) Products are fit for use and safe.

(c) Standards and regulation so designed/framed or laid down by the regulating authority/ies, industry associations and other professional bodies are being complied with.

(d) Conformation to the specification.

(e) Procedures are adequate and being followed.

(f) The data system provides accurate and adequate information on quality to all concerned.

(g) Identify the deficiencies and initiate the corrective measures.

(h) Identify the opportunities for the improvement and further development and if need appropriate modification/amendments must be incorporated.

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Audit Reporting

The audits results are complied in a form of report/draft to review during the post audit meeting with the management of the organisation/with the management of the activity that was audited.

Note. The report may be jointly issued by the auditor and auditee.

The audit report includes:

(a) Purpose and scope of the audit.

(b) Details of the audit plan, including audit personnel, dates, the activity to be audited, personnel contacted, material reviewed, number of observations made etc. Each detail must be placed as appendix.

(c) Standards, checklists or other references/documents used during the course of audit.

(d) Audit observations including supporting evidence, conclusion and recommendations.

(e) Recommendations to improve and opportunities.

(f) Recommendations for follow-up, corrective actions proposed, and implementation by the line management along with subsequent audits if necessary.

(g) Distribution list for the audit report.

Essentials of Quality Audit Programme

There are five essentials for a successful quality audit programme:

1. An uncompromising emphasis on conclusions base on facts. Any conclusion lacking a factual base must be so labeled.
2. An attitude on the part of auditors that the audits but only serve to provide assurance to management but also must provide a useful service to line managers in managing their departments. Thus, audit reports must provide sufficient detail on deficiencies to facilitate analysis and action by line managers.
3. An attitude on the part of auditors to identify opportunities for improvement. Such opportunities include highlighting good ideas used in practice that are not part of formal procedures. Sometimes, an audit can help to overcome deficiencies by communicating through the hierarchy the reasons for deficiencies that have a source in another department.

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4. Addressing of human relations issues.
5. The basic education and experience of the auditors should be sufficient to enable them to learn in short order the technological aspects of the operations they are to audit. In the absence of this background will unable to earn the respect of the operations personnel.

Note. Auditors must have special training in human relations aspects of auditing.

Quality Surveys

Quality audits are—however, not sufficient to provide full assurance to upper management that all is well with respect to quality since they are not concerned with the following:

1. Relative standing in the market place with regard to quality.
2. Analysis of user's situations with respect to cost, convenience etc., are the life of the product.
3. Opportunities for reducing cost of poor quality.
4. Challenge to product development, design engineering and other monopolistic departments on quality adequacy, perfections cost etc.
5. Challenge to top management itself with respect to polices, goals, premises and axiomatic beliefs.
6. Employee perception on quality.

To extend the quality assurance keeping in view the above discussed elements, a broader view of quality assurance is required, generally known as quality survey or quality assessment or company wide audit.

Note.

1. Here audit means the existence of established criteria against which plans and their execution can be checked.
2. Survey means the inclusion of matters not covered by agreed criteria.

Product Audit

It is an independent evaluation of product quality to determine its fitness for use and confirmance to specification. This activity starts after the inspections.

Purpose of Product Audit

There are numerous purposes of product audit however in important ones are as below:

(*a*) Estimating the quality level as delivered to customers.

(*b*) Evaluation of effectiveness of the inspection decision in determining confirmance to specifications.

(*c*) It provides useful information in improving the outgoing product quality level and improving the effectiveness of the inspection.

(*d*) It extends an additional assurance about quality beyond the inspection.

Stages of Evaluation

Product audit is a compare between the actual service performance with the user's service needs. Hence in real term a quite expensive affair and will the cost of product which is not desirable for the producer nor the customer. That is why product auditing is done in approximation.

There are a few potential product auditing stages which are listed below along with their pros and cons.

Stages:

1. After acceptance by inspectors
2. After packing but before shipment to market
3. Upon receipt by dealers
4. Upon receipt by customers/users
5. Performance in service.

Pros and Cons

1. **After Acceptance by Inspectors:** Though economical but not effective on packing, shipment, storage or uses.
2. **After Packing but Before Shipment to Market:** It requires unpacking and repacking which is costly affair, simultaneously evaluates the effect of original packing.
3. **Upon Receipt by Dealers:** It reflects effect of shipping and storage. But a difficult task as dealers are in multiple locations. Even if it is carried out or planned it is very expensive.
4. **Upon Receipt by Customer/Users:** It evaluates the added effects of dealer's handling, storage, effect of shipment to user and unpacking, but it is quite expensive to adopt.
5. **Performance in Service:** Most ideal because it is the real stage of product auditing where the customer's requirement can be compared with the performance of the product with the level of customers satisfaction. However it is most difficult to administer because of multiple locations, number and variety of customers.

Note.

1. This can be solved to a great extent by doing proper sampling.
2. In case of simple, stable products, the approximation of test results vs. specification is useful economic way of conducting the product audit.
3. Those products which are not so simple, the majority of the quality characteristics are identifiable by user as well as by the producers hence can be evaluated at the appropriate stage of production. Whether in factory or some more advance stage of progression.
4. The products which are complex need auditing at multiple stages. The bulk of characteristics may be evaluated at the most economical stage usually often factory inspection, the remaining usually sophisticated ones may be evaluated at other stages.

SIX SIGMA (6σ)

As in the name there is 6 which is number and other is sigma (σ) which is a symbol of standard deviation. Six sigma is a data driven quality measure that strives for a near perfection of any process.

"Six Sigma focuses on improving quality i.e., reduce waste by helping organisations produce products and services better, faster and cheaper. Six sigma focuses on direct prevention, cycle time reduction hence cost reducing and savings. Unlike cost

cutting programmes which reduce value and quality, it identifies and eliminates costs which provide no value to customers i.e., waste costs"—**Thomas Pyzdek.**

NOTES

Concept

The concept of Six Sigma ("6σ") can be easily understood with the concept of normal distribution curve.

In case of normal distribution curve, there is a symmetrical. 'Bell' shaped graph representing the distribution of data set. This Bell shaped curve results when a normal distribution is represented graphically by plotting the frequency mean with mean (*i.e.,* f_x and x). The curve is symmetrical about the mean value.

Features of Normal Distribution Curve

(*a*) It is symmetrical around their mean.

(*b*) This distribution has two parameters.

(*i*) mean 'μ'

(*ii*) standard deviation 'σ'

(*c*) Mean, median and mode of a normal distribution are equal.

(*d*) Usually 68% of area *i.e.,* data points lies within ± 1 σ of mean.

(*e*) 95% of area *i.e.,* data points lies ± 2 σ of the mean.

(*f*) 99.7% of area *i.e.,* data points lies ± 3 σ of the mean.

'6 σ' → Prior to the inspection of 6 σ system, the 3 σ tolerance level in any given process was used as bench mark for the quality measurement.

Motorola engineers observed that there is a shift of 1.5 σ in regular course. To keep the data points with in earlier permissible area, with mean shifting by 1.5 σ, the sigma level has to be half. To accommodate 1.5 σ sigma shift they proposed that the tolerance has to '± 6σ' from the mean.

Features:

1. In six sigma methodology 99.9996599% or more of process data lies with in ± σ from the mean.
2. Thus DPMO (defects per million opportunities) lies to 3.4.
3. 99.9996599% value is actually for 4.5 σ level in normal curve. But keeping in view the 1.5 sigma process shift the process signal level is actually six.
4. In six sigma process 99.9996599% data will be within ± 6σ level, which is a total of 12 sigma under the curve.
5. 12 standard deviations should be able to fit in the permissible spread *i.e.,* customer specification limits.

The permissible spread under the curve is

$$\text{Spread (p)} = U_{SL} - L_{SL}$$

where

U_{SL} = upper specification limit

L_{SL} = lower specification limit

S_P = spread permissible

$$12\ \sigma = S_p$$

Values of area under Normal curve: Sigma Percentage Data Parts/levels with in curve million:

6.0	99.9999999%	0.0
5.5	99.9999981%	0.0
5.0	99.9999713%	0.3
4.5	99.9996599%	3.4
4.0	99.9968314%	31.7
3.5	99.9767327%	232.7
3.0	99.8650033%	1350.0
2.5	99.3790320%	6209.7
2.0	97.7249938%	22750.1
1.5	93.3192771	66807.2
1.0	84.1344740%	158655.3
0.5	69.1462488%	308537.5
0.0	50.0000001%	500000.0

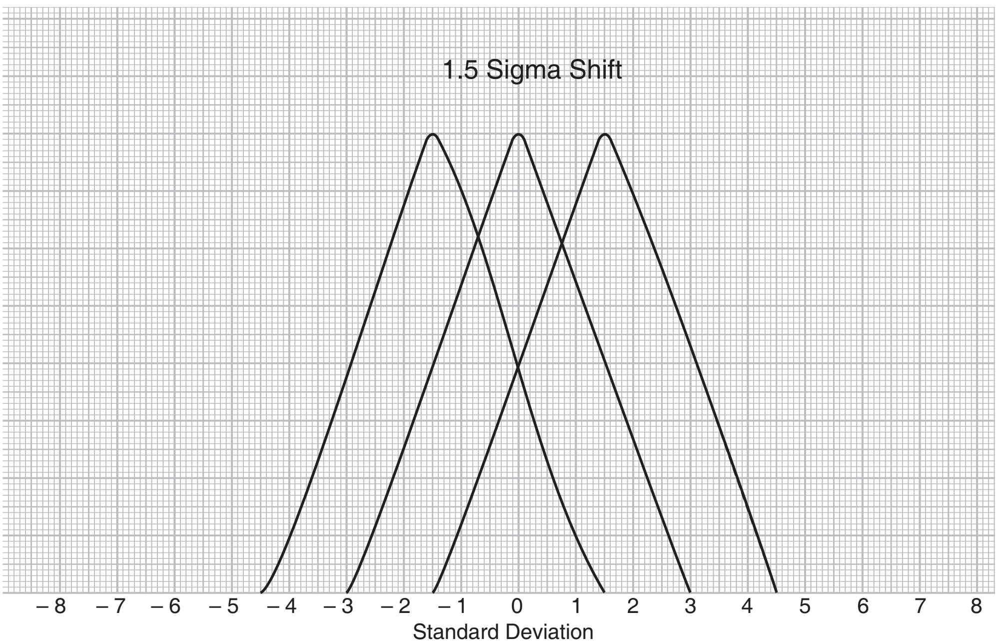

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Illustration

A customer *X* wants metal sheet of 1 mm thickness with a tolerance of 0.001 mm.

So the customer wants thickness between 0.999 mm to 1.001 mm means.

$L_{SL} = 0.999$ mm

$U_{SL} = 1.001$ mm.

$S_p = U_{SL} - L_{SL} = 1.001 - 0.999 = 0.002$ mm.

$12\ \sigma = S_p$

$12\sigma = 0.002$ or $\sigma = 0.002/12 = 0.000167$

standard deviation for a six sigma = 0.000167.

NOTES

Advantages

There are numerous advantages out of which a few important ones are as below:

(*a*) Less defects
(*b*) Higher customer focus (called voice of customer or VOC)
(*c*) Lower cost
(*d*) High employee focus (also called as voice of employee or VOE)
(*e*) Data based hence better and quick decision making
(*f*) Effective management vision
(*g*) Multiply benefits by integration with ERP etc.

Methodologies

There are basically four methodologies in 6 σ which are as below:

(*a*) DMAIC (Define, measure, analyse, impure and control)
(*b*) DMADV (Define, measure, analyse, design and verify)
(*c*) DFSS (Design of Six Sigma by IDOV-Identify, design, optimise and validate)
(*d*) BPMS (Business process management system)

Implementation of Six Sigma

The following steps are involved in the implementation of six sigma in an organisation:

1. Define the priorities of the customers with respect to quality.
2. Measure the processes and the defects arising in the product due to the process.
3. Analyse the process to determine the most likely causes of defect.
4. Improve the process performance and remove the causes of defects.
5. Ensure the improvements are maintained over time.

1. **Define the Priorities of the Customers with Respect to Quality.** This step involves the identification of those attributes which are considered most important by the customers while evaluating the quality of the products. These attributes are usually called critical to quality characteristics.

   Note. The customer's perception of quality attributes is updated from time to time by conducting customers surveys.

2. **Measure the Processes and the Defects Arising in the Product due to the Process.** In this step, those processes are identified which are influencing the CTQ (Critical to quality) characteristics and then performance measurement techniques are established for these processes. The processes are measured and thus the defects arising in the product due to processes are identified.
3. **Analyse the Process to Determine the Most Likely Causes of Defects.** This step involves the identification of key variables responsible for variation in the process. This helps in finding out the reason for defect generation.
4. **Improve the Process Performance and Remove the Causes of Defect.** Specification limits of the key variables are fixed and a system for measuring the deviations of the variables is established and validated. The process is improvised in order to keep the variables within the specifications limits.

5. **Ensure the Improvements are Maintained Over Time.** The modified process is subjected to vigil at regular intervals of time to ensure that the key variables do not show any unacceptable variations.

INTERNATIONAL STANDARDISATION ORGANISATION

ISO is an International Organisation for Standardisation. It is made up of national standards institutes from countries large and small, industrialised and developing, in all regions of the world. ISO develops voluntary technical standards which add value to all types of business operations. They contribute in making the development, manufacturing and supply of products and services more efficient, safer and clearner. They made trade between countries easier and fairer. ISO standards also serve to safeguard consumers and uses in general of products and services and to make their lives simpler. ISO develops only those standards which are required by the market. This work is carried out by experts on loan from the industrial, technical and business sectors which have asked for the standards and which subsequently put them to use. These experts may be joined by others with relevant knowledge, such as representatives of government agencies and testing laboratories. Published under the designation of international standards, ISO standards represent an international consensus on the "state of the art" in the technology concerned.

The idea behind ISO 9000 which is an attempt to being in uniformity in the quality standards prevailing each pertaining to a different country, *e.g.,* BSI (British Standards), DIN (German Standards), ASQC (American Standards and MIL Standards). The genesis of ISO 9000 began with the launch of technical committee 176 in year 1979 and culminated in the ISO-9000 series, which was issued in year 1987. Different countries have now adopted ISO 9000 series under their respective national standards.

Note. India has adopted it as IS-14000 series while United States of America has adopted it as ANSI/ASQC Q 90 series (Q 90, Q 91, Q 92, Q 93 and Q 94) and European Union as Ex (European Norm) 29000 series.

The ISO 9000 standards, which consists of 6 parts *i.e.,* ISO 8402, ISO 9000, ISO 9001, ISO 9002, ISO-9003 and ISO 9004, stand for system standardisations and certification rather than product standardisation and certification. They do not replace but complement the product standard.

Objectives of ISO-9000

There are two basic objectives of ISO-9000 given as below:

(*a*) To facilitate international trade of goods and services.

(*b*) To obtain competitiveness by obtaining required quality in a cost effective way.

Means to Achieve the Objectives

(*i*) Promoting a single third party assessment of quality standard.

(*ii*) Becoming part of a national/regional/international quality standard.

(*iii*) Encouraging bilateral and multilateral agreements in trade, technology and manufacture.

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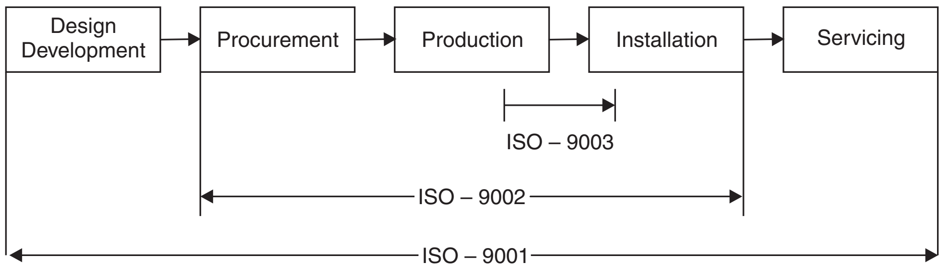
(*iv*) Helping industries to improve their quality standards.

(*v*) Promoting Total Quality Control (TQC) systems.

Documentation: ISO-9000 provides the essential documentation and systems to enable an establishment to translate their quality assurance policy into specific actions plans. Some of these important documents are as below:

1. ISO-8402 → Quality Vocabulary
2. ISO-9000 → Quality Standard—general guidelines
3. ISO-9001 → Quality Standard—for supplies
4. ISO-9002 → Quality Standard—for manufactures
5. ISO-9003 → Quality Standard—for test houses
6. ISO-9004 → Quality Standard—systems and elements



ISO-9000 Standards and their areas of application in production flow.

Elements of ISO-9000

Following are the essentials of ISO-9000:

(*a*) Management responsibility
(*b*) Quality system
(*c*) Contract review
(*d*) Design control
(*e*) Document control
(*f*) Purchasing
(*g*) Customer-supplied material
(*h*) Product identification and traceability
(*i*) Process control
(*j*) Inspection and testing
(*k*) Inspection, measuring and test equipment
(*l*) Inspection and test status
(*m*) Control of non-conforming product
(*n*) Correction action
(*o*) Handling, storage, packing, delivery
(*p*) Quality Records
(*q*) Internal quality audits
(*r*) Training
(*s*) Servicing
(*t*) Statistical techniques.

Management Responsibility

1. The quality policy shall be defined, documented, understood implemented and maintained.
2. Responsibilities and authorities for all personnel specifying achieving and monitoring quality shall be defined. In house verification resources shall be

defined, trained and funded. A designated management person sees that the *Q* 91 programme is implemented and maintained.

Quality System

1. Procedures shall be prepared.
2. Procedures shall be implemented.

Contract Review

In coming contracts and purchase orders shall be reviewed to see whether the requirements are adequately/defined, agreed with the bid and can be implemented.

Design Control

1. Project design shall be planned.
2. Design input parameters shall be defined.
3. Design output, including crucial product characteristics shall be documented.
4. Design output shall be verified to meet input requirements.
5. Design changes shall be controlled.

Document Control

1. Generation of documents shall be controlled.
2. Distribution of documents shall be controlled.
3. Changes to documents shall be controlled.

Purchasing

1. Potential sub-contractors and sub-suppliers shall be evaluated for their ability to provide stated requirement.
2. Requirements shall be clearly defined in contracting data.
3. Effectiveness of the sub-contractors quality assurance system shall be assessed.

Customer-Supplied Material

Any customer-supplied material shall be protected against loss or damage.

Product Identification and Traceability

The product shall be identified and traceable by item, batch of lot during all stages of production, delivery and installation.

Process Control

1. Production and installation processes shall be defined and planned.
2. Production shall be carried out under controlled condition documented instructions, in process controls, approval of processes and equipment and criteria for work man ship.
3. Special processes that cannot be verified after the fact shall be monitored and controlled throughout the processes.

Inspection and Testing

1. The incoming material shall be in inspected or verified before use.
2. In process inspection and testing shall be performed.

3. Final inspection and testing shall be performed prior to release of finished product.
4. Records of inspection and test shall be maintained.

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Inspection, Measuring and Test Equipment

1. Equipment used to demonstrate conformance shall be controlled, calibrated and maintained.
   (*i*) Identify measurements to be made.
   (*ii*) Identify affected instruments.
   (*iii*) Calibrate instruments, maintain procedures and status indication.
   (*iv*) Periodically check calibration.
   (*v*) Assess measurement validity if found out of calibration.
   (*vi*) Control environmental conditions in metrology lab.
2. Measurement uncertainty and equipment capability shall be known.
3. Where test hardware or software is used, it shall be checked before use and rechecked during use.

Inspection and Test Status

1. Status of inspections and tests shall be maintained for items as they progress through various processing steps.
2. Records shall show who released conforming product.

Control of Non-Conforming Product

1. Non-conforming product shall be controlled to prevent in advertent use of installation.
2. Review and disposition of non-conforming product shall be accomplished in a formal manner.

Corrective Action

1. Problem causes shall be identified.
2. Specific problems and their causes shall be corrected.
3. Effectiveness of corrective actions shall be assessed.

Handling, Storage, Packing and Delivery

1. Procedures for handling, storage, packing and delivery shall be developed and maintained.
2. Handling control should be such to prevent damage and deterioration.
3. Secure storage shall be provided. Production storage must be checked at a regular interval for deterioration.
4. Packing, preservation and marking processes shall be controlled.
5. Quality of the product after final inspection shall be maintained. This might include delivery controls.

Quality Records

Quality records shall be identified, collected, indexed, filed, stored, maintained and dispositioned.

Internal Quality Audits

1. Audits shall be planned and performed.
2. Results of audits shall be communicated to management.
3. Any deficiencies found shall be corrected.

Training

1. Training needs must be identified and training must be provided.
2. Selected tasks might require qualified individuals.
3. Records of training must be maintained.

Servicing

1. Servicing activities must be carried out in a routeen and should be as per the written procedures.
2. Servicing activities must meet all the requirements of production.

Statistical Techniques

1. Statistical techniques must be identified, adopted and used to verify acceptability of process capability and product characteristics.

Advantages

There are numerous advantages to those organisation which have ISO certification. These advantages can be classified in the following classes:

1. For users/customers
2. For suppliers
3. For manufacturers
4. For marketing.

For User/Customers

1. Confidence in quality and reliability of product and services received.
2. Economy and competitive prices.
3. Assured after sales service.
4. Traceability of manufacturer, design and specifications.

For Suppliers

1. QC-001005 Qualified product list is available for reference. This helps in identification of vendors.
2. Rationalization of component product based on international standard/ specification.
3. Simplified control for long-range contracts.
4. Availability of world-wide on line database called CODUS.

For Manufacturers

1. Rationalisation of product range.
2. No huge investment of inward Goods inspection (TGI) department.
3. No need to have separate vendor indentification/development/evaluation process.
4. Cost reduction due to reduced rework and scraps.

For Marketing

1. Global viability due to international standards.
2. Provides national/international reputation.
3. Competitiveness.
4. Assumed international quality level.

Benefits

1. ISO-9000 certification has became the de facto minimum requirement for those wishing to compete globally.
2. All actions in preparing for ISO-9000 certification and in maintaining the certification would result in streamlining of the quality management system which may lead to improved quality product. The extent of improvement may vary from one firm to another. With the formal documentation procedures which ISO-9000 demands, would minimise misinterpretation manipulations and mal practices.
3. It also leads to significant cost reduction with the help of reduction in rework, warranty work repair, scrap etc.
4. ISO-9000 lays stress on customers orientation. This would result in better overall results for the company in addition to improving customer relations.
5. There may be an impetus to improve employee relations, employee empowerment and organisational development.

Procedure of Registration

ISO is located in Geneva, Switzerland but each member country which is affiliated to ISO, has its own National Standard Organisation (NSO). The systems and procedures are laid down by NSO's. In general procedure is as following:

(1) Preliminary information
(2) Formal application
(3) Screening and evaluation
(4) Issue 1st stage approval
(5) Issue 2nd stage approval
(6) Grant of certificate from the concerned authority (international)
(7) Follow up/surveillance.

Getting the ISO 9000 certification is not sufficient. There are re-audits by the ISO registrars every three years and surveillance audits approximately twice a year in order to ensure continued compliance.

Note. ISO-9000 certification is valid for not more than three years.

In order that the system standards translate to product/service quality, it requires that a strong commitment to quality continues to be present with the top levels of management and there are attitudinal changes at all levels in the entire organisation. It takes time, training and sustained management effort, because ISO-9000 is a part of TQM.

ISO-14000

It is the family of International Standards on environmental management, is a relative newcomer to ISO's portfolio but environment related standardization is far from being a new departure for ISO. In fact, ISO has a two pronged approach to meeting the needs of business, industry, governments, NCO's and consumers in the field of environment.

1. It offers a wide ranging portfolio of standardized sampling testing and analytical methods to deal with specific environmental challenges. It has developed more than 350 international standards out of a total of more than 12,000 for the monitoring of such aspects as the quality of air, water and soil. These standards are a means of providing business and government with

scientifically valid data on the environmental effects of economic activity. They also serve in a number of countries as the technical basis for environmental regulations.

2. ISO is leading a strategic approach by developing environmental management system standards that can be implemented in any type of organisation in either public or private sectors (companies, administration, public utilities). To spearhead this strategic approach, ISO established a new technical committee, ISO/TC 207, Environment management in 1993. This followed ISO's successful pioneering experience in management system standardization with the ISO-9000 series for quality management. ISO's direct involvement in environmental management stemmed from an intensive consultation process, carried out within the frame work of a Strategic Advisory Group on Environment (SAGE), set up in 1991, in which 20 centres, 11 international organisations and more than 100 environmental experts participated in defining the basic requirements of a new approach to environment-related standards. This pioneering work was consolidated with ISO's commitment to support the objective of "Sustainable development". Today, delegations of business and Government experts from 55 countries participate actively within TC-207, and another 16 countries have observer status. These delegations are chosen by the National Standards Institute concerned and they are required to bring to TC-207 a national consensus on issues being addressed by the committee.

ISO-14000 series meets the needs of the international business community and the concerns of those interested in the environmental management of organisations.

1. ISO-14001—Environmental management system (specification in the guidance for use)
2. ISO-14004—Environmental management system—General guidelines on principles, systems and supporting techniques.
3. ISO-14010—Guidelines for environmental auditing—General principles.
4. ISO-14011—Guidelines for environmental auditing—Audit procedures, auditing of environmental management systems.
5. ISO-14012—Guidelines for environmental auditing—Qualification criteria for environmental auditors.
6. ISO/WD 14015—To be environmental assessment of sites and entities determination.
7. ISO-14020—Environmental labels and declarations—General principles.
8. ISO/DIS-14021—Environmental labels and declaration—Self-declared environmental claims.
9. ISO/FDIS-14024—Environmental labels and declarations-Type I environmental labelling—Principles and Procedures.
10. ISO/WD/TR 14025—To be environmental labels and declarations-Type III environmental determined declarations—Guiding principles and procedures.
11. ISO/DIS 14031—Environmental management—Environmental performance evaluation—Guidelines.
12. ISO/TR-14032—Environmental management—Environmental performance evaluation—Case studies illustrating the use of ISO 14031.
13. ISO-14040—Environmental management—Life cycle assessment—Principles and frame work.

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14. ISO-14041—Environmental management—Life cycle assessment—Goal and scope definition and inventory analysis.
15. ISO/CD-14042—Environmental management—Life cycle assessment—life cycle impact assessment.
16. ISO/DIS-14043—Environmental management—Life cycle assessment—life cycle interpretation.
17. ISO/TR-14048—Environmental management—Life cycle assessment—life cycle assessment data documentation format.
18. ISO/TR-14049—Environmental management—Life cycle assessment—Examples for the application of ISO 14041.
19. ISO-14050—Environmental management—vocabulary.
20. ISO/TR-14061—Information to assist forestry organisation in the use of the environmental management system standard ISO-14001 and ISO-14004.
21. ISO Guide 64—Guide for the inclusion of environmental aspects in product standards.

ILLUSTRATIONS

1. Construct $\bar{X}$ and R chart from the following data:

Sub-group no.	$\bar{x}$	R	*Sub-group no.*	$\bar{x}$	R
1	6.36	0.10	11	6.32	0.18
2	6.38	0.18	12	6.30	0.10
3	6.35	0.17	13	6.34	0.11
4	6.39	0.20	14	6.39	0.14
5	6.32	0.15	15	6.37	0.17
6	6.34	0.16	16	6.36	0.15
7	6.40	0.13	17	6.35	0.18
8	6.33	0.18	18	6.35	0.13
9	6.37	0.16	19	6.34	0.18
10	6.33	0.13	20	6.34	0.16

assume constant $\Delta_2 = 0.73,\ D_3 = 0,\ D_4 = 2.28.$

Solution. For $\bar{x}$ chart

(*a*) $\bar{x}$ central line $= \dfrac{\Sigma\bar{x}}{k}$

$\bar{\bar{x}} = 127.03/20 = 6.351$ K = 20 (no. of sub-group)

$\bar{\bar{R}} = \Sigma R/k = 3.06/20.$ $\Sigma\bar{x} = \bar{x}_1 + \bar{x}_2 \ldots x_n^n$

$= 0.153.$ $= 127.03$

$K = 20,\ \Sigma\bar{R} = \bar{R}_1 + \bar{R}_2 \ldots \bar{R}_n$

$= 3.06.$

$$UCL_{\bar{x}} = \bar{\bar{x}} + \Delta_2 \bar{R}$$
$$= 6.351 + 0.73 \times 0.153$$
$$= 6.351 + 0.112 = 6.463.$$
$$LCL_{\bar{x}} = \bar{\bar{x}} - \Delta_2 \bar{R}$$
$$= 6.351 - 0.112 = 6.239$$

(*b*) For $\bar{R}$ chart

$$\text{central line} = \bar{R} = 0.153$$
$$UCL_R = D_4 \bar{R}$$
$$= 2.28 \times 0.153 = 0.349.$$
$$LCL_R = D_3 \bar{R}$$
$$= 0 \times 0.153 = 0 \text{ or NIL}$$

2. During the visual inspection to find out the defects in the production following data for a sample size of 30 numbers were received.

Sub-group No.	*No. of defectives*	*Sub-group No.*	*No. of defectives*
1	5	11	5
2	4	12	7
3	4	13	4
4	4	14	5
5	7	15	4
6	4	16	5
7	5	17	5
8	6	18	1
9	4	19	6
10	5	20	4

In the subsequent week 30 pieces were again inspected on each of two occasions and 6 pieces and 9 pieces were found to be defective in each case respectively. Determine whether the process is under statistical control or not.

Solution:

Since sample size (n) = Constant = 30 sub-groups hence np. chart has to be constructed.

Central line = $n\bar{p}$ where n = sample number

$\bar{p}$ = average of fraction defects

$$\bar{p} = \frac{101}{20 \times 30} = \frac{101}{600} = 0.168. \qquad \bar{p} = \frac{\text{sum of all the defectives}}{\text{k.n}}$$

NOTES

Central line:

$$n\bar{p} = \frac{101}{600} \times 30 = \frac{101}{20} = 5.05 \qquad = \frac{\Sigma np}{kn} \quad k = 20,\ n = 30.$$

$$\Sigma_{np} = \Sigma C = C_1 + C_2 \ldots C_n = 101$$

$$\text{VCL} = n\bar{p} + 3\sqrt{n\bar{p}\,(1-\bar{p})}$$

$$= 5.05 + 3\sqrt{5.05\,(1-1.68)}$$

$$= 5.05 + 3\sqrt{5.05 \times 0.832} = 5.05 + 3\sqrt{4.2}$$

$$= 5.05 \times 3 \times 2.05 = 5.05 + 6.15 = 9.20$$

$$\text{LCL} = n\bar{p} - 3\sqrt{n\bar{p}\,(1-\bar{p})}$$

$$= 5.05 - 6.15 = (-)\ 1.10$$

$$= 0 \text{ as negative.}$$

For 2 sub-groups from which samples are inspected this week the defectives found were 6 and 9 nos. Since these values are less than UCL *i.e.,* 9.20. Hence process is under statistical control.

3. For the following data, construct a fraction defective chart.

Group Number	*Sample Size*	*No. of defectives*
1	32	2
2	32	3
3	50	3
4	50	2
5	32	1
6	80	4
7	50	2
8	50	0
9	32	2
10	32	1

Note. 1. Since the sample size is varying p-chart (fraction defective chart for varying sample size) has to be constructed.

2. With the varying sample size the control has varying control limits.

Central line CL = $\bar{p} = \Sigma p/k$.

where $p = \frac{C}{n}$ = Number of defective/sample size.

For Group Number $1 - p_1 = \frac{C_1}{n_1} = 2/32 = 0.0625$.

$2 - p_2 = C_2/n_2 = 3/32 = 0.0940$

$3 - p_3 = C_3/n_3 = 3/50 = 0.0600$

NOTES

For Group No. $4 - p_4 = \dfrac{C_4}{n_4} = \dfrac{2}{50} = 0.0400$

$5 - p_5 = \dfrac{C_5}{n_5} = \dfrac{1}{32} = 0.0300$

$6 - p_6 = \dfrac{C_6}{n_6} = \dfrac{4}{80} = 0.0500$

$7 - p_7 = \dfrac{C_7}{n_7} = \dfrac{2}{50} = 0.0400$

$8 - p_8 = \dfrac{C_8}{n_8} = \dfrac{0}{50} = 0.0000$

$9 - p_9 = \dfrac{C_9}{n_9} = \dfrac{2}{32} = 0.0625$

$10 - p_{10} = \dfrac{C_{10}}{n_{10}} = \dfrac{1}{32} = 0.0300.$

$K = 10, \Sigma p = p_1 + p_2 \ldots\ldots p_{10}$

$= 0.0625 + 0.0940 + 0.0600 + 0.0400 + 0.0300 + 0.0500$
$+ 0.0400 + 0.0000 + 0.0625 + 0.0300$

$= 0.469.$

$$\bar{p} = \frac{\Sigma p}{K} = \frac{0.469}{10} = 0.0469 \approx 0.047.$$

$$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{\text{Sample size}(n)}} = 0.047 + 3\sqrt{\frac{0.047(1-0.047)}{32}}$$

when $n = 32$

$$= 0.047 + 3\sqrt{\frac{0.047(0.953)}{32}}$$

$$= 0.047 + 3 \times \sqrt{\frac{0.0448}{32}}$$

$= 0.047 + 3 \times \sqrt{0.0014}$

$= 0.047 + 0.112$

$UCL_{32} = 0.159$

$$LCL = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = 0.047 - 3\sqrt{\frac{0.047(1-0.047)}{32}}$$

$$= 0.047 - 3 \times \sqrt{\frac{0.0448}{32}}$$

$LCL_{32} = 0.047 - 0.0112 = \text{(negative)}$

NOTES

When $n = 50$

$$UCL_{50} = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

$$= 0.047 + 3\sqrt{\frac{0.047(1-0.047)}{50}}$$

$$= 0.047 + 3\sqrt{\frac{0.047 \times 0.953}{50}}$$

$$= 0.047 + 3\sqrt{\frac{0.0448}{50}}$$

$$= 0.047 + 3 \times \sqrt{0.0009}$$

$$= 0.047 + 3 \times 0.03$$

$$UCL_{50} = 0.047 + 0.09 = 0.137$$

$$LCL_{50} = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = 0.047 - 3\sqrt{\frac{0.047(1-0.047)}{50}}$$

$$= 0.047 - 3\sqrt{\frac{0.047 \times 0.953}{50}}$$

$$= 0.047 - 3\sqrt{\frac{0.0448}{50}}$$

$$= 0.047 - 3\sqrt{0.009}$$

$$= 0.047 - 3 \times 0.03$$

$$LCL_{50} = 0.047 - 0.09 = \text{(negative) NIL}$$

When $n = 80$

$$UCL_{80} = 0.047 + 3\sqrt{\frac{0.047 \times 0.953}{80}}$$

$$= 0.047 + 3\sqrt{\frac{0.0448}{80}}$$

$$= 0.047 + 3\sqrt{0.000056}$$

$$= 0.047 + 3 \times 0.024$$

$$= 0.047 + 0.072$$

$$UCL_{80} = 0.119$$

$$LCL_{80} = 0.047 - 0.072 = \text{(negative) means NIL}$$

In the above question three values of 'n' are taken *i.e.,* 32, 50, 80 because maximum no. of sample size are 32, 50, 80.

4. Construct a 'C' chart or number of defects chart for the following data.

Sub-group	*Sample size (n)*	*No. of defect (c)*
1	1	15
2	1	28
3	1	41
4	1	26
5	1	26
6	1	35
7	1	40
8	1	24
9	1	10
10	1	38

For the '*C*' chart or number of defects chart for constant sample size.

Central line = $\bar{C}$ = Total number of defects/Total no. of samples

$$= \frac{\Sigma C}{\Sigma n}, \ \Sigma C = C_1 + C_2 + C_3 \ ...... \ C_{10}$$

$$\Sigma n = n_1 + n_2 + n_3 \ ... \ n_{10}$$

$$\Sigma C = 283, \ \Sigma n = 10.$$

then $$\bar{C} = \frac{\Sigma C}{\Sigma n} = \frac{283}{10} = 28.3$$

$$UCL = \bar{C} + 3\sqrt{\bar{C}}$$

$$= 28.3 + 3\sqrt{28.3}$$

$$= 28.3 + 3 \times 5.32$$

$$= 28.3 + 15.96 = 44.26.$$

$$\text{LCL} = \bar{C} - 3\sqrt{\bar{C}} = 28.3 - 3 \times 5.32$$

$$= 28.3 - 15.96 = 12.34.$$

5. Draw a $\bar{X} - \bar{R}$ chart for the following:

Sum of mean of all sample = 585,

Sum of ranges of all samples = 410.

No. of samples = 20.

Sample size = 5 each.

$$A_2 = 0.58, \ D_4 = 2.28, \ D_3 = 0.$$

Solution:

Given $$\Sigma \bar{x} = 585, \ \Sigma \bar{R} = 410, \ K = 20,$$

$$A_2 = 0.58, \ D_4 = 2.28, \ D_3 = 0.$$

NOTES

$$CL = \bar{\bar{x}} = \frac{\Sigma \bar{x}}{k} = \frac{585}{20} = \frac{58.5}{2} = 29.25$$

$$\bar{\bar{R}} = \frac{\Sigma R}{k} = \frac{410}{20} = \frac{41}{2} = 20.5$$

for $\bar{X}$ chart

$$UCL_{\alpha} = \bar{\bar{x}} + A_2\bar{R}$$
$$= 29.25 + 0.58 \times 20.5$$
$$= 29.25 + 1.189$$
$$= 30.44 \text{ approx.}$$

$$LCL_{\alpha} = \bar{\bar{x}} - A_2\bar{R}$$
$$= 29.25 - 0.58 \times 20.5$$
$$= 29.25 - 1.189$$
$$= 28.061$$

for $\bar{R}$ chart

Central line = 20.5

$$UCL_R = D_4\bar{R} = 2.28 \times 20.5 = 46.75$$

$$LCL_R = D_3\bar{R} = 2.28 \times 0 = \text{zero. (NIL)}$$

6. 10 samples each of size 100 of a components were inspected. The results of the inspection are as below:

Sample No.	1	2	3	4	5	6	7	8	9	10
No. of defects	2	0	4	3	1	2	3	1	1	2.

Draw the relevant control chart taking 3 sigma limits.

Solution: As the sample size is constant the '*np*' chart *i.e.,* fraction defectives chart for constant sample size has to be made.

Sample size $n = 100$, No. of sample (sub-group) $k = 10$

No. of defective per sub-group = C

fraction defective $p = c/n$.

Central line $= n\bar{p} = n \times Sp/k$

as $\bar{p} = c/n$ then $\Sigma p = \Sigma c/n$.

then $n\bar{p} = n \frac{\Sigma c}{n} \Big/ k$

or $= \Sigma c/k$

$\Sigma C = C_1 + C_2 \ldots C_{10} = 2 + 0 + 4 + 3 + 1 + 2 + 3 + 1 + 1 + 2$

$= 19.$

$n = 10.$

then $n\bar{p} = 19/10 = 1.9.$

NOTES

$$UCL = n\bar{p} + 3\sqrt{n\bar{p}\,(1-\bar{p})}$$

$$= 1.9 + 3\sqrt{1.9\left(1-\frac{19}{100}\right)}$$

$$= 1.9 + 3\sqrt{1.9 \times 0.981} = 1.9 + 3 \times \sqrt{0.1864}$$

$$= 1.9 + 3 \times 1.365 = 1.9 + 4.096$$

$$= 5.996 \approx 6$$

$$\text{LCL} = n\bar{p} - 3\sqrt{n\bar{p}\,(1-\bar{p})}$$

$$= 1.9 - 3\sqrt{1.9\left(1-\frac{19}{100}\right)}$$

$$= 1.9 - 3\sqrt{1.9\,(0.981)}$$

$$= 1.9 - 3 \times \sqrt{1.864} = 1.9 - 3 \times 1.365$$

$= 1.9 - 4.095 = -2.2$ (negative) NIL.

7. Calculate the process capability from the given data, 20 samples of 5 each were measured and the readings are $\Sigma\bar{x} = 585$, $\Sigma R = 410$, $d_2 = 2.33$,

Solution: $n = 5$, $k = 20$, $\Sigma\bar{x} = 585$, $\Sigma R = 10$, $d_2 = 2.33$.

For $\bar{x}$ chart.

$$C_L = \bar{\bar{x}} = \frac{\Sigma\bar{x}}{k} = \frac{585}{20} = 29.25$$

$$\text{CL for } R = \bar{\bar{R}} = \frac{\Sigma R}{k} = \frac{410}{20} = 20.5.$$

$$\boldsymbol{UCL\bar{x}} = \bar{\bar{x}} + RA_2$$

$$= 29.25 + 0.576 \times 20.5$$

$$= 29.25 + 11.89 = 41.14$$

$$A_2 = 3/\sqrt{n} \times d_2$$

$$= 3/\sqrt{5} \times 2.33$$

$$= \frac{3}{2.33 \times 2.23} = \frac{3}{5.20}$$

$$= 0.576.$$

$$LCL\ \bar{x} = \bar{\bar{x}} - A_2R$$

$$= 29.25 - 0.576 \times 20.5$$

$$= 29.25 - 11.89 = 17.36.$$

PROBLEMS

1. Construction of $\bar{X}$-R chart on the basis of following informations:
   Product-wire bound transistor
   Parameter-Bond strength

NOTES

Specification limit = 3 gms.
No. of samples/sub-group = n = 3.
No. of sub-groups = k = 26.
Data collected for 26 sub-groups are

Bond length in gms				*Bond length in gms*			
Sub-group No.	*Sample 1*	*Sample 2*	*Sample 3*	*Sub-group No.*	*Sample 1*	*Sample 2*	*Sample 3*
1.	6.5	6.5	5.0	14.	6.0	4.5	4.5
2.	6.5	6.0	7.0	15.	4.0	6.5	5.5
3.	7.0	5.5	5.5	16.	4.0	7.0	7.0
4.	4.0	3.0	3.5	17.	5.0	6.0	4.0
5.	2.0	0	1.0	18.	3.0	6.0	6.0
6.	6.0	6.0	6.0	19.	5.5	5.0	7.5
7.	6.0	4.0	4.0	20.	7.0	6.0	5.0
8.	6.0	4.0	6.0	21.	5.0	5.0	5.0
9.	5.5	5.0	4.5	22.	5.5	2.5	3.5
10.	7.0	6.0	6.0	23.	4.0	3.5	4.5
11.	5.0	3.5	5.0	24.	3.5	4.5	5.0
12.	4.0	3.5	3.0	25.	6.0	5.5	6.0
13.	4.0	3.0	3.5	26.	5.5	6.0	6.0

2. Construct $\bar{X}$-R chart for following data:

Sample No.	*Sample mean*	*Sample Range*
1	21.5	2.1
2	22.2	1.1
3	22.7	0.4
4	22.2	1.3
5	22.5	1.6
6	21.6	2.5
7	21.1	3.5
8	22.9	3.8
9	22.1	3.7
10	22.9	2.1

3. Construct a number of defects chart based on the following data:

Sample No.	*No. of defects*	*Sample No.*	*No. of defects*
1	7	13	16
2	6	14	6
3	6	15	6
4	7	16	15
5	4	17	8
6	7	18	7
7	8	19	13
8	9	20	4
9	9	21	6
10	8	22	8
11	5	23	9
12	12	24	5

4. Sample of 4 each were taken for study the measurement of which were noted as below:

Sample No.	*Measurement in m.m.*			
1	20	25	22	24
2	18	20	23	26
3	24	22	20	25
4	23	26	24	24
5	24	24	25	21

Draw a control chart for mean (A_2 = 0.73 for sample size 4).

5. Construct a fraction defective chart for the following data and plot the chart on a graph sheet.

Sample size = 400 nos.

No. of sub-groups = 12

Sub-group No.	*No. of defectives*
1	24
2	38
3	52
4	26
5	36
6	30
7	42
8	24
9	20
10	16
11	20
12	32

NOTES

SUMMARY

- Quality is an important dimension of production and operations management. It is not enough to produce goods or services in the right quantity and at the right time. It is important to ensure that the goods and services produced are of right quality.
- "*The sum of the attributes or properties that describe a product. These are generally expressed in terms of specific product characteristics such as length, width, colour, specific gravity and the like.*"
- A typical control chart consists of a central line corresponding to the average quality at which the process is to perform and two other lines corresponding to the upper and lower control limits, also called as tolerance limits.
- When 100% inspection is not practically possible because either it is too costly and time consuming or when inspection itself is of destructive in nature, sampling inspection is the best way of estimating the quality of incoming or outgoing lots.
- In sequential sampling plan, units are randomly selected from the lot and tested one by one. After each one is tested a reject, accept or continuous sampling decision is made.
- In the past the quality used to be considered as the by-product of the manufacturing system. Due to the variations in the process there use to be some defective parts or the finished products and if these so called defective parts/finished products lie with the permissible tolerance were send to the market otherwise back to the manufacturing system for the rework.
- Quality movement is more than just a series of awards and quality standards, the movement involves a total rethinking of how a business should be run.
- It is an independent review conducted to compare some aspect of quality performance with the standard set/laid down for that performance.
- The audits results are complied in a form of report/draft to review during the post audit meeting with the management of the organisation/with the management of the activity that was audited.
- *"Six Sigma focuses on improving quality i.e., reduce waste by helping organisations produce products and services better, faster and cheaper. Six sigma focuses on direct prevention, cycle time reduction hence cost reducing and savings.*

QUESTIONS

1. What is the meaning of quality? What are the components of quality?
2. What are the tools and techniques of quality improvements?
3. What are Gautt Chart? What is Group Length?
4. Explain acceptance Sampling Technique.
5. What is Sequential Sampling?
6. What is Total Quality Management?
7. What is Quality Audit? What is Audit Reporting?
8. What is Six Sigma?
9. What is Quality Planning?
10. Wha is Quality implementation? What is Quality Monitoring?
11. What is ISO?

NOTES

7. PRODUCTIVITY

STRUCTURE

- Ways to Improve Productivity
- Work Study
- Method Study or Method Analysis
- Motion Study
- Work Measurement
- Time Study
- Synthesis Method
- Analytical Estimating
- Predetermined Motion Time System (PMTS)
- Work Sampling
- Problems
- Maintenance Management
- Total Productive Maintenance (TPM)

The work study, inclusive of methods study and time study, job evaluation, merit rating, job redesign and financial incentives have been known as productivity techniques.

Productivity means a measure of the quantity of output per unit of input. The input can be man-hours spent on producing that output or it could be the number of machine hours spent or the amount of material consumed.

Basically productivity is a ratio between the output and the input.

Productivity = amount of output/amount of input.

In the earlier days of industrial management, it was considered very critical to control the labourers, productivity use to be meant labour productivity. Time study, method study, incentives schemes were the ways of managing or controlling the labour. These managerial control methods formed a major part of the techniques for productivity. Some of the ratios for labour productivity measurement are as follows:

$$\text{Worker's productivity} = \frac{\text{Worker's output in standard hours}}{\text{Man-hours worked by the workers}}$$

NOTES

A worker's or a group of worker's productivity.

= Number of units of output/No. of days taken

$$\text{Labour productivity} = \frac{\text{Worker's output (₹)}}{\text{Worker's salaries and wages (₹)}}$$

Productivity as measured above, represent the efficiency of the labour. These indices show how efficiently is the labour being utilised.

Productivity is seen as the ratio of output to input, it needs to be understood as to what constitutes the output. In terms of productivity output can be quantity produced, useful life and monetary term. Inputs are of varied types—human input, material input, machinery input, money input, technology input and time inputs. Sometimes, it is better not to combine any, productivity can be judged on each of the inputs. Certain inputs are critical and therefore very important from the point of view of productivity.

(1) Productivity = No. of units of output/No. of persons employed in production

(2) Productivity = No. of units produced/No. of man-hours worked

(3) Productivity = Output at standard price/amount of wages paid for output.

There are other inputs which are also important as materials, capital, management know how, technology and time.

Capital productivity = Value added/capital employed

or = Total sales (₹)/Depreciation of capital assets.

Labour productivity = Standard hours/Actual hours.

$$\text{Material productivity} = \frac{\text{Standard material usage}}{\text{Actual material usage}}$$

Managerial productivity = Profit Before Tax (PBT)/net sales.

Inventory Turnover = Sales (Rs)/Inventory (Rs)

Fixed assets Turnover = Net sales/fixed assets.

Total factors Productivity (TFP)

= Production at standard price/labour + materials + overhead + K (capital invested).

WAYS TO IMPROVE PRODUCTIVITY

Productivity can be increased in several ways such as:

(*a*) Increase production using the same or a smaller amount of resources.

(*b*) Reduce the amount of resources used while keeping the same production or increasing it.

(*c*) Allow the amount of resources used to increase as long as production increases more.

(*d*) Rate of decrease in production should be less than the rate of decrease in resources used.

Importance of Productivity

(*a*) Reduction in the price of goods.

(*b*) Increase in the reserve fund that can be utilised for expansion and modernization.

(*c*) Reduction in overheads and power costs per unit of output.

(*d*) Better standards of living for people through increase in their incomes and improvement in the quality of goods that can be made available at cheaper prices.

(*e*) Increase in the competitive strength of the country in export market through reduction in cost of production and improvement in quality of output.

(*f*) Reduction in the cost of raw materials by increasing in the productivity of raw materials.

(*g*) Increase in wages and salaries.

WORK STUDY

It concerns itself with better ways of doing things and control over the output of these things by setting standards with respect to time. It is of great importance for the smooth running of any organisation. Usually the concepts of work study relates to manufacturing organisation and are equally valid for other than manufacturing situated where services are generated.

The means of improving ways and means of doing thing is called method study, the primary purpose of improving methods is to save time, and therefore, effort of labour and machinery. Hence a measurement of the work involved in any job and the setting up of standards for control purposes of the time normally expected and the effort involved will be necessary. This aspect of setting work standards for comparison, control and other managerial action purposes is termed as work measurement since, the standards are mentioned in time units required to perform a job, given a particular work setting and method.

Work measurement is also alternatively called time study. Method study and time study together comprise work study. The study of methods of accomplishing a job by the movement of human limbs and eyes etc., is termed as motion study, and is a part of method study.

Work Study Definition

According to **Dr. Taylor:** *The greatest production results when each worker is given a definite task to be performed in a definite time in a definite manner*.

It can be 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 standardisation of proposed work methods.

Work study has contributed inmeasurably to the search for better methods and the effective utilisation of this management tool has helped in the accomplishment of higher productivity. Work study is a management tool to achieve higher productivity in any organisation. Whether manufacturing tangible products or offering services to its customers.

It can also be understood as a systematic, objective and critical examination of the factors, affecting productivity for the purpose of improvement.

According to ILO hand book: "*Work study is a term used to embrace the techniques of method study and work measurement, which are employed to ensure the best possible use of human and material resources in carrying out a specific activity*."

According to BSI (British Standard Institute): "*Work study is a generic term for those techniques, particularly method study and work measurement, which are used in examination of human work in all its contents and which lead systematically to the investigation of all factors which affect the efficiency and economy of the situation being removed in order to effect improvement*.

Objective of Work Study

There are many objectives of work study out of which the most important ones are as below:

1. To analyse the present method of doing a job, systematically in order to develop a new and better method.
2. To measure the work content of a job by measuring the time required to do the job for a qualified worker and hence to establish standard time.
3. To increase the productivity by ensuring the best possible use of human, machine and material resources and to achieve best quality product/service at minimum possible cost.
4. To improve operational efficiency.
5. The most effective use of human efforts.
6. The evaluation of human work to make it more convenient.

Benefits of Work Study

(*a*) Increased productivity and operational efficiency.
(*b*) Reduced manufacturing cost.
(*c*) Improved work place layout.
(*d*) Better manpower planning and capacity planning.
(*e*) Fair wages to employees.
(*f*) Better working condition to employees.
(*g*) Improved work flow.
(*h*) Reduced material handling costs.
(*i*) Provides a standard of performance to measure labour efficiency.
(*j*) Better industrial relations and employee morale.
(*k*) Basis for sound incentive schemes.
(*l*) Provides better job satisfaction to employees.

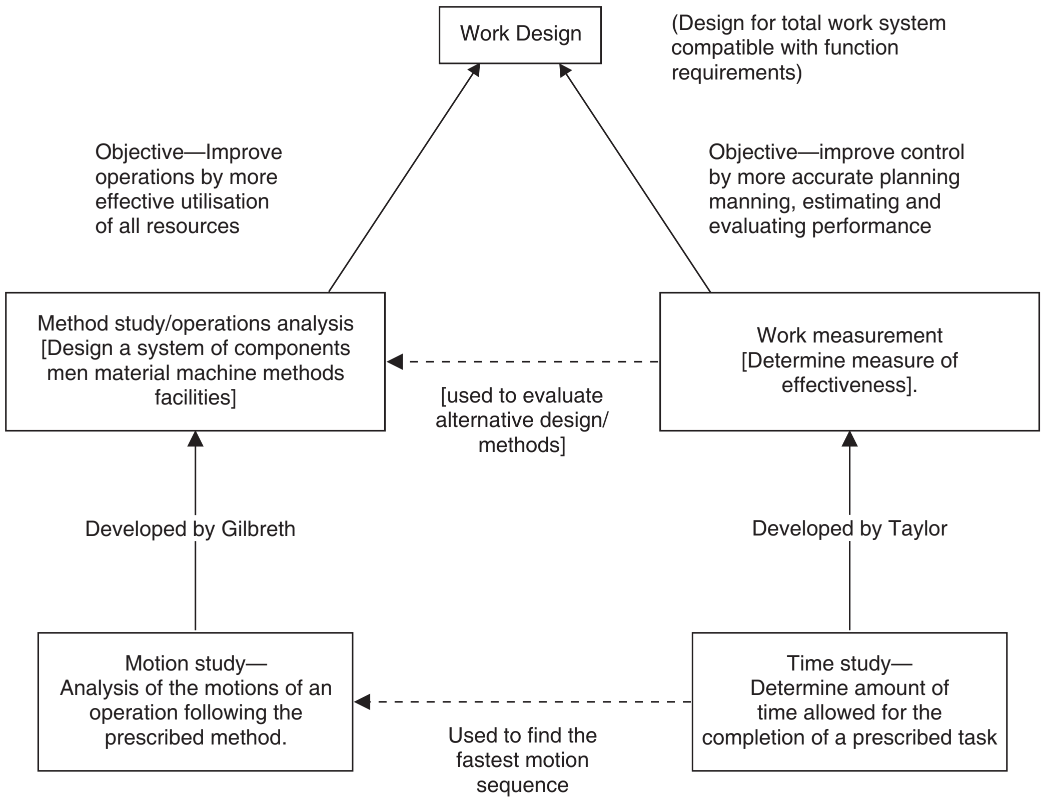
The purpose of the work study is to determine the best or most effective method of accomplishing a necessary operation or function. The criteria for the best method could be an increase in job satisfaction and individual morale, reduction in physiological fatigue, decrease in number of accidents and incidents, personal injuries, minimisation of material usage, tool breakage or usage of consumable supplies and increase in productivity by reduction of performance time. Every operation/activity in an organisation contains to a certain degree of mechanical, physiological, psychological and sociological factors. The purpose of work measurement is to quantify these factors.

Both time study and motion study which resulted from the integration of concepts and practices developed by **Taylor, Frank** and **Gilbreth** are concerned with the systematic analysis and improvement of manually controlled work situations. However, time study is a quantitative analysis leading to the establishment of a time standard whereas motion study is a qualitative analysis of a work station leading to the design or improvement of an operation/activity.

Work study as a discipline is concerned with:

(*a*) Better ways of performing jobs/tasks and

(*b*) Exercising control over the output in respect of these jobs/tasks by setting standards for performance *i.e.,* output/work with respect to time.



The former technique is known as method study/method analysis/operational analysis and latter technique is known as work measurement or time study.

Method study and work measurement are closely linked. Method study is concerned with reduction of work content while work measurement is concerned with the investigation and reduction of the ineffective time and subsequent establishment of time standards for the task or job or operation on the basis of work content established by the method study.

NOTES

Note. 1. Usually method study should precede work measurement.

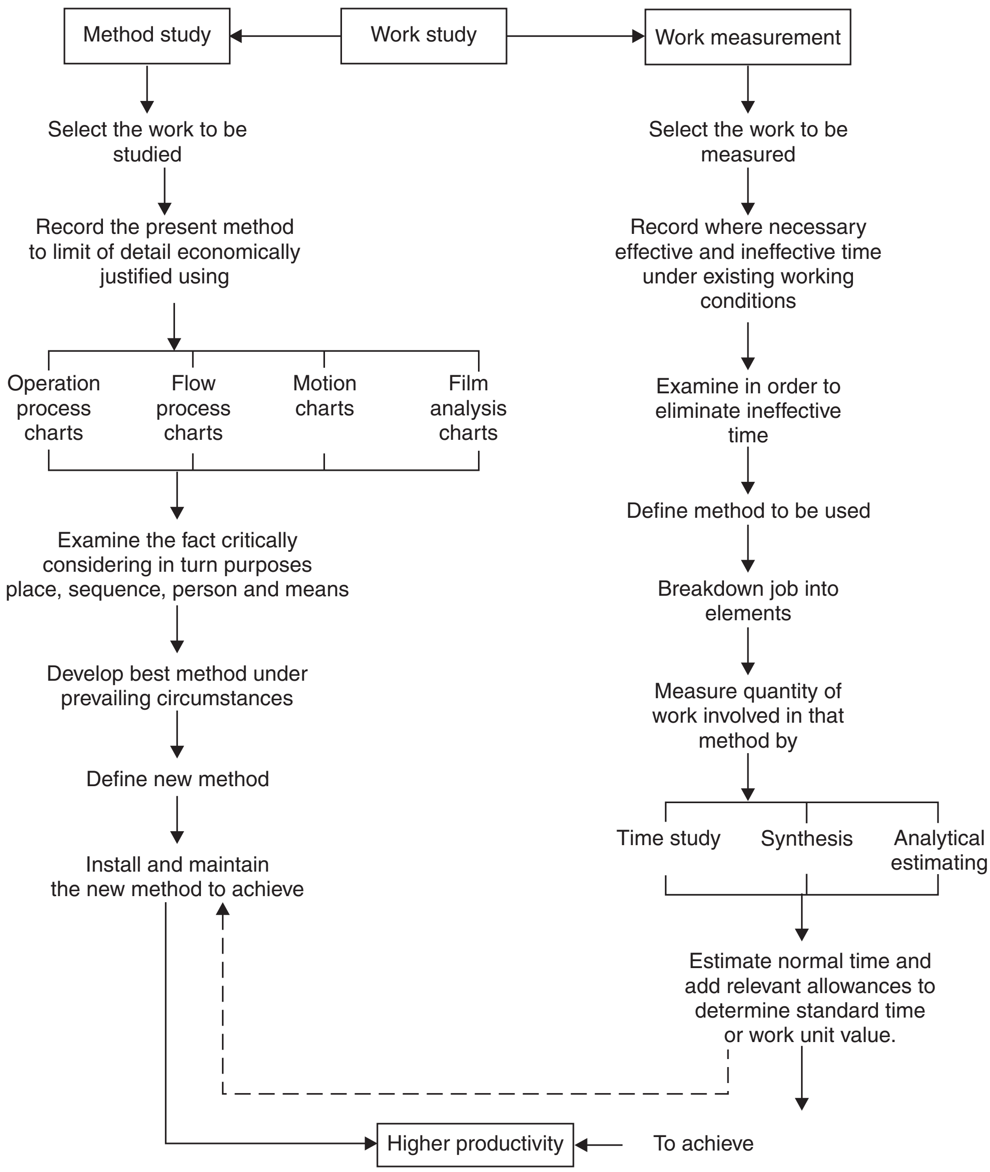
2. When time standards for output are being set, it is often necessary to use an appropriate work measurement technique such as activity sampling in order to determine the ineffective time or idle time. This will facilitate corrective action to be taken by the management before going for method study.

3. Time study may be used to compare the effectiveness of alternative work methods or operations.

Work Study Procedure

There are eight basic steps involved in a work study procedure. These steps are:

1. Select the job or the process or the operations to be studied.
2. Record all relevant facts about the job or process or operations using suitable techniques such as operations process charts, flow process chart, motion charts or film analysis charts etc.



3. Examine critically all the recorded facts, questioning the purpose place, sequence, person and the means of doing the job/process/operations
4. Develop the new method for the job/process/operation
5. Measure the work content and establish the standard time using an appropriate work measurement technique as time study using stopwatch, synthesis method, analytical estimating method, pre-determined motion time system and work sampling
6. Define the new method for the job/process/operations
7. Install the new method as standard practice
8. Maintain the new method for the job/process/operations.

METHOD STUDY OR METHOD ANALYSIS

It is a scientific technique of observing, recording and critically examining the present method of performing a task or job or operations with the aim of improving the present method and developing a new and cheaper method, also called as methods improvement or work improvement. It encompasses the study of work processes, working conditions and equipments and tools used to carry out the job.

In other words, it is the systematic recording and critical examination of existing and proposed ways of doing work, as a means of developing and applying easier and more effective method and reducing costs.

Objectives of Method Study

(*a*) To study the existing/proposed method of doing any job, operation or activity.

(*b*) To develop an improved method to improve productivity and to reduce operating costs.

(*c*) To reduce excessive materials handling or movement and thereby reduce fatigue of workman.

(*d*) To improve the utilization of resources.

(*e*) To eliminate wasteful and inefficient motions.

(*f*) To standardise work methods or processes, working conditions machinery, equipments and tools.

Factors Facilitating Method Study

1. High operating cost
2. High wastage and scrap
3. Excessive movement of material and workmen
4. Excessive production bottlenecks
5. Complaints about quality
6. Complaints about poor working conditions
7. Increasing number of accidents
8. Excessive over time in production
9. Excessive rejections and reworks.

NOTES

Method Study Procedure

There are basically six main steps involved in the method study. These are as below:

(*a*) Selection (*b*) Recording
(*c*) Examination (*d*) Development
(*e*) Installation (*f*) Maintaining.

Selection

Select the job or work to be studied and define the objectives to be achieved by method study. The job selected to have maximum economic advantages, shall offer vast scope for work improvement through reduction of excessive materials handling and fatigue of workmen, offer scope for improving the working conditions and improving the utilization of resources.

Recording

All the relevant facts/informations pertaining to the existing method are to be recorded using the following techniques:

1. Process chart
2. Diagrams.

Process Charts

It includes any of the following:

(*i*) Outline process chart.
(*ii*) Operation process chart.
(*iii*) Flow process chart-material type, man-type and machine type/equipment type.
(*iv*) Man-machine chart.
(*v*) Two handed process chart.
(*vi*) Multiple activity chart.
(*vii*) Simultaneous motion chart (SIMO chart).
(*viii*) Motion chart.
(*ix*) Film analysis chart.

Diagrams

It includes any of the following:

(*i*) Flow diagram (*ii*) String diagrams
(*iii*) Cycle graph (*iv*) Chronocycle graph.

Examinations

It includes the examination of all the recorded facts, critically, challenging everything being done and seeking alternatives, questioning the purpose, the means, sequence, place and the person.

Questions:

Purpose – What is achieved?
Means – How is it achieved?
Sequence – When is it achieved?
Place – Where is it achieved?
Person – Who achieved it?

NOTES

Developing

Developing means the improved method by generating several alternatives and selecting the best method. The factors to be considered while evaluating alternatives and selecting the best methods are:

(*a*) Cost of implementation
(*b*) Expected savings in time and cost
(*c*) Feasibility
(*d*) Productibility
(*e*) Acceptance to design, production planning and control, quality control, production and sales departments
(*f*) Reaction of employee to the new method
(*g*) Short term or long term implication of the alternatives.

Installation/Implementation

Installation or implementation of a new method is usually in three phases:

(*a*) Planning
(*b*) Arranging
(*c*) Implementing

In the first two phase, the programme of installation and a schedule are planned and necessary requirements such as resources, equipments, tools, operating instructions of the developed method is provided to the workers. In the implementation phase the introduced developed method as standard practice to achieve the desired results.

Maintaining

Maintaining the new method by ensuring that the installed method is functioning well which is done by periodic checks and verifications at regular intervals. Proper control procedures are to ensure that the new method in practice to achieve the benefits of method study along with higher productivity.

Advantages

1. Better productivity.
2. Better working conditions/environment.
3. Better materials handling and lesser materials handling cost.
4. Higher safety to workmen.
5. Higher job satisfaction for workmen.
6. Improved working method.
7. Improved equipment design.
8. Improved workflow.
9. Less fatigue to operator hence more efficiency.
10. Optimum utilisation of resources.
11. Reduced material consumption and wastages.
12. Reduced manufacturing cost and higher productivity.
13. Shorter production cycle time.
14. Work simplification.
15. Improved and effective plant layout.

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Criteria for Methods Improvement

The improvement in method refers to criteria which are relevant to the organisation such as:

(*a*) Improved cost performance

(*b*) Improved time or delay performance

(*c*) Improved work satisfaction

(*d*) Improved standardization of operations and products.

Note. The last two aspects are not of less significance infact, sometimes the method study has much to do with improving the always important industrial relations and with changes in product design in consultation with marketing and other appropriate departments.

Recording Techniques used in Method Study

Some of the useful recording techniques used in method study are process chart, flow charts/diagram multiple activity charts, man-machine chart, flow process chart and string diagrams.

In the charting process certain symbols are used. A few important ones are as below:

O	→	Operation	→	Modification of an object at one work place, object may be changed in any of its physical or chemical characteristics, assembled or disassembled or arranged for another operations, transportation, inspection or storage.
⇒	→	Transportation or movement	→	Change in location of an object from one place to another.
□	→	Inspection	→	Examination of an object to check on quality or quantity characteristics.
D	→	Delay/temporary storage	→	Retaintion of an object to check storage in a location, awaiting next activity.
∇	→	Storage	→	Retaintion of an object in location in storage which is protected against unauthorised removal.
□ ⇒	→	Combined activity	→	A combined activity occurs when two activities occur simultaneously. Various combinations of simultaneous occurrence of two activities could be possible.

Process Charts in Method Study

1. ***Outline Process Chart*:** It records an overall picture of the process and records only the main events sequence wise. It considers only the main operations and inspections.
2. ***Operation Process Chart*:** Called as basic process chart and is graphic representation of the points at which the materials are introduced into the

process and of the sequence of inspections and all operations except those involved in materials handling. It includes information consider desirable for analysis such as time required to carry out the operations and the location.

3. ***Flow Process Chart*: These are graphic representation of the sequence of all operations, transportation, inspection, delays and storages occuring during a process or a procedure and include information considered desirable for analysis such as time required and distance moved. These flow process charts are of three types as:
   (*a*) Flow process chart material or product type
   (*b*) Flow process chart man type
   (*c*) Flow process chart machine type or equipment type.

Note. 1. Material or product type flow process chart records the changes the material or product undergoes in location or condition includes operations and transportation.

2. Man type process chart records the activities of a worker or operator *i.e.,* what he does.

3. Equipment or machine type process chart records the manner in which an equipment or machine is used.

4. ***Two Handed Process Chart*:** In this chart, the activities of a worker's or operator's both hands or limbs are recorded chronographically.
5. ***Multiple Activity Chart*:** In this chart, the activities of more than one subject may be a worker, machine or equipment, are recorded on a common time scale to show their interrelationship.
6. ***Man-machine or Worker-machine Chart*:** This is a variation of multiple activity chart and illustrates the operation and delays of the operator and the machine which he operates.
7. ***Flow Diagram*:** It is a drawing or diagram drawn to a scale to show the relative position of a machine or equipment, jigs and fixtures, gang ways or aisles and shows the path followed by materials or machines.
8. ***String Diagram*:** It is a scale plan or model on which a string or a thread is used to trace and measure the path of workers, materials or equipments during a specified sequence of events.
9. ***SIMO Chart:*** It is a type of two handed process chart in which the micromotions of both the hands are recorded.

MOTION STUDY

It is the science of eliminating wastefulness, resulting from using unnecessary, ill-directed and inefficient motion. The aim of motion study is to find and perpetuate the scheme of the least waste methods of labour.

Micromotion study provides a valuable technique for making minute analysis of those operations that are short in cycle, contain rapid movements and involve high production over a long period of time.

Note. Micromotion study may be used for the following purposes in addition to its primary use for job analysis work.

1. To study the interrelationship pursuing the members of a work group.
2. To study the relationship between an operator and the machine which he operates.
3. To obtain time of an operation.
4. To establish a permanent record of the method of doing a job.

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Motion Economy and Work Efficiency

Most of the workers does not enjoy making unnecessary or wasted motions, particularly if they result in unnecessary fatigue. In addition to providing some social and psychological rewards, a job should be reasonably efficient motion study helps to reduce fatigue and waste motions.

Principles of Motion Economy

The rules of motion economy and efficiency which referred to hand motions of operators were developed by Gilbreth. The principles of motion economy are classified in following:

(*a*) Effective use of the operators
(*b*) Arrangement of the work places
(*c*) Tools and equipment.

WORK MEASUREMENT

It is also a technique of work study and it establishes the work content of a job. Work content of a job can accurately be established only after the method of doing a job is standardised hence method study must precede work measurement.

Method study and work measurement both are important elements in achieving higher labour productivity. The overall productivity of an organisation depends up the optimum utilization of all available resources.

Note. Labour productivity is determined by the work measurement. Work measurement can be defined as the application of techniques designed to establish the work content of a specified task by determining the time required for carrying out the task at a defined standard of performance by a qualified worker. A qualified worker is one who is accepted as having the necessary physical attributes, possessing the required intelligence and education and having acquired the necessary skill and knowledge to carry out the work inhand to satisfactory standards of safety, quantity and quality.

In other words, work measurement may be defined as the techniques applied to determine the amount of time necessary for a qualified worker to perform a particular task. The amount of time that a job is expected to take is expressed as time standard, work standard, labour standard, production standard or standard time.

Note. Standard time is the amount of time a qualified worker, working at a normal rate of speed, will require to perform the specific task.

Work measurement is concerned with measuring the work content of any activity under study with a view to assess the human effectiveness or to compare one method with another or to develop labour standards that will be used for planning and controlling operations and thereby achieving high labour productivity.

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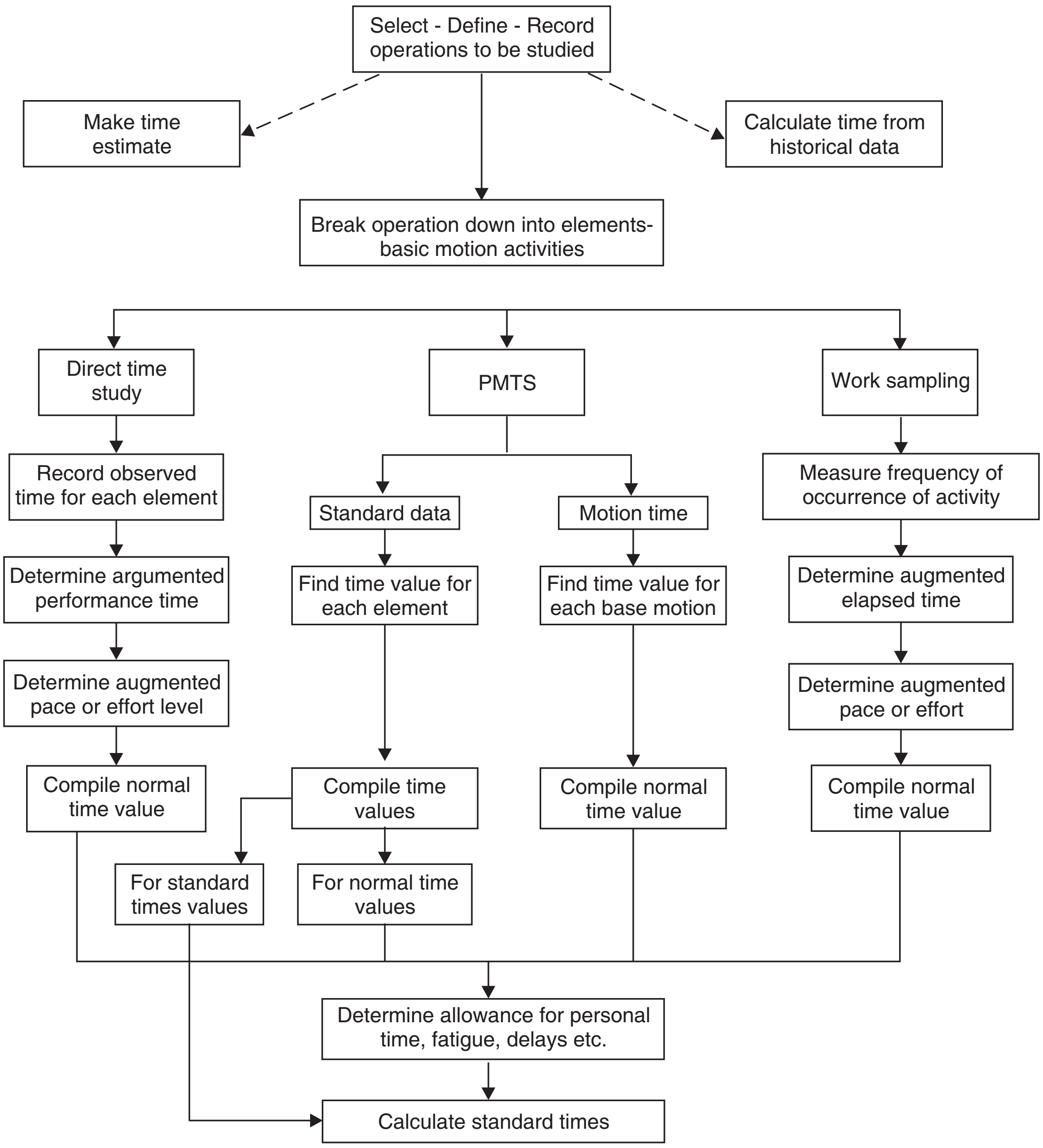


Objectives of Work Measurement

1. Improved planning and control of activities or operations.
2. More efficient manning of the plant.
3. Reliable ideas for labour performance.
4. Reliable basis for labour cost control.
5. Basis for sound, incentive schemes.

Techniques of Work Measurement

The main techniques used to measure work are as following:

(*a*) Direct time study

(*b*) Synthesis method

(*c*) Analytical estimating

(*d*) Pre-determined motion time system (PMTS)

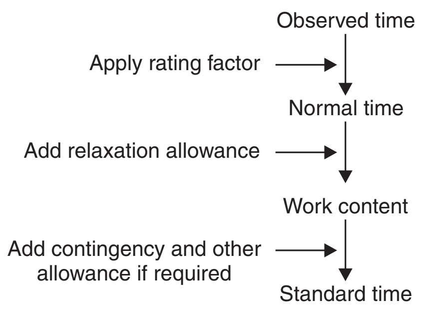
(*e*) Work sampling or Activity Sampling or Ratio Delay Method.

Steps in Work Measurement

Following are the main steps in work measurement:

1. Break the job into elements
2. Record the observed time for each element by means of either time study, synthesis or analytical estimating method.
3. Establish elemental time values by extending observed time into normal time for each element by applying a rating factor.
4. Assess relaxation allowance for personal needs and physical and mental fatigue involved in carrying out each element.
5. Add relaxation allowance time to the normal time for each element to arrive at the work content.
6. Determine the frequency of occurrence of each element in the job, multiply the work content of each element by its frequency and add up the times to arrive at the work content for the job.
7. Add contingency allowance, if any, to arrive at the standard time to do the job.

Diagrammatic representation of the steps:



Advantages

There are many advantages of work measurement however the important ones are as below:

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

(*b*) To prepare realistic work schedules by accurate assessment of human work.

(*c*) To set standards of performances for labour utilisation by establishing the labour standards for an element of work, operation or product under ordinary working conditions.

(*d*) To compare actual time taken by the worker with the allowed time *i.e.,* standards time for proper control of labour.

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

(*f*) To assist in labour cost estimations.

TIME STUDY

It is concerned with the determinations of the amount of time required to perform a unit of work and consists of the process of observations and recording the time required to perform each element of an operation so as to determine the reasonal time in which the work should be completed. "*Time study is a work measurement technique for recording the times and rates of working for the elements of a specified job carried out under specified conditions and for analysing the data so as to obtain the time necessary for carrying out the job at a defined level of performance.*"—**ILO**

It is also direct time study, a stop watch study or clocking the job. This technique is certainly the most widely used method of establishing work standards in manufacturing.

Objectives

The main objectives is "*to determine by direct observation, the quantity of human work in a specified task and hence to establish the standard time, within which an average worker working at a normal pace should complete the task using a specified method*". The other objectives are:

(*a*) To furnish a basis of comparison for determining operating effectiveness.

(*b*) To set labour standard for satisfactory performance.

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

(*d*) To determine standard costs.

(*e*) To determine equipment and labour requirements.

(*f*) To determine basic times/normal times.

(*g*) To determine the number of machines an operator can handle.

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

(*i*) To provide a basis for setting piece rate or incentive wages.

(*j*) To set the completion schedules for individual operations or jobs.

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

Uses

The utility of the time study comes in:

1. Determining the work content and thereby setting wages and incentives.
2. Arriving at cost standards/unit of output for the various jobs used for cost control and budgeting for deciding on sales price.
3. Comparing the work efficiency of different operators.
4. Arriving at job schedules for production planning.
5. Manpower planning.
6. Aiding in method study:

   (*i*) To appropriately sequence the work of an operator and the machines or that of a group of workers.

NOTES

(*ii*) To highlight time consuming elements.
(*iii*) To compare costs of alternative methods.

7. Product design by providing basic data on costs of alternative materials and methods required to manufacture the product.

Time Study by Stop Watch

It involves the following steps:

1. Selection of job to be studied.
2. Selection of worker to be studied.
3. Conducting stop watch time study.

Reasons for Selecting a Job for Time Study are as below:

(*a*) New job taken for production.
(*b*) Change in manufacturing method.
(*c*) Design change.
(*d*) Change in raw material or components used for a job.
(*e*) Complaint about inadequacy of allowance time.
(*f*) For bottleneck operations.
(*g*) When labour cost is high.
(*h*) To establish standard time as a basis for incentive scheme.
(*i*) When new tools, jigs and fixtures are used.

Selection of Workers to be Studied

The ideal worker would be the qualified worker. Since the ideal worker or qualified worker may not be available in the organisation, the best available worker is choosen and his rating is determined as compared with the qualified worker.

Conducting Stop Watch Time Study

In this step following various activities are involved.

(*a*) Obtain and record all information available about the job, operation and working conditions.
(*b*) Record the method of doing the job and break down the jobs into elements.

An element is a distinct part of a specified job selected for convenience of observation, measurement and analysis.

Following are the various types of elements:

(*i*) *Repetitive element:* These occur in every work cycle of the job.
(*ii*) *Occasional element:* These occur at intervals.
(*iii*) *Constant element:* Basic or normal time for these elements remains constant, whenever it is performed.
(*iv*) *Variable element:* For these elements basic or normal time varies.
(*v*) *Manual element:* These are performed manually.
(*vi*) *Machine element:* These are performed automatically by machine.
(*vii*) *Governing element:* These occupy a longer time than any other element of a job.
(*viii*) *Foreign element:* These are unnecessary element of a job.

(c) Examine the various elements to ensure that the most effective motion are used in the elements of job performed.

(d) Measure the actual time taken by the operator to perform each element of the job, using stop watch.

(e) Assess the effective speed of working of the operator with respect to the time study observer's concept of the speed of working of the qualified worker who is assumed to have a standard rating.

NOTES

Notes.

1. Rating or levelling factor is determined by comparing the actual pace or speed of working of the worker studied, with the standard pace or speed of working of qualified worker.
2. Rating scales are:

   (i) 60–80 scale (ii) 75–100 scale

   (iii) 100–$113\frac{1}{3}$ scale.
3. Comparison of rating scales:

Rating assigned in the scale			*Level of Performance*	*Corresponds to walking speed*
60–80	*75–100*	*100–133½*		
0	0	0	No activity	NIL
40	50	67	Very slow, clumsy, not interested	2 mph
60	75	100	Normal, steady, unhurried performance	3 mph
80	100	133	Businessman like, brisk, performance of qualified worker	4 mph
100	125	167	Very fast, incentive motivated	5 mph

4. Rating factor = Rating of observed worker/Rating of qualified worker

(f) *Determination of normal or basic time:* After the rating of choosen worker on the choosen rating scale is done it is compared with the standard rating of qualified workers.

Normal or basic time = Observed time × Rating factor.

We know:

Rating factor = Rating observed/Standard rating then

$$\text{Normal or basic time} = \frac{\text{Observed time} \times \text{Rating observed}}{\text{Standard rating}}$$

Note. Calculation of observed time for each element: A number of reading are taken for each element, depending on the degree of accuracy desired and the length of the work cycle. The average observed time for each element is calculated by dividing the total of the element times by the number of cycles for which the element times are recorded.

(g) Determination of relevant-allowance: Once the basic time per cycle required by the qualified worker to perform each element at standard rate of working is determined, the rent slip is to determine the time allowance to be given to the operator for relaxation, fatigue, contingency etc.

Note. Usually these allowances are taken as a percentage of basic or normal time.

NOTES

Various types of allowance are as follows:

(*i*) Relaxation allowance (RA) (*ii*) Contingency allowance (CA)

(*iii*) Process allowance (PA) (*iv*) Special allowances (SA)

Special allowances are again of following two types:

(*a*) Interference allowance (*b*) Periodic activity allowance.

Relaxation Allowance

Also known as personal, fatigue and delay allowance [PFD] and is given to the worker to overcome the fatigue due to physical exertion, posture, concentration, working condition and personal needs such as going to toilet, drinking water, attending phone calls etc.

Note. It usually varies from 10% to 20% of normal or basic time.

Contingency Allowance

It is applicable for infrequent or non-repetitive activities such as obtaining special materials from store, sharpening of tools, getting special tool/tools from tool crib and consultation with the supervision.

Note. It is usually 5% of normal or basic time.

Process Allowance

This allowance is given to the workers to compensate himself for enforced wellness due to the nature of a process or operation.

Special Allowance

Interference Allowance

It is given to a worker when he/she is looking after 2 or more machines. One machine may be idle when the worker works or other machine for a short period and allowance has to be given to the worker for his loss of production.

Periodic Activity Allowance

It is applicable to these activities which are being carried out periodically during a work cycle.

(*h*) Determination of standard time: Add the relevant allowance to the normal or basic time.

Standard time = normal or basic time + all relevant allowances.

Computation of standard time:

where OT = Observed time, PRF = Performance rating factor

PA = Process allowance, RA = Relaxation allowances,

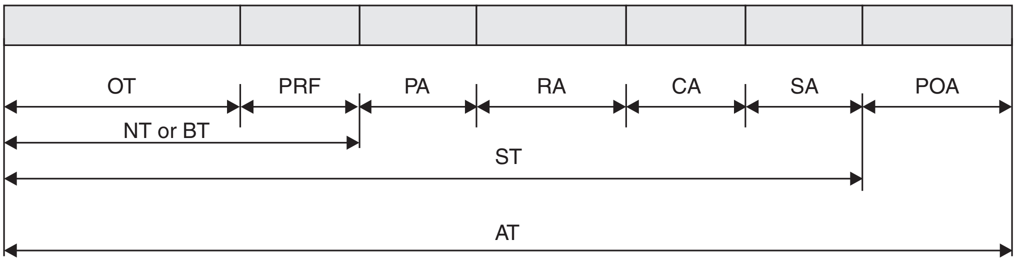
CA = Contingency Allowance, SA = Special allowances

POA = Policy allowance

NT = Normal time

BT = Basic time

ST = Standard Time, AT = Allowed time.



SYNTHESIS METHOD

It is also a technique of work measurement for building up the time required to do a job at a defined level of performance by synthesising or totalling elemental time values obtained from previous time studies on other job containing similar job elements or from standard data or synthetic data or build up time standard.

Standard Data

It is a catalogue of normal or basic time values for different element of jobs. This catalogue is prepared by compiling the timings of a number of standard elements. Since many similar elements or motions are involved in many jobs if time study is to be conducted for a new job, it is wastage of time and other resources as are common in nature and previously were timed. This data are known as standard data.

Once the standard data catalogue is build up, it is required to list the job elements of an operation and refer the standard data catalogue to obtain the values of the elements. Then add them up or synthesise them. The total time thus obtained gives an estimate of normal time for that particular job. This normal or basic time when added up with the relevant allowances gives standard time.

Advantages

1. Quite reliable as the build up time values of the standard data catalogue are based on data derived from a large number of time studies.
2. Very economical as the repetition of time study is avoided.
3. Useful in estimating labour time for preparing cost estimates for new jobs where selling prices have to be quoted to customers.

Applications

1. In the estimation of standard time for new jobs.
2. In the estimation of production time.
3. In the estimation of prices of the product to be sold.
4. Used as a basis for designing incentive schemes.

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ANALYTICAL ESTIMATING

It is also a work measurement technique used in determining the time values of those jobs which are long and non-repetitive operations.

Note. 1. This method or technique is applicable only when no synthetic or standard data are available.

2. It is essential for the estimation to have enough experience of estimating, motion study, time study and the use of standard data.

Procedure

There are basically following seven steps:

1. Find out the job details as job dimentions, standard procedure to do the job, job conditions, availability of jigs, fixtures and tools etc.
2. Break the given job into different elements.
3. Select the standard time from catalogue for those elements whose time value is available in it.
4. Estimate the time values for these remaining elements, whose standard data is not available, with the help of past experience and knowledge.
5. Add the time values of all the elements of the job to get total basic or normal time for 100% rating.
6. Add the appropriate relaxation allowance which is usually 10%–20% of the total normal or basic time.

   Note. In case of analytical estimating the relaxation time is not added to the individual element time values.

   Blanket relaxation allowance depends upon the job and job conditions.
7. Add any other allowance if applicable will give the standard time for the given job.

Application

(*i*) Suitable for non-repetitive jobs, jobs having long cycle times and jobs having elements of variable nature.

(*ii*) For such jobs where stop watch time study prove to be uneconomical.

(*iii*) For repair and maintenance work.

(*iv*) For job production, one time large projects, office renters, tool room jobs and engineering construction works.

Advantages

(*a*) Helps in planning and scheduling the production.

(*b*) Provides a basis for fixing the labour rate for non-repetitive jobs.

(*c*) Steps of improve labour control.

(*d*) Cost effective.

Disadvantages

(*a*) Reliability on the judgement of estimator is uncertain.

(*b*) Time value may not be accurate.

NOTES

PREDETERMINED MOTION TIME SYSTEM (PMTS)

It is defined as a work measurement technique by which normal or basic times are established for basic human motions and these time values are used to build up the time for a job at a defined level of performance.

It is an improvement over motion time study because besides affording detailed analysis of the motion, it makes it possible to set a measure of the time, that a series of motion ought to take.

Predetermined time standards are standard data for wide variety of basic body motions which are common in many industrial operations.

Advantages

1. Affords a fine analysis and improvement of work methods.
2. As the time for each basic motion is predetermined, the computations of standard time for a job or an operation is faster and economical.
3. Offers a precise means of recording time.
4. Avoid subjective judgement.
5. No interference is normal routine work hence either no or a very resistance from the workers.
6. Effective useful and economic specially for those job which are of short duration and repetitive jobs.

Disadvantages

1. Standards are not available for each and every human activity.
2. Limited scope as applicable only to uninhibited works.
3. Limited application for office activities and non-repetitive jobs.
4. Intensive training under the experts guidance/supervisor is necessary to use this technique.

Note. Despite their application, PMTs represents the most accurate time estimates as based on careful analysis of the motion required to perform a job.

Types of PMTs

PMTs are of following three types:

(*i*) Methods Time Measurement system (MTM)
(*ii*) Work Factor
(*iii*) Basic Motion Times system (BMT).

Methods Time Measurement

In this method, predetermined time values for basic motions or therbling are established in terms of TMUs. *i.e.,* time measurement units.

1 TMU = 10^{-5} hours or 0.00001 hour or 0.0006 minutes
or 0.36 sec.

The time values are listed in tables in terms of TMUs for basic motions and may be applied to any type of operations that may be resolved to the basic motions, thus eliminating the use of stop watch.

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Application

There are many applications of MTM out of which a few are as below:

(*a*) Developing effective methods in advance of beginning the production.

(*b*) Improving existing method.

(*c*) Establishing standard time data.

(*d*) Estimating labour time and cost.

(*e*) Training supervisors to be method–conscious.

(*f*) Choosing among the alternative method.

Work Factor

It is based on basic motions which are modified elements of difficulty, all of which tend to make movement slower. These features or work factors are weight or resistance, change of direction, need for care, stopping a motion and manual control. Each of these features is known as work factor and it modifies the basic time value.

Basic Motion Times (BMT)

In this system, the times were derived from laboratory experiments and were carefully checked against a variety of factory operations before being accepted for general use. BMT data are based on basic motions. A basic motion occurs everytime a body member which is at rest moves and again come to rest.

Basic motions are classified as—finger, hand and arm motions, foot and leg motions and other miscellaneous body motions.

Note.

1. The motion of finger, hand and arm are further classified as 'Class A' motion. 'Class B' and 'Class C' motions depending on the use of muscular control in stopping the motion.
2. 'Class A' motions are stopped without muscular control by an impact of the object.
3. 'Class B' motions are stopped entirely by the use of muscular control.
4. 'Class C' motions are stopped by the use of muscular control both to slow down the motion and to end it in grasping or placing action.

WORK SAMPLING

Also known as activity sampling or ratio-delay method. It is a work measurement technique that randomly samples the work of one or more employees at periodic intervals to determine the proportion of total operations that is accounted for in one particular activity.

Note. These studies are frequently used to estimate the percentages of time spent by the employees in unavoidable delays, repairing finished product from an operation and supplying material to an operation.

Uses

1. To estimate the percentage of a protected time period consumed by various activity states of a resource like equipment, machine or operators.
2. To determine the allowance for inclusion in standard times.
3. To indicate the nature of the distribution of work activities within a gang operations.
4. To estimate the percentage of utilisation of groups of similar machines or equipments.
5. To indicate how materials handling equipments are being used.
6. To provide basis for indirect labour time standards.
7. To determine productive and non-productive utilisation of clerical operations.
8. To determine the standard time for a repetitive operations as an alternative to the stop watch method.

NOTES

Procedure

In this system or method, the works study engineer takes a greater number of observations of a worker or machine randomly throughout the working shift or day, and make record of all the activities performed by the worker or machine *i.e.*, working or idle. The objective is to findout the frequency of occurrence of every work element.

Note. In this system stop watch is not used.

The technique is based upon a laws of probability and is based on the statistical premise that, the occurrences in an adequate random sample observations of an activity will follow the same distribution pattern that might be found in a length *y*, continuous study of the same activity.

$$p = \frac{x}{N}$$

where

x = No. of observations of the activity

N = Total no. of observation.

Thus, work sampling method consists of taking a number of intermittent randomly spaced instantaneous observations of the activity being studied and from this determining the percent of time denoted to each aspect of the operations.

Note.

1. In order to set a standard by the work sampling procedure it is necessary to level or rate the performance of the worker being studied and to count the actual number of units produced during the period under study.
2. The accuracy of this approach depends on the number of observations made. Higher is the number of observation, higher is the accuracy.

Principles in Work Sampling

It is based on statistical theory of random sampling and probability of normal distribution and confidence level associated with standard deviation.

NOTES

We know

$$p = x/N$$

where x = No. of observation of the activity in a pilot study

N = Total number of observations of the activity in the pilot study

The proportion of 'no activity' = $1 - p = q$.

or $$p + q = 1.$$

when p = probability of an occurrence (working)

q = probability of no occurrence (networking or idle).

if there are N observation. Then

$$(p + q)^N = 1. \text{ standard deviation } = \sqrt{\frac{P(1-q)}{n}}$$

Steps in Work Sampling

Work sampling study consists of following steps:

(*a*) Determine the objective of the study, including definition of the states of activity to be observed.

(*b*) Plan the sampling procedure including:

  (*i*) An estimate of the percentage of time being denoted to each phase of the activity.

  (*ii*) Setting of accuracy limits.

  (*iii*) An estimation of number of observation required.

  (*iv*) The selection of the length of the study period and the programming of the number of readings over this period.

  (*v*) The establishment of the mechanics of making the observation and route to follow along with recording of data.

(*c*) Collect the data as planned.

(*d*) Process the data and present the results.

Advantages

(*i*) Economical to use as cost of time study is less.

(*ii*) Can be used to measure many activities.

(*iii*) Not necessary to use a trained work measurement analyst to make the observation.

(*iv*) Work sampling measurements may be made with a pre-assigned degree of reliability.

(*v*) Measures the utilisation of people and equipment directly.

(*vi*) Provides observation over a significant long period of time to decrease the chance of day to day variation affecting the results.

Disadvantages

(*i*) A little value in helping to improve work methods.

(*ii*) Statistical work sampling may not be understood by workers.

(*iii*) If random sampling is not done, the results may be biased.

Illustrations:

1. HCC a construction company has established basic time for a certain element of work 20 sec. If for three observations a time study observer records rating of 100, 125 and 80 respectively, on a 100 normal scale. What are the observed timing?

Solution:

Given BT or NT = 20 sec. Standard rating = 100

$OR_1 = 100$, $OR_2 = 125$, $OR_3 = 80$.

We know that,

Observed time × observed rating = Basic or Normal time × Standard rating

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

for OR_1: $$\text{Observed time} = \frac{20 \times 100}{100} = 20 \text{ seconds.}$$

for OR_2: $$\text{Observed time} = \frac{20 \times 100}{125} = 16 \text{ seconds}$$

for OR_3: $$\text{Observed time} = \frac{20 \times 100}{80} = 25 \text{ seconds.}$$

2. An 16 hours work measurement study in a plant of electroplating reveals the following. Unit produced = 640, idle time = 15%, performance rating = 120% allowances = 12% of normal time. Determine the standard time per unit produced.

Solution:

Observed time for 640 units = Working time – idle time

$$= 16 - (16 \times 0.15) = 16 - 2.40$$
$$= 16 - 2.4 = 13.6 \text{ hour}$$

or 13.6 × 60 minutes = 816 minutes

$$\text{Observed time/unit} = \frac{13.6 \times 60}{640} \text{ minutes} = 1.275 \text{ minutes}$$

$$\text{Normal time/unit} = \frac{\text{observed time/unit} \times \text{observed rating}}{\text{standard rating}}$$

$$= \text{observed time/unit} \times \text{performance rating}$$

$$= \frac{13.6 \times 60}{640} \times \frac{120}{100} = 1.53 \text{ minutes}$$

NOTES

Standard time/unit = Normal time/unit + allowance

= 1.53 + 12% of 1.53

= 1.53 + (1.53 × 12/100)

= 1.53 + 0.1836 = 1.53 + 0.184

= 1.714 minutes.

3. Calculate the standard production/shift of 12 hours duration with the following data.

Observed time/unit = 15 minutes, Rating factor = 100% and 80%

Total allowance = 40% of normal time

Solution:

When rating factor is 100 %

Normal time/unit = observed time/unit × Rating factor

$$= \frac{15 \times 100}{100} = 15 \text{ minutes}$$

allowance = 40% of NT

$$= \frac{40}{100} \times 15 = \frac{600}{100} = 6 \text{ minutes}$$

standard time/unit = Normal time/unit + allowance

= 15 + 6 = 21 minutes/unit.

$$\text{standard production in 12 hrs.} = \frac{12 \times 60}{21} = 34.2857 = 34.3 \text{ units}$$

when rating factor is 80%

normal time/unit = observed time/unit × Rating factor

$$= \frac{15 \times 80}{100} = 12 \text{ minutes}$$

$$\text{allowance} = 40\% \text{ of NT} = \frac{40}{100} \times 12 = \frac{480}{100} = 4.8 \text{ minutes}$$

standard time/unit = Normal time/unit + allowance

= 12 + 4.8 = 16.8 minutes/unit.

$$\text{Standard production in 12 hrs} = \frac{12 \times 60}{16.8} = 42.857 = 42.9 \approx 43 \text{ units.}$$

4. During the work sampling study the practition or assesses the activity level of worker to be 70%. While working in a shift of 8 hours 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/unit?

Solution:

activity level = 70%

$$\text{actual working time/shift of 8 hours} = \frac{8 \times 70}{100} = 5.6 \text{ hours.}$$

NOTES

$$\text{Normal time taken/unit} = \frac{5.6 \times 60}{320} \text{ minutes}$$

= 1.05 minutes

Allowed time = 1.05 × 120/100 = 1.26 minutes.

5. Find out the standard time/article produced from the following data. Total no. of observation = 2500, no. of working observation = 2100, no. of units produced in 100 hours = 6000.

Production of manual labour = 66%, Proportion of machine time = 34%

Observed rating factor = 115%, Total allowance = 12% of basic time.

Solution:

Actual working time in the duration of 100 hrs.

= 100 × 2100/2600 = 84 hrs.

Time taken/article = 84 × 60/6000 = 0.84 minutes = 50.4 seconds.

Observed manual labour time per article

= 0.84 × 66/100 or 50.4 × 66/100 = 33.26 seconds.

Observed machine time/article

= 50.4 × 34/100 = 17.13 seconds.

Normal labour time/unit = Observed time/unit × rating factor

= 33.26 × 115/100

= 38.25 seconds.

$$\text{standard labour time per unit} = 38.25 + \frac{12}{100} \times 38.25$$

= 38.25 + (4.59)

= 42.84 seconds.

standard time/unit of article produced = 42.84 + 17.13 seconds

= 59.97 seconds ≈ 1 minute.

6. Find out the production cost/piece from the following data.

(*i*) Cost of direct material/piece = ₹ 2.

(*ii*) No. of working days = 25.

(*iii*) Shift hours = 8/day.

(*iv*) Wage rate = ₹ 2000 p.m.

(*v*) Overhead expenses = 200% of direct labour cost.

(*vi*) The times for manufacture of 4 pieces of the time was observed during time study. The manufacture of the item consists of 4 elements *a*, *b*, *c* and *d*. The data collected during the time study are as below:

Element	*Cycle 1 in (min)*	*Cycle 2 (in min)*	*Cycle 3 (in min)*	*Cycle 4 (in min)*	*Element rating on B.S. Scale (0–100)*
a	1.2	1.3	1.3	1.4	85
b	0.7	0.6	0.65	0.75	120
c	1.4	1.3	1.3	1.2	90
d	0.5	0.5	0.6	0.4	70

Personal, fatigue and delay allowance = 25%.

NOTES

Solution:

(A) **Standard time:**

Element 'a': average observed time = 1.2 + 0.7 + 1.4 + .5/4 = 1.3 min.

Normal time = $OT \times OR/SR$ = 1.3 × 85/100 = 1.105 min.

Element 'b': average observed time = 1.3 + 0.6 + 1.3 + 0.5/4 = 0.675 min.

Normal time = 0.675 × 120/100 = 0.81 min.

Element 'c': average observed time = 1.3 + 0.65 + 1.3 + 0.6/4 = 1.3 min.

Normal time = 1.3 × 90/100 = 1.17 min.

Element 'd': average observed time = 1.4 + 0.75 + 1.2 + 0.4/4 = 0.5 min.

$$\text{Normal time} = 0.5 \times \frac{70}{100} = 0.35 \text{ min.}$$

$$\begin{aligned}\text{Normal time for the job} &= NT_a + NT_b + NT_c + NT_d \\ &= 1.105 + 0.81 + 1.17 + .35 \\ &= 3.435 \text{ minutes.}\end{aligned}$$

$$\begin{aligned}\text{Standard time} &= \text{NT + allowance} \\ &= 3.435 + 25/100 \times 3.435 \\ &= 3.435 + 0.858 \\ &= 4.29 \approx 4.3 \text{ minutes/4 piece.}\end{aligned}$$

Standard time for each piece = 4.3/4 = 1.075 minutes.

(B) Calculation of costs:

Direct labour cost of the job = ST/job in hour × labour rate/hour

Labour rate per hour = 2000/25 × 8 = ₹ 10.

$$\text{direct labour cost/job} = \frac{1.075}{60} \times 10 = ₹\ 0.18$$

direct material cost/piece = ₹ 2.

$$\text{Overhead @ 200\% of labour cost} = \frac{200}{100} \times 0.18 = ₹\ 0.36$$

Total cost of product/piece = 0.18 + 2 + 0.36 = ₹ 2.54.

PROBLEMS

1. The basic or normal time is 40 seconds for a certain element of work. On a normal scale, what are observed timings by stop watch for rating of 80, 100 and 125.
2. From the following information find out the standard time/unit.

   (*a*) Work sampling carried out over 48 hrs work per week.

   (*b*) Total units produced = 300

   (*c*) Average performance rating = 90%

   (*d*) Idle time = 18%

   (*e*) Total allowance = 20% of basic time

NOTES

3. Following data were recorded during a time study:

Element	*OT(in min)*	*Rating*	*RA*	*Frequency/cycle*
1	0.15	120	15%	1
2	0.07	110	20%	3
3	1.25	90	20%	2
4	0.50	100	18%	1

Calculate the standard time per work cycle.

MAINTENANCE MANAGEMENT

Maintenance management has been one of the most neglected aspect of management in India. In most industries, be the public or private sector, little attention is paid to proper stocking of spare parts, to maintain proper policies and procedures, to acquisition and development of required quantity and quality of technicians and junior and senior managers who may have appropriate skills to operate and maintain the modern equipment properly, to the application of the principles of work study, incentives and performance evaluation to the extent possible.

The reasons for the lack of management input in maintenance are:

(*i*) Machine failures occur at random.

(*ii*) One machine job is not like another maintenance job so as to put in a standard category.

(*iii*) Different types of equipment are imported at different times, resulting in a heterogeneous stock of equipment, this makes it difficult to provide proper skilled manpower and facilities for maintenance and repair.

(*iv*) Obtaining spare parts from foreign countries is difficult, making them within the country is not economical since the quantity required of each item is small. It is difficult to apply management principles and generate economics in such circumstances.

Note. 1. Some of real problems in applying management principles/techniques to maintenance: the last two reasons *i.e.*, (*iii*) and (*iv*) are particularly true for developing countries like India. Therefore, the need for proper management of maintenance is vital as also the need to make the best use of available management concepts even if the circumstances do not allow their application.

2. It must be appreciated that good maintenance management is an important input for achieving the desired quality of the products and services.

Maintenance may be understood as a set of activities which help plant, machinery and other facilities in good condition. A formal definition of maintenance is—

"*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 ensure the availability of the machines, buildings and services needed by other parts of the organisation for the performance of their functions at an optimum return on the investment, whether this investment is in machinery materials or employee.*"

Note. Maintenance is not just repair. It has much wider scope than repairs. It 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

Every manufacturing organisation needs maintenance because, machines break down, parts wear out and building deteriorate over a period of time of use. All segments of a factory—building, machinery, equipments, tools, cranes, jigs and fixtures, heating and generating equipments, waste disposal system, air-conditioning equipments, washrooms, dispensaries, and so on need attention.

Maintenance covers two broad categories of functions as below:

(1) Primary functions.

(2) Secondary functions.

Primary function includes:

(*a*) Maintenance of existing plant and equipments.

(*b*) Maintenance of existing plant building and grounds.

(*c*) Equipment inspection and lubrication.

(*d*) Utilities generation and distribution.

(*e*) Alternatives to existing equipments and buildings.

(*f*) New installations of equipments and buildings.

Secondary functions includes:

(*a*) Storekeeping.

(*b*) Plant protection including fire protection.

(*c*) Waste disposal.

(*d*) Salvage.

(*e*) Insurance administration against fire, theft etc.

(*f*) Territorial services.

(*g*) Property accounting.

(*h*) Pollution and noise abatement or control.

(*i*) Any other service deligated towards maintenance by the plant management.

Importance of Maintenance Management

There are many advantages of maintenance management out of which a few most important one's are as below:

1. Dependability of service is one of the performance measures by which a company can distinguish itself from others. To establish a competitive edge and to provide good customer services, companies must have reliable equipments that will respond to customer demands when needed. Equipments must be kept in reliable condition without costly work stoppage and down time due to repairs, if the company is to remain productive and competitive.
2. Maintenance is an important factor in quality assurance, which is another basis for the successful competitive edge. Inconsistencies in equipments lead

to variability in product characteristics and result in defective parts that fail to meet the established specifications. Beyond just preventing break downs, it is necessary to keep equipments. Operating with in specification.

3. Many manufacturing organisations specially with just-in-time programme are maintaining minimum level of inventory hence can't afford a lengthy equipment failure. Beyond the cost of idle equipment, idle labour and cost sales that can result from a break down, there is a danger of permanently losing market shares to companies that are more reliable. The maintenance function can help in preventing of such occurrence.
4. Good maintenance management is important for the company's cost control. With the more and more automation, companies rely more and more on equipments to produce a greater percentage of their output. It is essential that equipments operate reliably and within specification.

   Note. The cost of idle time is quite higher as equipment becomes more high-tech and expensive.
5. Organisation like airlines and oil refineries have very huge investment in the equipment hence high fixed cost (FC). If there is a failure firstly the FC on further production is high secondly replacement of these equipment will further increase cost. Thereby need proper maintenance to keep the equipment in good conditions.

Impact of Poor Maintenance

Maintenance operations includes all efforts to keep production facilities and equipments in an acceptable operating condition. Failure or malfunctioning of machines or equipments in manufacturing and service industry/ies have a direct impact on the following:

1. Employee or customer safety
2. Customer satisfaction
3. Production capacity
4. Production costs
5. Product and service quality.

Employee or Customer Safety

Worn out equipments is likely to fail at any moment and these failures can cause injuries to the workers, working on those equipments. Products such as vehicles etc., if not serviced periodically, can breakdown suddenly and cause injuries to the users.

Customer Satisfaction

When production equipments breakdown, 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.

Production Capacity

Machines idled by breakdowns cannot produce, thus the capacity of the system is reduced.

Production Costs

Labour costs per unit rise because of idle labour due to machine breakdowns. When machine malfunctions result in scarp, unit labour and material costs increase. Besides, cost of maintenance which includes such costs as cost of providing repair facilities, repair crews, preventive maintenance inspections, spare parts and standby machines will increase as machines breakdown frequently.

NOTES

Product and Service Quality

Poorly maintained equipments produce low quality or sub-standard products. Equipments that have not been properly maintained have frequent breakdowns and cannot provide adequate service to customers.

The importance and impact can be easily understood with the help of following cost concept :

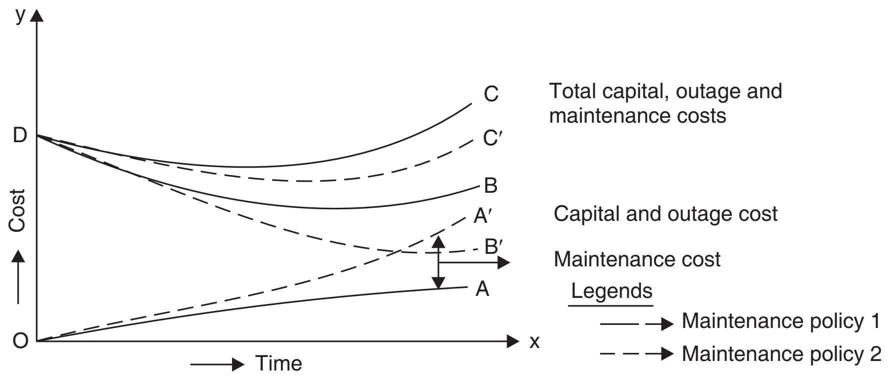
Maintenance programmes are closely related to production planning and control. All manufacturing concerns and operations follows some maintenance routine for two reasons.

(*a*) There is the cost of production associated with unexpected breakdown of machine/equipment.

(*b*) There is an implicit capital cost.

In fact the capacity cost of owning an asset is usually lower than when the asset receives proper case.

Note. The quality of production may also be higher with better maintenance.



The above diagram reveals that maintenance costs are lower when a machine is new. But cost increases with age because more work is needed to maintain a given level of performance. At the initial stage of a machine's life, capital costs are usually high. Later on such costs tend to remain constant. But there is an offsetting consideration. The cost of repairs is often more than out weighted by lower capital and outage costs. The optimum policy is one that provides the lowest total cost.

Objective

The objective of equipment maintenance is maximization of the performance of production facilities by attempting to prevent breakdowns and minimising the loss or inconvenience caused by unavoidable breakdowns.

Following are some of the objectives of maintenance management:

(*i*) Minimising the loss of production time because of equipment failure means minimising idle time of equipment due to breakdown.

(*ii*) Minimising the repair time and cost.

(*iii*) Minimising the loss due to production stoppage.

(*iv*) Efficient use of maintenance facilities *i.e.,* men and materials.

(*v*) Prolonging the life of capital assets by minimising the rate of wear and tear.

(*vi*) To keep all productive assets in good working conditions.

(*vii*) To maximise efficiency and economy in production through optimum use of facilities.

(*viii*) To minimise accidents through regular inspection and repair of safety devices.

(*ix*) To minimise the total maintenance cost which includes the cost of repairs, cost of preventive maintenance and inventory carrying costs, due to spare parts inventory.

(*x*) To improve the quality of products and to improve productivity.

Major areas of maintenance are civil maintenance, mechanical maintenance and electrical maintenance. All these areas in the organisation may be maintained by any one, all the five or in any other combination of following five types of maintenance:

(1) Breakdown or Corrective maintenance

(2) Preventive maintenance

(3) Predictive maintenance

(4) Routine maintenance

(5) Planned maintenance.

Breakdown or Corrective Maintenance

It occurs when there is a work stoppage due to machine/equipment breakdown. Here maintenance is repair work.

Note. 1. In this maintenance firstly stoppage in production occurs then only repair work starts.

2. In these cases, the maintenance department checks into the difficulty and makes the necessary repairs. Role of department is passive.

Objective of Corrective Maintenance

(*a*) To make equipment/machine operational as soon as possible. So that interruption in production is minimised. This objective can directly effect production capacity, production cost, product quality and quantity with consumer satisfaction.

(*b*) To control the cost of repair crews.

(*c*) To control the cost of the operation of repair shops.

(*d*) To control the investment in replacement, spare machines etc.

(*e*) To perform the appropriate amount of repairs at each malfunctions some parts can be replaced early to extend the time until the next repair is required.

Preventive Maintenance

1. It is used to reduce the frequency and magnitude of major repairs and is undertaken before the need arises with an aim to minimise the possibility of unanticipated production interruptions or major breakdowns.

   Note. The question is whether preventive maintenance is used to reduce the frequency and magnitude of major repairs made as needed and if it is more economical, how often should the preventive checks be made. These questions are usually treated by probability models.

2. Another important consideration in any maintenance programme is the size of repair facilities. There is need to strike an economic balance between the cost of idle repair facilities and the cost of machines waiting to be repaired when facilities are crowded. This is an aspect of queneing theory.

NOTES

3. A cost minded manager has to determine whether preventive maintenance *i.e.,* replacement of parts, overhauls etc., is less experience than repairing on call. It is also necessary to set the most economical period for preventive maintenance checks.

Objective of Preventive Maintenance

These are three main objectives of preventive maintenance *i.e.,*

1. To attain longer life
2. To increase useful time
3. To maintain the design level of performance.

Preventive maintenance consists essentially of two aspects:

(*a*) Inspection of equipment in order to diagnose impending failure

(*b*) Servicing to reduce wear and hence attempt to prevent or delay breakdowns.

Note. The major problem in planning preventive maintenance is that of determining when a piece of equipment should receive attention. So it is essential to apply preventive maintenance first before a piece of equipment otherwise have brokendown.

Preventive Maintenance Planning-PMP

The guide rule for preventive maintenance planning is that "the time spent on preventive maintenance should be less than the time required for repairs, and the value imparted to machines by preventive maintenance should exceed the programme cost." A difficult part of planning is the distribution of preventive maintenance cost among operating departments.

Guidelines for PMP

Following are the guidelines for PMP:

(*a*) Machines can be overdesigned and their reliability improved.

This leads to reduction in maintenance cost.

(*b*) Extra stock can be carried to provide a buffer against the effect of machine failure.

(*c*) Inspections of machines and their cleaning, adjusting and other maintenance work can be done at the same time to reduce cost and inconvenience.

(*d*) It is necessary to check the machines periodically to assume the level of care needed.

(*e*) Physical conditions of machines as friction, vibrations, corrosion and erosion should be detected and controlled before they lead to major problem.

Advantages

(*a*) It includes greater safety for workers.

(*b*) It decreases production down time.

(*c*) Fewer large scale and repetitive repairs.

(*d*) Less cost for simple repairs made before breakdown.

(*e*) Less standby equipment required.

(*f*) Better spare parts control.

(*g*) Identification of items with high maintenance cost and lower cost of manufacture.

Predictive Maintenance

One among the new types of maintenance that may be anticipated to gain increasing attention. In this sensitive instruments such as vibration analysis, amplitude metres, audio gauges, optical tooling, pressure, temperature and resistance gauges are used to predict trouble.

Conditions can be measured periodically or on a continuous basis and this enables the maintenance people to plan for an overhaul.

Note. This will allow an extension to the service life without fear of failure.

Routine Maintenance

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

Routine maintenance can be of following two types:

(*a*) Running maintenance (*b*) Shutdown maintenance.

Running Maintenance

These are in which the maintenance work is carried out while the equipment is in the operating condition and is in operation.

Shutdown Maintenance

These are 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.

Planned maintenance

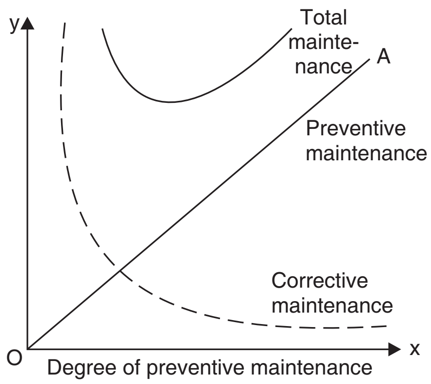
Though the breakdown of a machine or equipment is unplanned but maintenance work can be planned well in advance. This is also called as scheduled/productive maintenance.

It includes inspection of all plant and equipments, machinery buildings, according to a pre-determined schedule in order to service, overhaul, lubricate or repair, before the actual breakdown or deterioration in service occurs. The aim is to reduce machine stoppage due to sudden break down necessitating emergency maintenance.

Planned approach to maintenance reduces the machine or equipment down time, reduces the cost of maintenance and increases productivity as compared to haphazard or unplanned maintenance.

Comparison of Breakdown and Preventive Maintenance

A relationship exist between the amount of preventive maintenance which has been performed and the amount of corrective maintenance which will be required. An increase in preventive maintenance can be expected to reduce the frequency with which the need for corrective maintenance arises.



(*a*) A component which is not replaced or repaired for preventive reasons, when it eventually malfunctions and damages other components of the equipment/ machine/asset.

(*b*) The corrective maintenance cannot be planned and scheduled as systematically and efficiently as preventive maintenance.

NOTES

Preventive maintenance is a planned activity and analyst known when it will take place how much time it will require and what resources are required for its implementation.

For corrective maintenance the analyst have to know the number of future breakdown, the point in time when those will occur and the nature of malfunctions. All these informations/predictions can be based on the past maintenance records of the assets/equipments/machine involved.

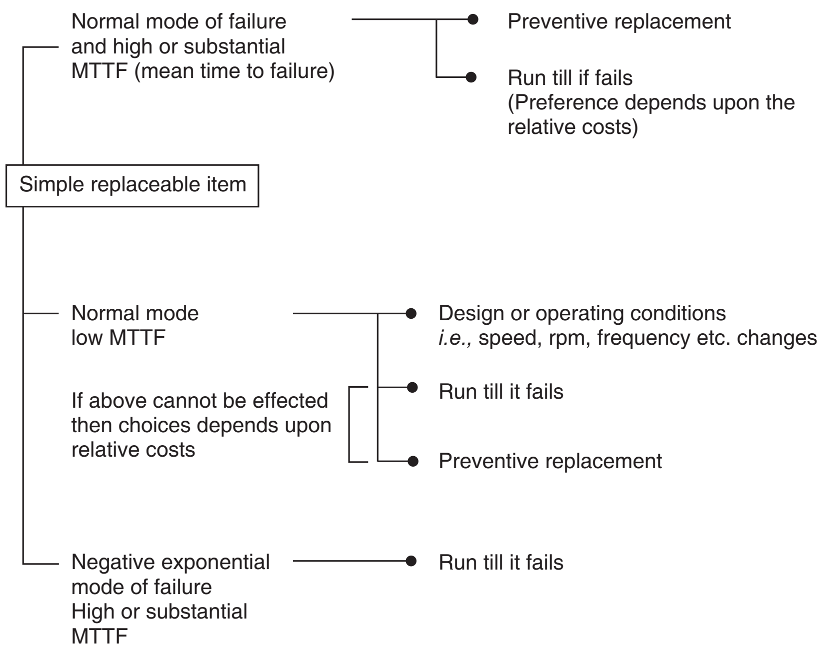
Maintenance Policy

Though there is nothing like a pure preventive maintenance rather it is always an approximate mix of the preventive and breakdown maintenance.

All items are amenable to all types of preventive maintenance for *e.g.,* an item is showing a time independent *i.e.,* negative exponential failure behaviour, then the cause of failure is external to the item, therefore any amount of preventive replacement is not going to serve the intended purpose.

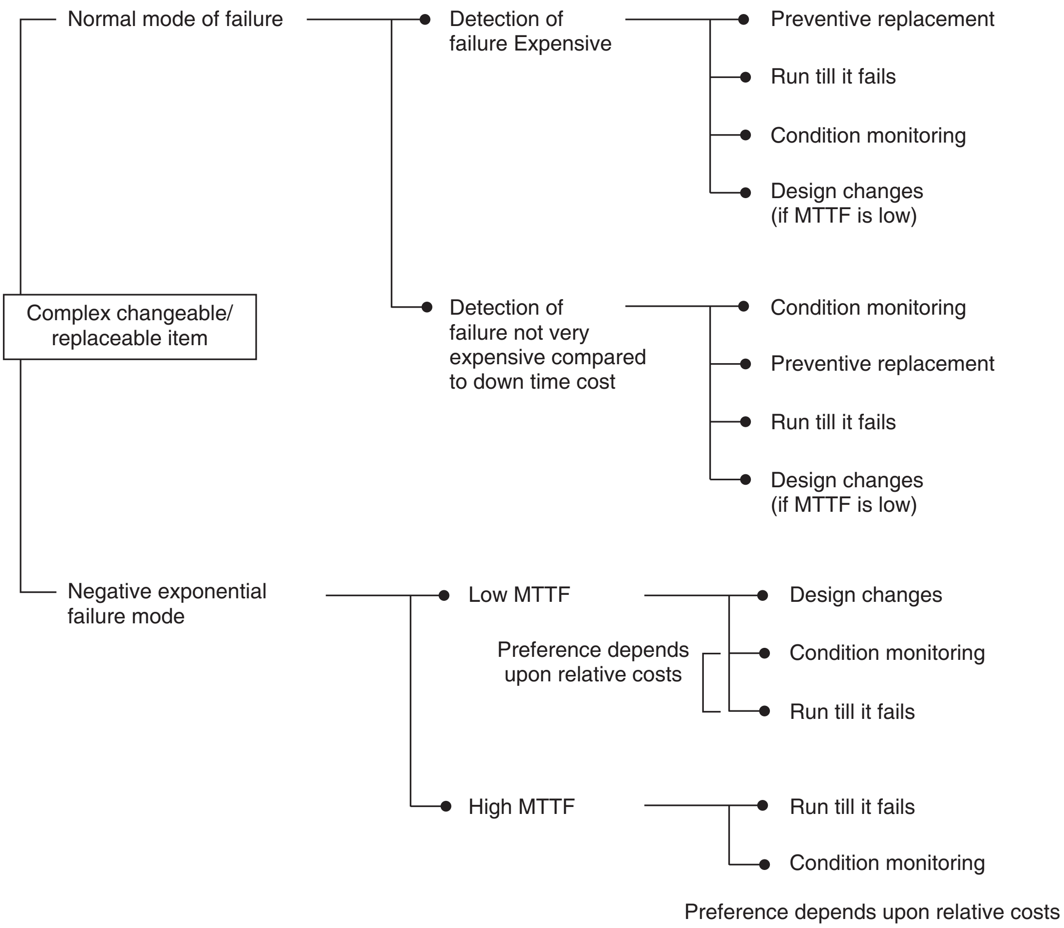
Preventive or fixed time replacement of parts individually or in a group is a policy that is appropriate for items that wear out with time due to use, means for items that show a normal failure mode. Such a policy may be useful only if the cost of preventive actions are significantly lower than those of the breakdown maintenance replacement, means that the item should preferably be a simple replaceable item not a complex one.

Note. Preventive replacement is not totally ruled out for the complex parts, here cost-cum-safety factor has to be considered. Condition monitoring is usually advised for the complex replaceable part. If economics of monitoring by instrumentation and that of tangible cost plus safety work out in favour of such monitoring. Such policy is applicable in normal as well as negative exponential failure mode, because condition monitoring is to detect the extent of wear out and/or a minor defect that may have developed which may lead to major damage. "A stick in time saves nine."



Guidelines for the formulation of maintenance policy for the simple replaceable item.

NOTES



Note. Cost includes tangle as well as intangle both.

Guidelines for the formulation of maintenance policy for the complex replaceable items.

Organisation for Maintenance

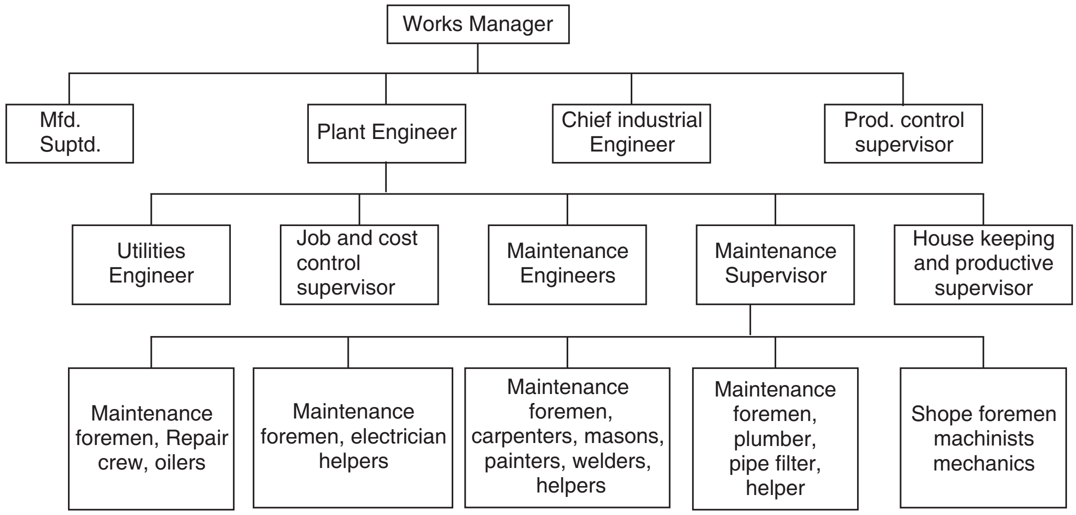
The organisation structure of maintenance changes from one company to another usually it depends upon:

(*a*) Nature of the industry (*b*) Size of the plant

(*c*) Scope of activities to be performed.

NOTES

A typical organisation chart for a medium size plant is as below:



A typical organisation of Maintenance Department.

TOTAL PRODUCTIVE MAINTENANCE (TPM)

In the concepts of maintenance management one assumption is always present that is the failure of breakdowns are inevitable. Hence the trade off or compromise between the preventive maintenance and the breakdown maintenance or the computation for optimal stock of spare parts. This compromising attitude leads to compromises in other areas also. When a machine/equipment breakdown it not only hampers the production but also the quality of the product with the upset deliveries of product.

To overcome this problem, the Japanese have shown a new path to the world of management by ceaselessly working towards the ideal goods of 'zero' breakdown and 'zero' defects or zero defectives. The quality Guru **Philp Crosby's** goal of zero defect is helped considerably by the Japanese concept of the pursuit of zero breakdown. "*Less is the breakdowns of machines, the less will be the proportion of defective quality*."

Breakdown of equipments/machines are usually due to following:

(*a*) Equipment/machine stops performing its function. So there are downtime losses of repair time, setup and adjustment time.

(*b*) Equipment/machine deteriorates and its performing ability is diminished leading to a reduction in functions such as a reduction in speed of the equipment leading to speeds and/or yields lower than designed or the equipment keeps having minor stoppages and/or produces more defective products.

(*c*) Equipment has hidden defects which do not become apparent until the breakdown situation is reached.

These are the breakdowns which have to be eliminated. There is no room for trade offs. This is the rationale behind the total productive maintenance (TPM).

Objective

The objective of TPM is much wider than just minimising equipment downtime. The objective is to minimise the life cycle costs *i.e.,* the costs for the entire life span of the equipment.

NOTES

TPM Includes

(*i*) Optimising equipment effectiveness by elimination of all types of breakdown or failures, speed losses, defects and other wastes in operation.

(*ii*) Autonomous maintenance by operations, which means the people who operate the machines will look after their machines by themselves. It involves training and involvement of the operators. The idea behind this is the operating people would get to know their equipment even better so that they will be able to contribute not only in maintenance of the preventive and breakdown kind but also in the prevention of maintenance itself through their suggestions for improvement in design of machines, processes, systems, materials and products.

(*iii*) Organisation wide involvement of all employees through small group activities which would support the above such participative management would enhance creative thinking and cross-flow of information. Continuous improvement can be achieved only through such participative processes.

1. **Total Operations Orientation:** Attained to machines predominantly only when the machines breakdown.

   Breakdown Maintenance = BM.

2. **Cost Optimisation:** Have Preventive Maintenance (PM) in addition to Breakdown maintenance (BM) optimal combination of the two is required for total cost minimisation profitable preventive maintenance (PPM)

   PPM = BM + PM

3. **System Orientation:** PM alone cannot eliminate or sharp decline in beakdowns. Supporting it there should be various steps taken in design, development and engineering such that maintenance itself is found rarely necessary *i.e.,* maintenance prevention (MP). If even maintenance is required, the maintainability should be high *i.e.,* reduction in losses of time efforts, resources called as maintainability improvement (MI).

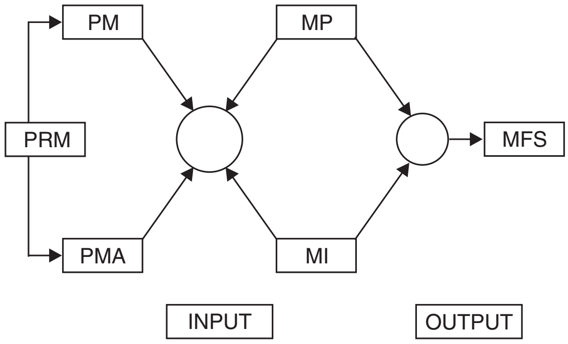
   Productive Maintenance = BM + PM + MI + MP

4. **Company Wide/Organisation Wide Involvement:** Autonomous maintenance by operators, small group activities by R and D, Engineering, manufacturing logistics, marketing and such various departments at all levels organisation/company wide. Company wide Involvement (CI), Total Productive Maintenance (TPM)

   TPM = BM + PM + MI + MP + CI.

NOTES

TPM Cycle



PRM → PM + PMA → MP + MI → MFS.

Legend:

PRM = Productive Maintenance
PM = Preventive Maintenance
PMA = Predictive Maintenance
MP = Maintenance Prevention
MI = Maintainability Improvement
MFS = Maintenance-Free-Service

SUMMARY

- Productivity is seen as the ratio of output to input, it needs to be understood as to what constitutes the output. In terms of productivity output can be quantity produced, useful life and monetary term. Inputs are of varied types—human input, material input, machinery input, money input, technology input and time inputs.
- It concerns itself with better ways of doing things and control over the output of these things by setting standards with respect to time. It is of great importance for the smooth running of any organisation.
- According to **Dr. Taylor:** *The greatest production results when each worker is given a definite task to be performed in a definite time in a definite manner*.
- It is a scientific technique of observing, recording and critically examining the present method of performing a task or job or operations with the aim of improving the present method and developing a new and cheaper method, also called as methods improvement or work improvement.
- It is the science of eliminating wastefulness, resulting from using unnecessary, ill-directed and inefficient motion. The aim of motion study is to find and perpetuate the scheme of the least waste methods of labour.
- It is also a technique of work study and it establishes the work content of a job. Work content of a job can accurately be established only after the method of doing a job is standardised hence method study must precede work measurement.
- It is concerned with the determinations of the amount of time required to perform a unit of work and consists of the process of observations and recording the time

required to perform each element of an operation so as to determine the reasonal time in which the work should be completed.

- It is also a technique of work measurement for building up the time required to do a job at a defined level of performance by synthesising or totalling elemental time values obtained from previous time studies on other job containing similar job elements or from standard data or synthetic data or build up time standard.

QUESTIONS

1. What is Productivity?
2. What are the ways to improve Productivity?
3. What is the importance of Productivity?
4. Explain the Work Study procedure?
5. What is Method Analysis?
6. What is Motion Study?
7. Explain Work Measurement.
8. What is Time Study?
9. What is Synthesis Method?
10. What is Analytical Estimating?