

**Bachelor of Business Administration  
(B.B.A.)**

**BBA - 303**

**PRODUCTION MANAGEMENT**



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# LESSON : 1

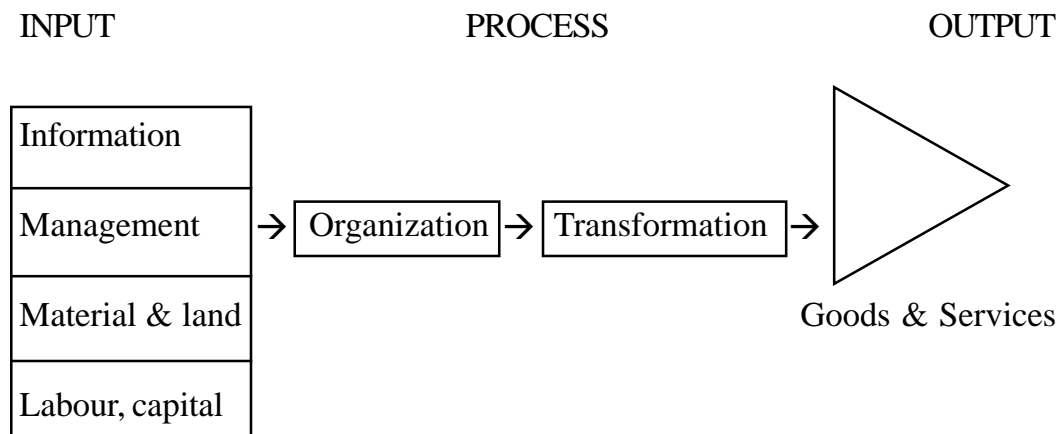
## ROLE AND SCOPE OF PRODUCTION MANAGEMENT, CONCEPT OF PRODUCTION MANAGEMENT

### MEANING OF PRODUCTION

Production is an intentional act of producing something in an organized manner. It is the fabrication of a physical object through the use of men, material and some function which has some utility e.g. repair of an automobile, legal advice to a client, banks, hotels, transport companies etc.

Thus irrespective of the nature of organization, production is some act of transformation, i.e. inputs are processed and transformed into some output. The main inputs are information, management, material, land, labour and capital. Fig. shown below explains the production process of an organization.

### PRODUCTION PROCESS SYSTEM



Labour, capital

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

- (i) optimum use of resources at optimum cost.
- (ii) manufacture of the desired quality and quantity of goods and services.

### **Meaning of Production Management**

Production management is a branch of management which is related to the production function. Production may be referred to as the process concerned with the conversion inputs (raw materials, machinery, information, manpower, and other factors of production) into output (semi finished and finished goods and services) with the help of certain processes (planning, scheduling and controlling etc.) while management is the process of exploitation of these factors of production in order to achieve the desired results. Thus production management is the management which by scientific planning and regulation sets into motion the part of an enterprise to which it has been entrusted the task of actual transformation of inputs into output. A few definitions of production management are being reproduced hereunder to understand the meaning of the term clearly :

- (i) “Production management then becomes the process of effectively planning and regulating the operations of that part of an enterprise which is responsible for actual transformation of materials into finished products”.

The definition seems to be quite incomplete as it ignores the human factors involved in a production process and lays stress only on the materialistic features.

Elwood S. Buffa has defined the term in a broader sense as :

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

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

Production management, thus, is assigned with the following tasks –

- (i) Specifying and accumulating the input resources, i.e., management, men, information, materials, machine and capital.
- (ii) Designing and installing the assembly or conversion process to transform the inputs into output, and
- (iii) Coordinating and operating the production process so that the desired goods and services may be produced efficiently and at a minimum cost.

### **SCOPE OF PRODUCTION MANAGEMENT**

Production management is mainly associated with the factory management crept with the development of factory system. Before the evolution of factory system, manufacturing activities were carried on by single person that posed

no or very insignificant problem of production and therefore question of production management did not arise. But with the inception of factory system, the situation changed and so many problems of production were begun to creep up and necessity arose to tackle with the problems of quality control, layout facilities, meeting the schedules and organization of production activities. Thus the scope of production management began to develop. In early stage, the stress was on controlling the labour costs because labour cost was the major element of the total cost of production. With the continuing development of factory system, the trend towards mechanization and automation developed and it resulted in the increased costs of indirect labour higher than the direct labour costs. So concerns found it difficult to run the business in these circumstances and evolved many controlling devices to regulate the cost of production. They had developed devices like designing and packing of products, indirect labour cost control, production & inventory control and quality control.

Since the level of production has increased tremendously, so many other production problems have been added to its scope. In the present era of intense competition, the scope of production management is very wide. The production department in an enterprise is not only concerned with the full exploitation of production facilities but also the human factor that indirectly affects the production, utilization of latest techniques of production and the production of quality goods to the satisfaction of customers of the product.

The various activities that form scope of production function can be studied in the following broad areas –

1. *Product Selection and Design* : The product mix makes the production system either efficient or inefficient. Choosing the right products, keeping

the mission and overall objectives of the organization in mind is the key to success. Design of the product, which gives it enough functional and aesthetic value, is of paramount importance. It is the design of the product which makes the organization competitive or noncompetitive. Value engineering does help to retain enough features, while eliminating the unnecessary ones.

2. *Activities Relating to Production System Designing* : Decision related to the production system design is one of the most important activity of the production management. This activity is related to production engineering and includes problems regarding design of tools and jigs, the design, development and installation of equipment and the selection of the optimum size of the firm. All these areas require the technical expertise on the part of the production manager and his staff.
3. *Facilities Location*: The selection of an optimum plant location very much depends upon the decision taken regarding production engineering. A wrong decision may prove disastrous. Location should as far as possible cut down the production and distribution cost. There are diverse factors to be considered for selecting the location of a plant.
4. *Method Study* : The next decision regarding production system design concerns the use of those techniques which are concerned with work environment and work measurement. Standard methods should be devised for performing the repetitive functions efficiently. Unnecessary movements should be eliminated and suitable positioning of the workers for different processes should be developed. Such methods should be

devised with the help of time study and motion study. The workers should be trained accordingly.

5. *Facilities Layout and Materials Handling* : Plant layout deals with the arrangements of machines and plant facilities. The machines should be so arranged that the flow of production remains smooth. There should not be overlapping, duplication or interruption in production flow. Product layout, where machines are arranged in a sequence required for the processing of a particular product, and process layout, where machines performing the similar processes are grouped together are two popular methods of layout. The departments are laid out in such a way that the cost of material handling is reduced. There should be proper choice of materials handling equipment. These days, computer software is available for planning the process layout (e.g. CRAFT, CORELAP etc.). Group Technology (G.T.), Cellular Manufacturing Systems (CMS) and Flexible Manufacturing Systems (FMS) have made our concepts of layout planning undergo a tremendous change.
6. *Capacity Planning* : This deals with the procurement of productive resources. Capacity refers to a level of output of the conversion process over a period of time. Full capacity indicates maximum level of output. Capacity is planned for short-term as well as for long term. Process industries pose challenging problems in capacity planning, requiring in the long run, expansion and contraction of major facilities in the conversion process. Some tools that help us in capacity planning are marginal costing (Break Even Analysis), learning curves, linear programming, and decision trees.



7. *Production Planning* : The decisions in production planning include preparation of short-term production schedules, plan for maintaining the records of raw materials, finished and semi-finished stock, specifying how the production resources of the concern are to be employed over some future time in response to the predicted demand for products and services. Production planning takes a given product or line of products and organizes in advance the manpower, materials, machines and money required for a predetermined output in a given period of time.

Thus, production planning is a management technique which attempts to gain the best utilization of a firm's manufacturing facilities. It is gained by the integration and coordination of the manpower, machines, materials and plant services employed in the manufacturing cycle.

8. *Production control* : After planning, the next managerial production function is to control the production according to the production plans because production plans cannot be activated unless they are properly guided and controlled. For this purpose, production manager has to regulate work assignment, review work process, check and remove discrepancies, if any, in the actual and planned performances.

According to Soriegel and Lansburgh "Production control is the process of planning production in advance of operations; establishing the exact route of each individual item, part or assembly; setting, starting and finishing dates for each important item, assembly and the finished products; and releasing the necessary orders as well as initiating the required follow-up to effect the smooth functioning of the enterprise".

Thus production control involves the following stages :

- (i) Planning — setting targets of production.
- (ii) Routing — to decide the route or flow-of production activity.
- (iii) Dispatching — to issue materials and authorizations for the use of machines and plant services.
- (iv) Follow-up — it compares the actual production with the targeted production. Deviations are found out and corrected and reasons are investigated.

9. *Inventory Control* : Inventory control deals with the control over raw-materials, work-in-progress, finished products, stores, supplies, tools, and so is included in production management.

The raw materials, supplies etc. should be purchased at right time, of right quality, in right quantity, from right source and at right price. This five 'R's consideration enables the scientific purchases.

Store-keeping is also an important aspect of inventory control. The raw materials, work-in-progress, finished goods, supplies, tools etc. should be stored efficiently. The different levels of inventory should be managed properly and the issue of materials to departments should be made promptly and effectively. Proper records should also be kept for various items of inventory control.

The production manager has to look after the inventory control activities at three levels –

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

- (ii) Control of flow of materials into the plants through the technique of judicious purchasing;
- (iii) Control of work-in-progress through production control.

10. *Quality control* : The other important decision taken by the production manager concerns quality control. Product quality refers to the composite product characteristics of engineering and manufacturing that determines the degree to which the product in use will meet the expectations of the customers. Quality control can be ensured through the techniques of inspection and statistical quality control.
11. *Maintenance and Replacement* : In this we cover preventive methods to avoid machine break-downs, maintenance, policies regarding repair and replacement decisions. Maintenance manpower is to be scheduled and repair jobs are to be sequenced. There are some preventive replacements also. Machine condition is to be constantly monitored. Effective maintenance is a crucial problem for India which can help better capacity utilization and make operations systems productive enough.
12. *Cost Reduction and Control* : Cost reduction ultimately improves productivity. The industry becomes competitive. Essentially cost reduction and cost elimination are productivity techniques. Value engineering, budgetary control, standard costing, cost control of labour and materials etc. help to keep costs optimal.

All Production decisions are subject to control measures, after receiving proper feed-back. Control function is exercised over the quantity to be

produced, quality expected, time needed, inventory consumed & carried and costs incurred. Control system is designed after due cost benefit analysis. Controls should be selective. A self-controlling cybernetic system though preferable is not possible in all complex industries.

Environmental changes ultimately affect all the systems of the organization. A dynamic environment makes it compulsory to adapt the production system to the changes in technology and other factors of the environment. Product mix, composition of products, introduction of new products, changing the layout system is some of the representative decisions which respond to environmental feedback.

Apart from these factors, the production system designer should pay full attention to two other important problems, viz. (i) human factor, i.e., the impact of production systems on the workers operating it and (ii) research and development activities. These two problems have a vital impact on production system designing.

### **Brief History of Production Management**

If we assess the past, covering a period of 200 years after Adam Smith, it can be observed that total production capacity as well as productivity have expanded considerably. Production Management has become an empirical applied science. Undoubtedly, during this period, we have responded to the expansion of markets and large scale business units by using the concepts of division of labour and progressive mechanisation in order to achieve economies of large scale production. The history of production management can be studied as under :

### **Individual Efficiency**

Fredric W. Taylor studied the simple output-to-time relationship for manual labour such as brick-laying. This formed the precursor of the present day 'time-study'. Around the same time, Frank Gilberth and his learned wife Lillian Gilberth examined the motions of the limbs of the workers (such as the hands, legs, eyes, etc.) in performing the jobs, and tried to standardize these motions into certain categories and utilize the classification to arrive at standards for time required to perform a given job. This was the precursor to the present day 'motion study'. Although, to this day Gilberth's classification of movements is used extensively, there have been various modifications and newer classifications.

### **Collective Efficiency**

So far the focus was on controlling the work-output of the manual labourer or the machine operator. The primary objective of production management was that of efficiency-efficiency of the individual operator. The aspects of collective efficiency came into being later, expressed through the efforts of scientists such as Gantt who shifted the attention to scheduling of the operations. (Even now, we use the Gantt Charts in operations scheduling). The considerations of efficiency in the use of materials followed later. It was almost 1930, before a basic inventory model was presented by F. W. Harris.

### **Quality Control**

After the progress of application of scientific principles to the manufacturing aspects, thought progressed to control over the quality of the finished material itself. So far, the focus was on the quantitative aspects; now it shifted to the

quality aspects. 'Quality', which is an important customer service objective, came to be recognized for scientific analysis. The analysis of productive systems, therefore, now also included the 'effectiveness' in addition to efficiency. In 1931, Walter Shewart came up with his theory regarding Control Charts for quality or what is known as 'process control'. These charts suggested a simple graphical methodology to monitor the quality characteristics of the output and to control it by exercising control over the process. In 1935, H.F., Dodge, and H.G. Romig came up with the application of statistical principles to the acceptance and/or rejection of the consignments supplied by the suppliers to exercise control over the quality. This field, which has developed over the years, is now known as 'acceptance sampling'.

### **Effectiveness as a Function of Internal Climate**

In addition to effectiveness for the customer, the concept of effectiveness as a function of internal climate dawned on management scientists through the Hawthorne experiments which actually had the purpose of increasing the efficiency of the individual worker. These experiments showed that worker efficiency went up when the intensity of illumination was gradually increased, and even when the intensity of illumination was gradually decreased, the worker efficiency still kept rising. This puzzle could be explained only through the angle of human psychology; the very fact that somebody cared, mattered much to the workers who gave increased output. Till now; it was Taylor's theory of elementalization of task and thus the specialization in one task which found much use in Henry Ford's Assembly Line.

### **Advent of Operations Research Techniques**

The application of scientific techniques in management really received a big

boost during the World War II period when the field of Operations Research came into being. During this war, the Allied Force took the help of statisticians, scientists, engineers, etc. to analyze and answer, questions such as : What is the optimum way of mining the harbours of the areas occupied by the Japanese? What should be the optimum size of the fleet of the supply ships, taking into account the costs of loss due to enemy attack and the costs of employing the defence fleet? Such research about the military operations was termed as Operations Research. After World War II, this field was further investigated and developed by academic institutions; and today, it has become one of the very important fields of management theory. Various techniques such as Linear Programming, Mathematical Programming, Game Theory, Queuing Theory, etc. developed by people such as George Dantzig, A. Charnes, W. W. Cooper, etc. have become indispensable tools for management decision-making today.

### **The Computer Era**

After the breakthrough made by Operations Research, another marvel came into being the Computer. Around 1955, IBM developed the digital computer and made it available later on a large-scale basis. This made possible the complex and repeated computations involved in various Operations Research and other Management Science techniques, and definitely added to the spread of the use of Management Science concepts and techniques in all fields of decision-making.

### **The Production and Operations Management Scenario Today**

More importantly, the long experience of industrial life, the growth of technology and the rapidly growing availability of its benefits, have all been

changing the value systems all over the world. The concepts of 'quality of life', whether expressed explicitly or otherwise, have gained solid ground. The demand for 'service' or the 'state' utility is fast catching up with the demand for 'form' utility. Services are becoming as important, if not more, as the availability of physical products. The demand for 'variety' in products and services is on the increase. The concepts of 'customer' and 'customer orientation' are very vital today, as also the definition of the word 'customer' itself. The producing workers themselves are a part of the 'customers'. There is great pressure every where to enhance the quality of life in general. If in the developed countries there is an increased demand for 'flexi-time' (flexible times of working), in India we have already witnessed the shortening of the traditional six-day week to a five-day week in even traditional organizations such as the Central Government and State Governments. (Of course, the total time of working has remained the same.) In addition to all this, there is the increasing complexity of the space-age economies, the socio-techno-economic scene and the problem of depleting resources.

Such a complex scenario needs freedom from compartmentalized thinking and an integrated consideration of the various factors that impinge on the production and operations management system. It needs to introduce fresh variables, e.g. that of safety in the external and internal environment and an added emphasis on maintenance. These are the challenges of the production and operations management discipline.

### **Production Administration**

Production is a succession of work elements applied to natural materials with the purpose of transforming these into desired goods and services for the satisfaction of human wants. Thus modern production phenomenon is an

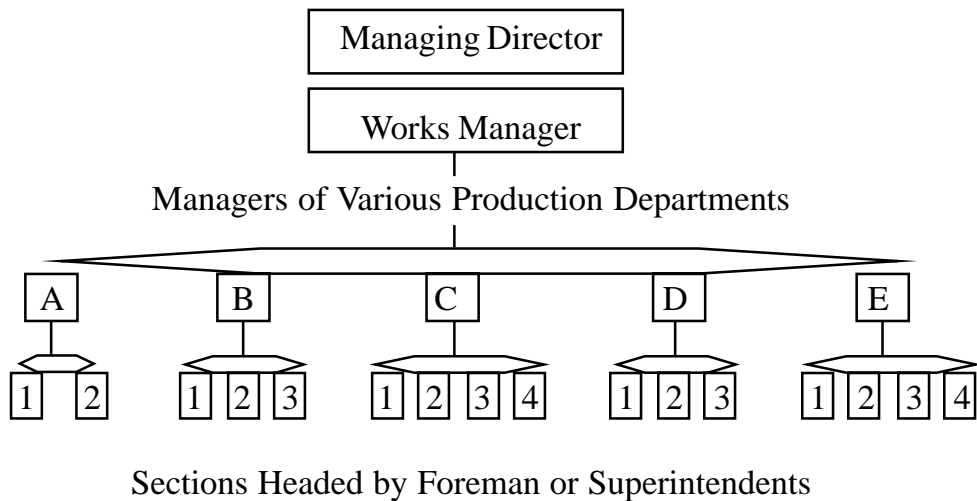


evolution and production administration deals with planning and control of various operations and components associated with production process. However there are a number of definitions given by different experts of Production administration according to their own experiences. The concept can be explained by the following definitions :

According to Frederick W. Taylor, father of scientific management, “functional management consists of division of management work in such a way that every person below the rank of assistant superintendent has as few responsibilities as possible. If possible the work of each man should be confined to perform a single leading function”.

The various departments of Production Administration can be listed as production engineering, production planning and production control.

**ORGANISATIONAL CHART OF PRODUCTION MANAGEMENT**  
**DEPARTMENT**



Many pioneers in the field of management namely Oliver, Sheldon, Gantt etc. limited the scope of production administration to planning and implementation

of work methods and in the opinion of many planning is the primary function of production administration and other functions like production control, progressing etc. comes into existence logically i.e. without planning, there cannot be any activity, no staff will be required and there will be no need of any control.

It is evident from above that in the absence of any clear cut idea about the activities, duties and responsibilities involved in production administration, the term appears to be misleading and confusing. There are different 'opinions about the phenomenon and the rapid industrial development in diversified fields, a single definition is not sufficient to explain the scope and meaning of production administration.

### **The Responsibilities of Production Manager**

In the present era of cut-throat competition at various stages of operations, an enterprise should produce goods and services keeping into consideration the requirements and satisfaction of the potential customer. The objective should be to produce good at least costs 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 organization production manager has to administer a great variety of activities. He assembles appropriate resources and direct the use of these resources, be they 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 organization 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 government regulations and behaviour of consumer and environmental 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 material at the right time. He should be able to do something real and constructive about production problems. He should be well conversant with the ways and means to attain the desired goals.

The nature of problems associated in production management are such that the Production Manager should have the capability as well as the aptitude to use qualitative and quantitative methods of analysis to get the desired solutions.

### **SELF-TEST QUESTIONS**

1. Define production. What do you understand by factors of production?
2. Give a brief history of the development of Production Management.
3. Define production management and discuss its scope.
4. “Production Management deals with decision making related to production processes so that the resulting goods or services are produced according to the specifications, in the amounts and by the schedules demanded and at a minimum cost”. Discuss.

## LESSON : 2

# TYPES OF PRODUCTION SYSTEMS AND PLANT LOCATION

### SYSTEM

A system is a logical arrangement of components designed to achieve particular objectives according to a plan. According to Webster, “System is a regularly interacting inter-dependent group of items forming a unified whole”. A system may have many components and variation 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. Production system is the framework within which the production activities of an organization are carried out. At one end of system are inputs and at the other end output. Input and output are linked by certain processes or operations or activities imparting value to the inputs. These processes, operations or activities may be called production systems. The nature of production system may differ from company to company or from plant to plant in the same firm.

### Elements of Production System

- (i) *Inputs* : Inputs are the physical and human resources utilised in the production process. They consist of raw materials, parts, capital equipments, human efforts etc.
- (ii) *Conversion Process* : It refers to a series of operations which are performed on materials and parts.

- (iii) *Outputs* : Outputs are the products or completed parts resulting from the conversion process. Output generates revenue.
- (iv) *Storage* : Storage take place after the receipt of inputs, between one operation and the other and after the output.
- (v) *Transportation* : Inputs are transported from one operation to another in the production process.
- (vi) *Information* : It provides system control through measurement, comparison, feedback, and corrective action.

### **Types of Production Systems**

There are two main types of production systems : (i) Continuous System (ii) Intermittent System

**i) Flow or Continuous System** : According to Buffa, “Continuous flow production situations are those where the facilities are standardised as to routings and flow since inputs are standardised. Therefore a standard set of processes and sequences of process can be adopted”. Thus continuous or flow production refers to the manufacturing of large quantities of a single or at most a very few varieties of products with a standard set of processes and sequences. The mass production is carried on continuously for stock in anticipation of demand.

*Characteristics* :

- (i) The volume of output is generally large (mass production) and goods are produced in anticipation of demand.
- (ii) The product design and the operations sequence are standardised i.e.

identical products are produced.

- (iii) Special purpose automatic machines are used to perform standardised operations.
- (iv) Machine capacities are balanced so that materials are fed at one end of the process and finished product is received at the other end.
- (v) Fixed path materials handling equipment is used due to the predetermined sequence of operations.
- (vi) Product layout designed according to a separate line for each product is considered.

*Merits*

- (i) The main advantage of continuous system is that work-in-progress inventory is minimum.
- (ii) The quality of output is kept uniform because each stage develops skill through repetition of work.
- (iii) Any delay at any stage is automatically detected.
- (iv) Handling of materials is reduced due to the set pattern of production line. Mostly the materials are handled through conveyer belts, roller conveyers, pipe lines, overhead cranes etc.
- (v) Control over materials, cost and output is simplified.
- (vi) The work can be done by semi-skilled workers because of their specialization.

*Demerits* : Continuous system, however, is very rigid and if there is a fault in one operation the entire process is disturbed. Due to continuous flow, it

becomes necessary to avoid piling up of work or any blockage on the line. Unless the fault is cleared immediately, it will force the preceding as well as the subsequent stages to be stopped. Moreover, it is essential to maintain stand-by equipments to meet any breakdowns resulting in production stoppages. Thus investments in machines are fairly high.

*Continuous production is of the following types :*

- (a) *Mass Production* : Mass production refers to the manufacturing of standardised parts or components on a large scale. Mass production system offers economies of scale as the volume of output is large. Quality of products tends to be uniform and high due to standardisation and mechanisation. In a properly designed and equipped process, individual expertise plays a less prominent role.
- (b) *Process Production* : Production is carried on continuously through a uniform and standardised sequence of operations. Highly sophisticated and automatic machines are used. Process production is employed in bulk processing of certain materials. The typical processing Industries are fertilizers plants, petrochemical plants and milk dairies which have highly automated systems and sophisticated controls. They are not labour-intensive and the worker is just an operator to monitor the system and take corrective steps if called for.

On the basis of the nature of production process, flow production may be classified into *Analytical and Synthetic Production*.

In *Analytical Process* of production, a raw material is broken into different products e.g. crude oil is analysed into gas, naphtha, petrol etc. Similarly, coal is processed to obtain coke, coal gas, coal tar etc.

*Synthetic Process* of production involves the mixing of two or more materials to manufacture a product for instance, lauric acid, myristic acid, stearic acid are synthesised to manufacture soap.

(c) *Assembly Lines* : Assembly line a type of flow production which is developed in the automobile industry in the USA. A manufacturing unit prefers to develop and employ assembly line because it helps to improve the efficiency of production. In an assembly line, each machine must directly receive material from the previous machine and pass it directly to the next machine. Machine and equipment should be arranged in such a manner that every operator has a free and safe access to each machine. Space should be provided for free movement of fork lifts, trucks etc. which deliver materials and collect finished products.

**(ii) Intermittent Production System**

According to Buffa, “Intermittent situations are those where the facilities must be flexible enough to handle a variety of products and sizes or where the basic nature of the activity imposes change of important characteristics of the input (e.g. change. in the product design). In instances such as these, no single sequence pattern of operations is appropriate, so the relative location of the operation must be a compromise that is best for all inputs considered together”. In the industries following the intermittent production system, some components may be made for inventory but they are combined differently for different customers. The finished product is heterogenous but within a range of standardized options assembled by the producers. Since production is partly for stock and partly for consumer demand, there are problems to be met in scheduling, forecasting, control and coordination.

*Characteristics* :

(i) The flow of production is intermittent, not continuous.



- (ii) The volume of production is generally small.
- (iii) A wide variety of products are produced.
- (iv) General purpose, machines and equipments are used so as to be adaptable to a wide variety of operations.
- (v) No single sequence of operations is used and periodical adjustments are made to suit different jobs or batches.
- (vi) Process layout is most suited.

Intermittent system is much more complex than continuous production because every product has to be treated differently under the constraint of limited resources. Intermittent system can be -effective in situations which satisfy the following conditions :

- (i) The production centres should be located in such a manner so that they can handle a wide range of inputs.
- (ii) Transportation facilities between production centres should be flexible enough to accommodate variety of routes for different inputs.
- (iii) It should be provided with necessary storage facility.

*Intermittent Production May be of two types :*

- (a) **Job Production** : Job or unit production involves the manufacturing of single complete unit with the use of a group of operators and process as per the customer's order. This is a 'special order' type of production. Each job or product is different from the other and no repetition is involved. The product is usually costly and non-standardised. Customers do not make demand for exactly the same product on a continuing basis

and therefore production becomes intermittent. Each product is a class by itself and constitutes a separate job for production process. Ship building, electric power plant, dam construction etc. are common examples of job production.

*Characteristics :*

- (i) The product manufactured is custom-made or non-standardised.
- (ii) Volume of output is generally small.
- (iii) Variable path materials handling equipment are used.
- (iv) A wide range of general purpose machines like grinders, drilling, press, shaper etc. is used.

*Merits :*

It is flexible and can be adopted easily to changes in product design. A fault in one operation does not result into complete stoppage of the process. Besides it is cost effective and time-effective since the nature of the operations in a group are similar. There is reduced material handling since machines are close in a cell. The waiting period between operations is also reduced. This also results in a reduced work-in-progress inventory.

*Demerits :*

Job shop manufacturing is the most complex system of production e.g. in building a ship thousands of individual parts must be fabricated and assembled. A complex schedule of activities is required to ensure smooth flow of work without any bottlenecks. Raw materials and work-in-progress inventories are high due to uneven and irregular flow of work. Work loads are unbalanced, speed of work is slow and unit costs are high.

(b) **Batch Production** : It is defined as “The manufacture of a product in small or large batches or lots at intervals by a series of operations, each operation being carried out on the whole batch before any subsequent operation is performed”. The batch production is a mixture of mass production and job production. Under it machines turn out different products at intervals, each product being produced for comparatively short time using mass production methods.

Both job production and batch production are similar in nature, except that in batch production the quantity of product manufactured is comparatively large.

*Demerits :*

Work-in-progress inventory is high and large storage space is required. Due to frequent changes in product design no standard sequence of operation can be used. Machine set-ups and tooling arrangements have to be changed frequently. The main problem in batch production is the idle time between one operation and the other. The work has to wait until a particular operation is carried out on the whole batch.

### **Comparison of Different Production Systems**

As we have discussed various systems and sub-systems in detail in the above lines, we can now make a comparative study of them as follows :

(i) **Manufacturing Cost** : Cost of production per unit is lowest in process production while it is highest in job production because large scale continuous production is carried out under process production. Unit cost in mass production is higher than the process production while it is lower than the batch production or job production.

(ii) *Size and Capital Investment* : As stated earlier, the scale of operation is small in job production, medium in batch production, large in mass production and very large in process production. Hence the size of capital investment differs from system to system. Process production calls for the higher investment while mass production requires lesser amount of capital investment. It is lower in case of job production and comparatively higher in batch production.

(iii) *Flexibility in Production* : In case of change in demand of the product, the production facilities may be adjusted very shortly without increasing much expenses under the system of job or batch production. But both the sub-systems of continuous production system i.e., mass production or process production employ single purpose machine in their manufacturing processes. They cannot adjust their production facilities so quickly and easily as is possible in job or batch production where general purpose machines are used.

(iv) *Required Technical Ability* : Both job and batch production require high skilled technical foreman and other executives. But under mass production for process production systems, managerial ability plays an important role because it require higher ability for planning and coordinating several functions in mass and process production than in the case of job and batch production.

(v) *Organisational Structure* : Mostly functional organisation is adopted in case of job and batch production systems. On the other hand, divisional organisation is preferred in mass and product process production systems due to the greater emphasis for centralisation.

(vi) *Job Security* : Job and batch systems of production do not provide and type of job security to workers due to their intermittent character. During odd times, workers particularly unskilled workers are thrown out of job. On the

contrary, mass and process production systems provide greater job security to workers because production operations are carried out continuously in anticipation of stable and continuous demand of the product.

(vii) *Industrial Application* : The application of different systems is suitable in different industries depending upon the nature of work. The mechanism of job production applies in products of construction and manufacturing industries like buildings, bridges, special purpose machines etc. Batch production is mostly used in mechanical engineering and consumer-goods industries like cotton, jute, machine tools, shoe-making etc. Mass production is found in automobiles, sugar refining, refrigerators, electrical goods etc. Process production is most appropriate in chemical, petroleum, milk processing industries etc.

Thus, a comparative view of the different systems of production reveals that no one system is suitable for all types of industries and therefore each system is different in itself and must be studied with reference to the nature of industry.

## **PLANT LOCATION**

*Plant* : A plant is a place, where men, materials, money, machinery etc. are brought together for manufacturing products. The objective of minimisation of cost of production can be achieved only when the plant is of the right size and at a right place where economies of all kinds in production are available. The planning for 'where' to locate the operations facilities should start from 'what' are organization's objectives, priorities, goals and the strategies required to achieve the same in the general socio-economic-techno-business-legal environment currently available and expected to be available in the long-term future. Unless the objectives and priorities of an organization are clear i.e. the general direction is clear, effective functional or composite strategies cannot be designed. And, it is these strategies of which the location design is a product.

## **Different Situations for Plant Location Decision**

- (i) ***To select a proper geographic region*** : The organizational objectives alongwith the various long-term considerations about marketing, technology, internal organizational strengths and weaknesses, region specific resources and business environment, legal-governmental environment, social environment and geographical environment suggest a suitable region for locating the operations facility.
- (ii) ***Selecting a specific site within the region*** : Once the suitable region is identified, the next problem is that of choosing the best site from an available set. Choice of a site is much less dependent on the organization's long-term strategies. It is more a question of evaluating alternative sites for their tangible and intangible costs if the operations were located there. Cost economies now figure prominently at this final stage of facilities-location problem.
- (iii) ***Location choice for the first time*** : In this case, there is no prevailing strategy to which one needs to confirm. However, the organizational strategies have to be first decided upon before embarking upon the choice of the location of the operating facility/facilities. The importance of the long-term strategies can not be over emphasized. Cost economics are always important but not at the cost of long-term business/organizational objectives.
- (iv) ***Location choice for an ongoing organization*** : A new plant has to fit into multi-plant operations strategy as discussed below :

  - (a) ***Plant Manufacturing Distinct Products or Product Lines***

This strategy is necessary where the needs of technological and resource inputs

are specialized for distinctively different for the different products/product-lines. For example, a high quality precision product-line should preferably not be located along with other product-line requiring little emphasis on precision. It may not be proper to have too many contradictions such as sophisticated and old equipment, highly skilled and not so skilled personnel, delicate processes and those that could permit rough handling, all under one roof and one set of managers. Such a setting leads to much confusion regarding the required emphasis and the management policies. Product specialization may be necessary in a highly competitive market; it may also be necessary in order to fully exploit the special resource potential of a particular geographical area. Instances of product specialization could be many : A watch manufacturing unit and a machine tools unit; a textile unit and a sophisticated organic chemical unit; an injectible pharmaceuticals unit and a consumer products unit; etc. All these pairs have to be distinctively different-in technological sophistication, in process, and in the relative stress on certain aspects of management. The more decentralised these pairs are in terms of the management and in terms of their physical location, the better would be the planning and control and the utilization of the resources.

*(b) Manufacturing Plants Each supplying to a Specific Market Area*

Here, each plant manufactures almost all of the company's product. This type of strategy is useful where market proximity consideration dominates the resources and technology considerations. This strategy requires a great deal of coordination from the corporate office. An extreme example of this strategy is that of soft-drinks bottling plants.

*(c) Manufacturing Plants Divided According to the Product/Product Line being Manufactured; and these Special-Product Plants Located in Various Market Areas.*

(d) *Plants Divided on the Basic of the Processes or Stages in Manufacturing*

Each production process or stage of manufacturing may require distinctively different equipment capabilities, labour skills, technologies, and managerial policies and emphasis. Since the products of one plant feed into the other plant, this strategy requires much centralized coordination of the manufacturing activities from the corporate office who are expected to understand the various technological and resources nuances of all the plants. Sometimes such a strategy is used because of the defence/national security considerations. For instance, the Ordnance Factories in India.

(e) *Plants Emphasizing Flexibility in Adapting to Constantly Changing Product Needs*

This needs much coordination between plants to meet the changing needs and at the same time ensure efficient use of the facilities and resources. The new plant or branch-facility has to fit into the organization's existing strategy, mainly because the latter has been the product of deep thinking about the long-term prospects and problems, and strengths and weaknesses for the organization as a whole.

**Factors Affecting Plant Location Decisions**

Hardly there is any location which can be ideal or perfect. One has to strike a balance between various factors affecting plant location. Some factors are crucial in deciding the location of the plant while some other factors are less important. In taking the decision of location of plant, due regard should be given to minimisation of cost of production & distribution and maximisation of profit. The decision of plant location should be based on nine M's, namely money, material, manpower, market, motive power, management, machinery, means of communication and momentum to an early start. The following are



some of the important factors which the management must carefully bear in mind in selecting an optimum site for the plant :

- (i) *Nearness to Raw Material* : It will reduce the cost of transporting raw material from the vendor's end to the plant. Especially those plants which consume raw material in bulk, or raw material is heavy weight, must be located close to the source of raw material. If the raw materials are perishable, the plant is to be located near the source of material. This is true of fruit canning industry. Sugar and paper and other industries using weight losing materials are also located near point of supply. Industries which depend for their raw materials on other industries tend to be located near such industries e.g. the petrochemicals industries are located near refineries. Similarly, Thermal Power Stations are situated near coal mines. In case the raw material are imported, the unit must be established near the port.

When a company uses a number of raw materials and their sources are at different location, the ideal site for the plant shall be a place where the transportation costs of various raw materials are the minimum.

Apart from these considerations, a promoter must view the supply of raw materials from the following angles also :

- (a) If supply of raw materials is linked with finance, it must be set up where the raw material is available at reduced or concessional rates.
  - (b) Reliability and continuity of the source of supply, and
  - (c) The security of means of transport.
- (ii) *Nearness to Markets* : It reduces the cost of transportation as well as the chances of the finished products getting damaged and spoiled in the way. Moreover a plant being near to the market can catch a big share

of the market and can render quick service to the customers. Industries producing perishable or fragile commodities are also attracted towards the market because of savings in time and transportation costs. Industrial units have a tendency to disperse if they find a new market for their products.

- (iii) *Availability of Labour* : Stable labour force, of right kind, of adequate size (number) and at reasonable rates with its proper attitude towards work are a few factors which govern plant location to a major extent. The purpose of the management is to face less bycotts, strikes or lockouts and to achieve lower labour cost per unit of production.
- (iv) *Availability of Fuel and Power* : Because of the wide spread of electric power, in most cases fuel (coal, oil etc.) has not remained a deciding factors for plant location. It is of course essential that electric power should remain available continuously, in proper quantity and at reasonable rates.
- (v) *Availability of Water* : Water is used for processing, as in paper and chemical industries, and is also required for drinking and sanitary purposes. Depending upon the nature of the plant, water should be available in adequate quantity and should be of proper quality (clean and pure). A chemical, fertilizer, thermal power station etc. should not be set-up at a location which IS famous for water shortage.
- (vi) *Climatic Conditions* : Climate conditions also influence the location decision. Some industries need special type of climate to run the unit effectively. For example, cotton industry requires a humid climate and therefore it is mainly localised at Bombay, Ahmedabad, etc. But the scientific development and new inventions have lowered down the

importance of the factor. So due to the development of artificial humidification, cotton textile industry can now be started in any region of the county. The question of climate is more important for agricultural product like tea, coffee, rubber, cotton etc. even today.

- (vii) *Government Policy* : Certain states give aid as loans, machinery, built up sheds etc. to attract industrialists. In planned economy, Government plays an important role on the location of industry. In India Government follows the policy of balanced regional growth of the country which is very important from the point of view of defence and social problems like slum, disparity of income & wealth and optimum use of resources. In order to implement this policy, Government offers several incentives to entrepreneurs to locate their industrial units in backward regions or no-industry regions. It offers tax concessions or loan facilities or factory sheds at cheaper rates. Sometimes Government announces certain disincentives to industries located at a certain place. Thus Government policy plays an important role in the location of industry.
- (viii) *Land* : The shape of the site, cost, drainage, the probability of floods, earthquakes (from the past history) etc. influence the selection of plant location.
- (ix) *Community Attitude* : Success of Industry depends very much on the attitude of local people and whether they want to work or not.
- (x) *Security* : Considerations like law and order situation, political stability and safety also influence the location decision. No entrepreneur will like to start the industry at a place which is not safe and where there are law and order disturbances off and on.

- (xi) *Transport Facilities* : A lot of money is spent both in transporting the raw material and the finished goods. Depending upon the size of raw material and finished goods, a suitable method of transportation like roads, rail, water or air is selected and accordingly the plant location is decided. Transportation costs depend mainly on the weight carried and the distance to be covered. In some industries, weight of the raw material is much higher than that of finished product. e.g. in a weight losing industry like sugar manufacturing four to five tons of sugarcanes have to be carried per ton of sugar. Similarly in Iron and Steel Industry two tons of iron is required to produce one ton of pig iron. Therefore the transport costs can be saved by locating near the source of materials. In case of weight gaining industry, location near the market may result in savings in transportation costs. e.g. in soft drink the weight of finished product is higher than raw material.
- (xii) *Momentum of an early start* : Another factor of some importance has been the momentum of an early start. Some places got localised only because one or two units of that industry started production there. With the passage of time, these places gained importance and attracted other units of the industry. As a place gains importance, certain facilities usually beg in to develop. For example, (i) transport facilities are developed because railways and other agencies find it economical to serve that centres, (ii) specialised firms start to take up repair and maintenance job for such units, (iii) banking facilities are made available and (iv) labour possessing various skills are attracted there. These facilities further attract more industries.
- (xiii) *Personal Factors* : Personal preferences and prejudices of an entrepreneur also play an important role in the choice of location.

Economic consideration do not weight much. For instance, Mr. Ford started cars manufacturing motor in Detroit because it was his home town. It must however, be recognized that such location cannot endure unless they prove to be economical enough in the long run.

- (xiv) *Communication Facilities* : Every business firm requires every type of business information regarding the position of labour, market, raw materials and finished goods and this facility is available only when communication facilities are there. As communications facilities are not adequately available in rural areas, industries are very much reluctant to start their business there.
- (xv) *Other Considerations* : There are certain other considerations that influence the location decisions which are :
  - (a) Presence of related Industry
  - (b) Existence of hospitals, marketing centres, schools, banks, post office, clubs etc.
  - (c) Local bye-laws, taxes, building ordinances etc.
  - (d) Facility for expansion
  - (e) New enterprise owned or operated by a single group of companies should be so located that its work can be integrated with the work of the associated establishments.
  - (f) Industries like nuclear power stations, processes explosive in nature, chemical process likely to pollute the atmosphere should be located in remote areas.
  - (g) Historical factors etc.

## **SELF-TEST QUESTIONS**

1. What are the important types of production systems? Explain.
2. Make a comparative study of different types of production systems.
3. What factors affect the choice of a suitable place for the location of a plant?
4. Discuss the importance of facilities location decision in operations planning.
5. Why are some industries located near the source of raw materials, whereas some other industries are located near the markets for their finished goods?

## **LESSON : 3**

### **PLANT LAYOUT**

#### **MEANING OF PLANT LAYOUT**

Plant layout means the disposition of the various facilities (equipments, materials, manpower etc.) within the area of the site selected. Plant layout begins with the design of the factory building and goes up to the location and movement of work. All the facilities like equipments, raw materials, machinery, tools, fixtures, workers etc. are given a proper place. In the words of James Lundy, “It identically involves the allocation of space and the arrangement of equipment in such a manner that overall costs are minimised”. According to Mo Naughton Waynel, “A good layout results in comforts, convenience, appearance, safety and profits. A poor layout results in congestion, waste, frustration and inefficiency”.

Plant layout is very complex in nature as it involves concepts relating to such fields as engineering, architecture, economics and business administration. Since a plant layout, when properly designed, encompasses all production’ and service facilities and provides for the most effective utilization of men, with materials and machines constituting the process, is a master blue print for coordinating all operations.

#### **Objective of a Good Plant Layout**

The principal objective of a proper plant layout is to maximize the production at the minimum of the costs. This objective should be kept in mind while

designing a layout for a new plant as well as while making the necessary changes in the existing layout in response to changes in management policies and processes and techniques of production. Besides, it must satisfy the needs of all people associated with the production system, i.e. workers, supervisors and managers.

If a layout is to fulfil this goal, it should be planned with the following clear objectives in mind :

- i) There is the proper utilization of cubic space (Le. length, width and height). Maximum use of volume available should be made. For example, conveyors can be run above head height and used as moving work in progress or tools and equipments can be suspended from the ceiling. The principle is particularly true in stores where goods can be stored at considerable heights without inconvenience.
- ii) Waiting time of the semi-finished products is minimised.
- iii) Working conditions are safer, better (well ventilated rooms etc.) and improved.
- iv) Material handling and transportation is minimised and efficiently controlled. For this, one has to consider the movement distances between different work areas as well as the number of times such movements occur per unit period of time.
- v) The movements made by the workers are minimised.
- vi) Suitable spaces are allocated to production centres.



- vii) Plant maintenance is simpler.
- viii) There is increased flexibility for changes in product design and for future expansion. It must be capable of incorporating, without major changes, new equipment to meet technological requirements or to eliminate waste.
- ix) A good layout permits materials to move through the plant at the desired speed with the lowest cost.
- x) There is increased productivity and better product quality with reduced capital cost.
- xi) Boosting up employee morale by providing employee comforts and satisfaction.
- xii) The workers should be so arranged that there is no difficulty in supervision, coordination and control. There should be no 'hiding-places' into which goods can be mislaid. Goods – raw materials and ready stocks – must be readily observable at all times. It will reduce the pilferage of material and labour.

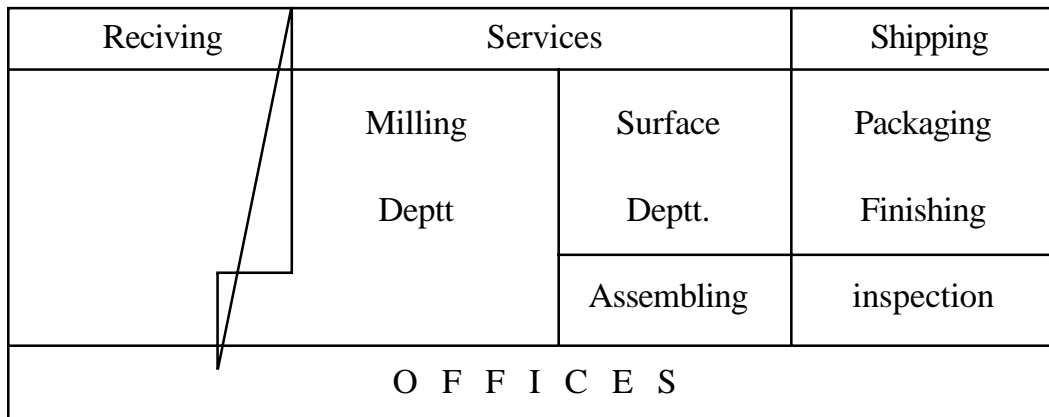
It should be noted here that the above stated objectives of plant layout are laudable in themselves, it is often difficult to reconcile all of them in a practical situation. And as such, the highest level of skill and judgement are required to be exercised. For this, close association between the entrepreneurs and experienced engineers is a must.

### **Types of Plant Layout**

There are three basic types of plant layout : (i) Functional or process layout,

(ii) product or line layout, (iii) stationary layout. However the choice of one or the other type of layout depends upon the machines and techniques used in the production.

(a) *Process Layout* : It is also known as functional layout and is characterised by keeping similar machines or similar operations at one location (place). In other words, separate departments are established for each specialised operation of production and machines relating to that functions are assembled there. For example, all lathe machines will be at one place, all milling machines at another and so on. This type of layout is generally employed for industries engaged in job order production and non-standardised products. The process layout may be illustrated in the diagram given below :



*Advantages :*

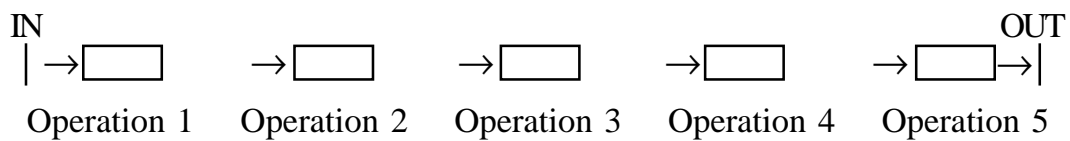
i) Wide flexibility exists as regards allotment of work to equipments and workers. The production capacity is not arranged in rigid sequence and fixed rate capacity with line balancing. Alteration or change in sequence of operations can easily be made as and when required without upsetting the existing plant layout plan.

- ii) Better quality product, because the supervisors and workers attend to one type of machines and operations.
- iii) Variety of jobs, coming as different job orders make the work more interesting for workers.
- iv) Workers in one section are not affected by the nature of operations carried out in another section. e.g. a lathe operator is not affected by the rays of welding as the two sections are quite separate.
- v) Like product layout, the breakdown of one machine does not interrupt the entire production flow.
- vi) This type of layout requires lesser financial investment in machines and equipment because general purpose machines, which are usually of low costs, are used and duplication of machine is avoided. Moreover, general purpose machines do not depreciate or become obsolete as rapidly as specialised machines. It results in lower investment in machines.
- vii) Under process layout, better and efficient supervision is possible because of specialisation in operation.

*Disadvantages :*

- i) Automatic material handling is extremely difficult because fixed material handling equipment like conveyor belt cannot be possible to use.
- ii) Completion of same product takes more time.
- iii) Raw material has to travel larger distances for getting processed to finished goods. This increases material handling and the associated costs.

- iv) It is not possible to implement the group incentive schemes on the basis of quantity of the products manufacturing.
  - v) This type of layout requires more floor space than the product layout because a distinct department established for each operation.
  - (vi) Compared to line layout inventory investments are usually higher in case of process layout. It increases the need of working capital in the form of inventory.
  - (vii) Under process layout, cost of supervision is high because (i) the number of employees per supervisor is less that result in reduced supervisory span of control, and (ii) the work is checked after each operation.
- (b) **Product Layout :** It is also known as line (type) layout. It implies that various operations on a product are performed in a sequence and the machines are placed along the product flow line i.e. machines are arranged in the sequence in which a given product will be operated upon. This type of layout is preferred for continuous production i.e. involving a continuous flow of in-process material towards the finished product stage. The fig. given below shows a product type of layout :



*Advantages :*

- i) Automatic material handling, lesser material handling movements, time and cost.
- ii) Product completes in lesser time. Since materials are fed at one end of the layout and finished product is collected at the other end, there is no transportation of raw materials backward and forward. It shortens the manufacturing time because it does not require any time consuming interval transportation till the completion of the process of production. Line balancing may eliminate idle capacity.
- iii) Smooth and continuous flow of work. This plan ensures steady flow of production with economy because bottlenecks or stoppage of work at different points of production is got eliminated or avoided due to proper arrangement of machines in sequence.
- iv) Less in-process Inventory. The semi-finished product or work-in-progress is the minimum and negligible under this type of layout because the process of production is direct and uninterrupted.
- v) Effective quality control with reduced inspection points. It does not require frequent changes in machine set-up. Since production process is integrated and continuous, defective practice can easily be discovered and segregated. This makes inspection easy and economical.
- vi) Maximum use of space due to straight production flow and reduced need of interim storing.

*Disadvantages :*

- i) Since the specific product determines the layout, a change in product involves major changes in layout and thus the layout flexibility is considerably reduced.
- ii) The pace or rate of working depends upon the output rate of the slowest machine. This involves excessive idle time for other machines if the production line is not adequately balanced.
- iii) Machines being scattered along the line, more machines of each type have to be purchased for helping a few as stand by, because if one machine in the line fails, it may lead to shut down of the complete production line.
- iv) It is difficult to increase production beyond the capacities of the production lines.
- v) As the entire production is the result of the joint efforts of all operations in the line, it is difficult to implement individual incentive schemes.
- vi) Since there are no separate departments for various types of work, supervision is also difficult.
- vii) Under this system, labour cost is high because (a) absenteeism may create certain problems because every worker is specialist in his own work or he specialises on a particular machine. In order to avoid the bottleneck, surplus workers who are generalists and can be fitted on a number of machines will have to be employed; (b) monotony is another problem with the workers. By doing the work of repetitive nature along assembly line, they feel bore (c) as machines play the dominant role

in production under this system, workers have no opportunity to demonstrate their talent; (d) noise, vibrations, temperature, moisture, gas etc. may cause health hazards. In this way, labour costs are high.

It is now quite clear from the above discussion that both the systems have their own merits and demerits. Advantages of one type of layout are generally the disadvantages of other type. Thus with a view to securing the advantage of both the systems a combined layout may be designed.

**(c) Static Product Layout or Project Layout or Stationary Layout**

The manufacturing operations require the movements of men, machines, and materials, in the product layout and process layout generally the machines are fixed installations and the operators are static in terms of their specified work stations. It is only the materials which move from operation to operation for the purpose of processing. But where the product is large in size and heavy in weight, it tends to be static e.g. ship building. In such a production system, the product remains static and men and machines move performing the operations on the product.

**Advantages of stationary Layout :** The advantages of this type of layout are as under :

1. *Flexible* : This layout is fully flexible and is capable of absorbing any sort of change in product and process. The project can be completed according to the needs of the customers and as per their specification.
2. *Lower labour cost* : People are drawn from functional departments. They move back to their respective departments as soon as the work is over. This is economical, if a number of orders are at hand and each

one is in a different stage of progress. Besides, one or two workers can be assigned to a project from start to finish. Thus it reduces labour cost.

3. *Saving in time* : The sequence of operations can be changed if some materials do not arrive or if some people are absent. Since the job assignment is so long, different sets of people operate simultaneously on the same assignment doing different operations.
4. *Other benefits* : (i) It requires less floor space because machines and equipment are in moving position and there is no need of fixing them.  
(ii) This arrangement is most suitable way of assembling large and heavy products.

**Disadvantages of stationary layout** : The disadvantages of this type of layout are :

- (i) *Higher capital investment* : Compared to product or process layout, capital investment is higher in this type of layout. Since a number of assignments are taken, investment in materials, men and machines is made at a higher cost.
- (ii) *Unsuitability* : This type of layout is not suitable for manufacturing or assembling small products in large quantities. It is suitable only in case where the product is big or the assembling process is complex.

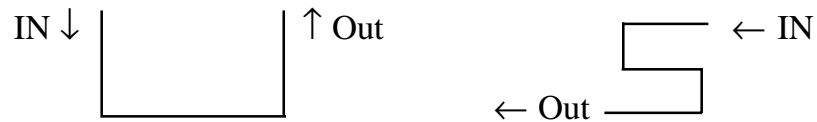
### **Factors influencing Plant Layout**

The following are some important factors which influence the planning of effective layout to a significant degree.



1. *Nature of the product* : The nature of product to be manufactured will significantly affect the layout of the plant. Stationary layout will be most suitable for heavy products while line layout will be best for the manufacture of light products because small and light products can be moved from one machine to another very easily and, therefore, more attention can be paid to machine locations and handling of materials.
2. *Volume of Production* : Volume of production and the standardisation of the product also affect the type of layout. If standardised commodities are to be manufactured on large scale, line type of layout may be adopted. If production is made on the order of the customers, the functional layout is better to be adopted.
3. *Basic managerial policies and decisions* : The type of layout depends very much on the decisions and policies of the management to be followed in producing a commodity with regard to size of plant , kind and quality of the product; scope for expansion to be provided for, the extent to which the plant is to be integrated, amount of stocks to be carried at any time, the kind of employee facilities to be provided etc.
4. *Nature of plant location* : The size, shape and topography of the site at which plant is located will naturally affect the type of layout to be followed in view of the maximum utilisation of space available. For example, if a site is near the railway line the arrangement of general layout for receiving and shipping and for the best flow of production in and out the plant may be made by the side of railway line. If space is narrow and the production process is lengthy, the layout of plant may

be arranged on the land surface in the following manner :



5. *Type of industry process* : This is one of the most important factors influencing the choice of type of plant layout. Generally the types of layout particularly the arrangement of machines and work centres and the location of workmen varies according to the nature of the industry to which the plant belongs. For the purpose of layout, industry may be classified into two broad categories :

(i) intermittent and (ii) continuous. Intermittent type of industries are those which manufacture different components or different machines. Such industries may manufacture the parts, when required according to the market needs. Examples of such industries are shipbuilding plants. In this type of industry functional layout may be the best. The second type of industry is 'continuous' industry. In this type of industry raw materials are fed at one end and the finished goods are received at another end. A continuous industry may either be analytical or synthetic. As analytical industry breaks up the raw material into several parts during the course of production process or changes its form, e.g. oil and sugar refineries. A synthetic industry, on the other hand mixes the two or more materials to manufacture one product alongwith the process of production or assembles several parts to get finished product. Cement and automobile industries are examples of such industry. Line layout is more suitable in continuous process industries.

6. *Types of methods of production* : Layout plans may be different according to the method of production proposed to be adopted. Any of the following three methods may be adopted for production – (i) Job order production, (ii) batch production, and (iii) Mass Production. Under job production goods are produced according to the orders of the customers and therefore, specifications vary from customer to customer and the production cannot be standardised. The machines and equipment can be arranged in a manner to suit the need of all types of customers. Batch production carries the production of goods in batches or groups at intervals. In this type of manufacturing the product is standardised and production is made generally in anticipation of sales. In such cases functional or process layout may be adopted. In case of mass production of standardised goods, line layout is most suitable form of plant layout.
7. *Nature of machines* : Nature of machines and equipment also affects the layout of plant. If machines are heavy in weight or creates noisy atmosphere, stationary layout may reasonably be adopted. Heavy machines are generally fixed on the ground floor. Ample space should be provided for complicated machines to avoid accidents.
8. *Climate* : Sometimes, temperature, illumination and air are the deciding factors in deciding the location of machines and their establishments. For example, in lantern manufacturing industry, the spray painting room is built along the factory wall to ensure the required temperature control and air expulsion and then the process of spray painting may be undertaken.
9. *Nature of Materials* : Design and specifications of materials, physical and chemical properties of materials, quantity and quality of materials

and combination of materials are probably the most important factors to be considered in planning a layout. So, materials storage and materials handling should be given due consideration. For materials storage factors such as rate of consumption of raw materials, space, volume and weight of raw materials, floor load capacity, ceiling height method of storing should be given special consideration. This will affect the space and the efficiency of the production process in the plant. It will facilitate economic production goods and prompt materials flow and a soundly conceived materials handling system.

10. *Type of machine and equipment* : Machines and equipment may be either general purpose or special purpose. In addition certain tools are used. The requirements of each machine and equipment are quite different in terms of their space, speed and material handling process and these factors should be given proper consideration while choosing out a particular type of layout. It should also be considered that each machine and equipment is used to its fullest capacity because machines involve a huge investment. For instance, under product layout, certain machines may not be used to their full capacity so care should be taken to make full use of the capacity of the machine and equipment.
11. *Human factor and working conditions* : Man is the most important factor of production and therefore special consideration for their safety and comforts should be given while planning a layout, specific safety items like obstruction-free floor, workers not exposed to hazards, exit etc. should be provided for. The layout should also provide for the comforts to the workers such as provision of rest rooms, drinking water, lavatory and other services etc. Sufficient space is also to be provided

for free movement of workers. For this, provisions of Factories Act should be followed strictly.

12. *Characteristics of the building* : Shape of building, covered and open area, number of storeys, facilities of elevators; parking area, storing place and so on also influence the layout plan. In most of the cases where building is hired, layout is to be adjusted within the space available in the building. Although minor modifications may be done to suit the needs of the plant and equipment. But if new building is to be constructed, proper care should be given to construct it according to the layout plan drawn by experts. Special type of construction is needed to accommodate huge or technical or complex or sophisticated machines and equipment.

It is clear from the above description that several factors are considered while choosing out a plan for plant layout because they affect the production and its cost to a great extent.

### **Costs Associated With Plant Layout**

The costs associated with a decision on plant layout are :

- (i) Cost of movement of materials from one work area to another.
- (ii) Cost of space.
- (iii) Cost of production delay, if any, which are indirect costs.
- (iv) Cost of spoilage of materials, if any, when the materials are stacked or stored in conditions which deteriorate the quality of the material.
- (v) Cost of labour dissatisfaction and health risks.

- (vi) Cost of changes required, if the operational conditions change in the future. This is a long-term cost.

A good layout should minimize all these costs put together.

### **Techniques of Plant Layout**

In designing or improving the plan of plant layout, certain techniques or tools are developed and are in common use today. The techniques or tools are as follows :

- i) Charts and Diagrams* : In order to achieve work simplification, production engineers make use of several charts and diagrams for summarising and analysing production process and procedures. These include :
  - (a) Operation Process chart* : It subdivides the process into its separate operations and inspections. When a variety of parts and products are manufactured which follow different parts across several floor areas, an operation process chart may be necessary for the important material items or products. The flow lines on the chart indicate the sequence of all operations in the manufacturing cycle.
  - (b) Flow process chart* : This chart is a graphic summary of all the activities taking place on the production floor of an existing plant. By preparing this type of a chart, it can be found out as to where operations can be eliminated, rearranged, combined, simplified or sub-divided for greater economy. This chart will also identify inflexible processes which cannot be adapted to the output of redesigned models or related outputs.

- (c) *Process flow diagram* : The diagram is both supplement and substitute of process flow chart. It helps in tracing the movement of material on a floor plan or layout drawing. A diagram may be drawn to scale on the original floor plan to show the movement of work. It is a good technique to show long material hauls and backtracking of present layouts, thereby indicating how the present layout may be improved. The flow of several standard products can be shown by coloured lines.

This diagram can be used to analyse the effectiveness of the arrangement of plant activities, the location of specific machines, and the allocation of space. It shows how a more logical arrangement and economical flow of work can be devised.

- (2) *Machine data card* : This card provides full information necessary for the placement and layout of equipment. The cards are prepared separately for each machines. The information generally given on these cards include facts about the machine such as capacity of the machine, space occupied, power requirements, handling devices required and dimensions.
- (3) *Templates* : Template is the drawing of a machine or tool cut out from the sheet of paper. The area occupied by a machine is shown by cutting to scale. The plant layout engineer prepares a floor plan on the basis of relevant information made available to him. Templates representing machines, tools, conveyors, furnaces, ovens, inspection stations, tanks, storages, bins, trucks etc. are then laid out on the floor plan according to the sequence or groupings indicated on the operation process chart and the overall layout plan prepared by the engineers and helps in trying out at possible alternative arrangements. The template technique is an

important technique because : (i) It eliminates unnecessary handlings, (ii) Minimised backtracking of materials, (iii) It make the mechanical handling possible, (iv) It provides a visual picture of the proposed or existing plan of layout at one place, (v) It offer flexibility to meet future changes in production requirements.

- (4) *Scale models* : Though two-dimensional templates are now in extensive use in the field of layout engineering but it is not of much use to executives who cannot understand and manipulate them. One important drawback of template technique is that it leaves the volume, depth, height and clearances of machines to imagination of the reader of the drawing. These drawbacks of template technique have been removed through the development of miniature scale models of machinery and equipment cast in metal.

With scale models, it has now become possible to move tiny figures of men and machines around in miniature factors. The miniature machines and models of material handling equipment are placed in a miniature plant and moved about like pawn on a chessboard.

- (5) *Layout drawings* : Completed layouts are generally represented by drawings of the plant showing walls columns, stairways, machines and other equipment, storage areas and office areas.

The above techniques and tools are used for the planning of layout for the new plant.

### **Construction of Plant Building**

For effective and efficient operation of the plant, design of the building is one of the main considerations. The building housing the plant should be designed



in such a way that it can meet the requirements of the concern's operations and its layout. According to James Lundy, "An ideal plant building is one which is built to house the most efficient layout that can be provided for the process involved, yet which is architecturally ultra active and of such a standard shape and design as most flexible in its use and expensive units construction."

The layout may be said to be efficient if it is housed in a building that ensures comfort and health of workers engaged on the plant with reference to heat, light, humidity, circulation of air etc. and on the other hand, it protects the plant and equipment and materials from weather.

There are several factors which are to be considered in constructing a new building for housing the plant. These are :

- (i) *Adaptability* : The building structure should be adaptable fully to the needs and requirements of the plant. In the beginning, most of the enterprises carry their business in rented building which is generally not suitable to the needs and special requirements of the industries with the obvious reason that landlord constructs the building to suit average conditions of a manufacturing unit and they cannot be persuaded to make the necessary changes affecting the flexibility. As to the degree of adaptability, it may be needed that buildings are more easily adapted to fit the needs of the continuous process than to those of any other.
- (ii) *Provision for additions and extensions* : In designing and constructing a new factory building, care must be taken to provide for additions and extensions which may arise to meet the necessary and peculiar needs in due course of time. There must be every possibility to add new units without disturbing the existing manufacturing system. Kimball and

Kimball has rightly suggested that “an ideal building plan is one built on some ‘unit’ system like a sectional book case, so that additional units can be added at any time without disturbing the manufacturing system and organisation”. As a general rule extension can be made most conveniently at right angles to the direction of flow of work.

- (iii) *Number of storeys* : Another important decision while designing new plant building is to consider the number of storeys to be built, Le., whether the building should be single-storeyed or multi-storeyed. The choice between single and multi-storeys depends obviously on various factors such as nature of the product, proposed layout, value of land, the cost of construction. Before taking a decision regarding number of storeys, the management should bear in mind the comparative advantages and disadvantages of one storey and many storeys.

### **SELF -TEST QUESTIONS**

1. What is plant layout? What are the objectives which management desires to attain through the efficient plant layout?
2. What are the different types of plant layout? What are the advantages and disadvantages of each type of layout?
3. What are the factors that are borne in mind while deciding upon plant layout?
4. Write short notes on the following :
  - (a) Techniques of plant layout.
  - (b) Factors affecting construction of plant building.

## **LESSON : 4**

### **PRODUCTION PLANNING AND CONTROL**

Planning and control are basic managerial functions which are essential to every organized activity. Proper planning and control of manufacturing activities or the production system is equally essential for efficient and economical production. Economy and productivity are to a large extent directly proportional to the thoroughness with which the planning and control functions are performed. In a modern industrial enterprise, production is a complex system and steps must be taken to ensure that goods are produced in the right quantity and quality, at the right time and place and by the most efficient methods possible. This is the task of production planning and control.

#### **PRODUCTION PLANNING**

Production planning is concerned with deciding in advance what is to be produced, when to be produced, where to be produced and how to be produced. It involves foreseeing every step in the process of production so as to avoid all difficulties and inefficiency in the operation of the plant. Production planning has been defined as the technique of forecasting or picturing ahead every step in a long series of separate operations, each step to be taken in the right place, of the right degree, and at the right time, and each operation to be done at maximum efficiency. In other words, production planning involves looking ahead, anticipating bottlenecks and identifying the steps necessary to ensure smooth and uninterrupted flow of production. It determines the requirements for materials, machinery and man-power; establishes the exact sequence of operations for each individual item and lays down the time schedule for its completion.

## Objectives of Production Planning

The basic objectives of production planning are as under :

- (i) On the basis of the sales forecast and its engineering analysis, to estimate the kind of the resources like men, materials, machines, methods etc. in proper quantities and qualities. It also estimates when and where these resources will be required so that the production of the desired goods is made most economically.
- (ii) It also aims to make all necessary arrangement so that the production targets as set in the production budget and master schedules are reached. While attaining these targets, adjustments are made for the fluctuations in the demand.

For an effective planning of production activities, the executives concerned must have complete information regarding the following :

- (i) *Engineering data* including complete analysis of the product to be manufactured, the operations, processes and methods through which each component or class of product must pass the nature of inspection required, and the method of assembly.
- (ii) *Machine analysis* giving full information regarding speeds of all available machines and their maximum capacity to perform certain operations, and the rate of output per day, week or month, and the maximum plant capacity per day for each process or operation.
- (iii) The various types and classes of *tools and equipment* required of production.
- (iv) *Material analysis* giving full information as to the type, quality and quantity of the raw material to be used in each process or operation.

Also, information as to raw materials in stores, how much are on order, and how much are located or reserved for current orders.

- (v) *The characteristics of each job* and the degree of skill and personnel if qualifications required for the effective performance of each such job.
- (vi) *Information relating to power production* and consumption, internal transport and material handling service.
- (vii) *Job analysis giving* information as to what methods of operation would yield uniformity of output, ease in production and reduction in costs.
- (viii) *Information as to the customers' orders* on hand and the delivery for customers, and what for stock purposes.

It is the job of the production planning department to arrange for the order in which the work will be run, the routing and scheduling of work, and determine what machines, tools, workplaces materials and operatives should do the work.

A balanced production planning would tend to increase operating efficiency by stabilizing productive activities, facilitate selling and customer service, and help reduce production cost by providing reliable basis for investment in raw materials and tools. It would promote fuller utilisation of plant, equipment and labour by controlling all time and efforts essential in manufacturing.

### **Levels of Production Planning**

Production planning can be done at three levels namely Factory Planning, Process Planning and Operation Planning which are as follows:

- (i) **Factory Planning** : At this level of planning, the sequence of work tasks is planned in terms of building machines and equipment required for manufacturing the desired goods and services. The relationship of workplaces in terms of departments is also planned at this stage taking

into consideration the space available for the purpose. This stage deals with plant location and layout.

- (ii) **Process Planning :** There are many operations involved in factory planning for transforming the inputs into some desired end product. In process planning these operations are located and the sequence of these operations in the production process is determined, Plans are also made for the layout of work centres in each process.
- (iii) **Operation Planning :** It is concerned with planning the details of the methods required to perform each operation viz. selection of work centres, designing of tools required for various operations. Then the sequences of work elements involved in each operation are planned. Specifications about each transfer, work centres, nature of tools required and the time necessary for the completion of each operation are prescribed.

### **PRODUCTION CONTROL**

All organizations irrespective of size, use production control to some degree. In small organizations, the production control may be performed by one person; but in large complex industries the production control department is normally well-organised and highly specialised. Production control presupposes the existence of production plans, and it involves the use of various control techniques to ensure production performance as per plans. Co-ordinating men and materials and machines are the task of production control.

Production control may be defined as “the process of planning production in advance of operations; establishing the exact route of each individual item, part of assembly; setting, starting and finishing dates for each important item, assembly, and the finished products, and releasing the necessary orders as well as initiating the required follow-up to effectuate the smooth functioning of the enterprise.” According to Henry Fayol, “production control is the art and

science of ensuring that all which occurs is in accordance with the rules established and the instructions issued”. Thus, production control regulates the orderly flow of materials in the manufacturing process from the raw material stage to the finished product.

Production control aims at achieving production targets, optimum use of available resources, increased profits through productivity, better and more economic goods and services etc. An effective production control system requires reliable information, sound organisation structure, a high degree of standardisation and trained personnel for its successful operation.

A sound production control system contributes to the efficient operation of a plant. In terms of manufacturing customer’s orders, production control assures a more positive and accurate completion and delivery date. Delivering an order on time is obviously important to the customer and to the development of customer goodwill. Production control also brings plan and order to chaotic and haphazard manufacturing procedures. This not only increases the plant efficiency but also makes it a more pleasant place in which to work. Most people recognize that employees prefer to work and do better work under conditions of obvious control and plan. Morale may be considerably improved. Effective production control also maintains working inventories at a minimum, making possible a real saving in both labour and material investment. Thus, good production control helps a company operate and produce more efficiently and achieve lowest possible costs.

### **Objectives of Production Control**

The success of an enterprise greatly depends on the performance of its production control department. The production control department generally has to perform the following functions :

- (i) Provision of raw material, equipment, machines and labour.

- (ii) To organize production schedule in conformity with the demand forecasts.
- (iii) The resources are used in the best possible manner in such a way that the cost of production is minimised and delivery date is maintained.
- (iv) Determination of economic production runs with a view to reduce setup costs.
- (v) Proper co-ordination of the operations of various sections/ departments responsible for production.
- (vi) To ensure regular and timely supply of raw material at the desired place and of prescribed quality and quantity to avoid delays in production.
- (vii) To perform inspection of semi-finished and finished goods and use quality control techniques to ascertain that the produced items are of required specifications.
- (viii) It is also responsible for product design and development.

Thus the fundamental objective of production control is to regulate and control the various operations of production process in such a way that orderly flow of material is ensured at different stages of the production and the items are produced of right quality in right quantity at the right time with minimum efforts and cost.

### **Levels of Production Control**

Production control starts with some particular goal and formulation of some general strategy for the accomplishment of desired objectives. There are three levels of production control namely programming, ordering and dispatching. Programming plans the output of products for the factory as a whole. Ordering plans the output of components from the suppliers and



processing departments. Dispatching considers each processing department in turn and plans the output from the machine, tools and other work centres so as to complete the orders by due date.

### **Factors Determining Production Control Operations**

The nature of production control operations varies from organisation to organisation. The following factors affect the nature and magnitude of production control methods in an organisation :

- (i) **Nature of production** : In job-oriented manufacturing, products and operations are designed for some particular order which may or may not be repeated in future. Here production usually requires more time, whereas in a continuous manufacturing system inventory problems are more complex but control operations are rather simple due to fixed process. In mixed stock and custom manufacturing systems the problem of control is further complicated due to simultaneous scheduling of combined process.
- (ii) **Nature of operations/activities** : In intermittent manufacturing system the operations are markedly varied in terms of their nature, sequence and duration. Due to this the control procedure requires continuous modifications and adjustments to suit the requirements of each order.
- (iii) **Magnitude of operations** : Centralised control secures the most effective coordination but as an organisation grows in size, decentralisation of some production control function becomes necessary. The degree to which the performance of an activity should be decentralised depends upon the scope of operations and convenience of their locations.

### **PRODUCTION PLANNING AND CONTROL**

Planning and control are interrelated and interdependent. Planning is meaningless unless control action is taken to ensure the success of the plan. Control also provides information feedback which is helpful in modifying the

existing plans and in making new plans. Similarly, control is dependent on planning as the standards of performance are laid down under planning. Therefore, production planning and control should be considered an integrated function of planning to ensure the most efficient production and regulation of operations to execute the plans successfully.

Production planning and control may be defined as the direction and coordination of the firm's material and physical facilities towards the attainment of pre-specified production goals in the most efficient available way. It is the process of planning production in advance of operations, establishing the exact route of each individual item, part or assembly, setting starting and finishing dates for each important item or assembly and finished products, and releasing the necessary orders as well as initiating the required follow up to effectuate the smooth functioning of the enterprise. Thus, production planning and control involves planning, routing, scheduling, dispatching and expediting to coordinate the movements of materials, machines and manpower as to quantity, quality, time and place. It is based upon the old adage of "first plan your work and then work your plan".

### **Objectives of Production Planning and Control**

The main objective of production planning and control is to ensure the coordinated flow of work so that the required number of products are manufactured in the required quantity and of required quality at the required time at optimum efficiency. In other words, production planning and control aims at the following purposes :

- (i) **Continuous Flow of Production** : It tries to achieve a smooth and continuous production by eliminating successfully all sorts of bottlenecks in the process of production through well-planned routing and scheduling requirements relating to production work.
- (ii) **Planned Requirements of Resources** : It seeks to ensure the availability

of all the inputs i.e. materials, machines, tools, equipment and manpower in the required quantity, of the required quality and at the required time so that desired targets of production may be achieved.

- (iii) **Co-ordinated work Schedules :** The production activities planned and carried out in a manufacturing organizations as per the master schedule. The production planning and control tries to ensure that the schedules to be issued to the various departments/ units/supervisors are in co-ordination with the master schedule.
- (iv) **Optimum Inventory :** It aims at minimum investment in inventories consistent with continuous flow of production.
- (v) **Increased Productivity :** It aims at increased productivity by increasing efficiency and by being economical. This is achieved by optimising the use of productive resources and eliminating wastage and spoilage.
- (vi) **Customer Satisfaction :** It also aims at satisfying customers requirements by producing the items as per the specifications or desires of the customers. It seeks to ensure delivery of products on time by co-ordinating the production operations with customers' orders.
- (vii) **Production and Employment Stabilization :** Production planning and control aims at ensuring production and employment levels that are relatively stable and consistent with the quantity of sales.
- (viii) **Evaluation of Performance :** The process of production planning and control is expected to keep a constant check on operations by judging the performance of various individuals and workshops and taking suitable corrective measures if there is any deviation between planned and actual operations.

### **Importance of Production Planning and Control**

The system of production planning and control serves as the nervous system of a plant. It is a co-ordinating agency to co-ordinate the activities of

engineering, purchasing, production, selling and stock control departments. An efficient system of production planning and control helps in providing better and more economic goods to customers at lower investment. It is essential in all plants irrespective of their nature and size. The principal advantages of production planning and control are summarized below :

- (i) **Better Service to Customers** : Production planning and control, through proper scheduling and expediting of work, helps in providing better services to customers in terms of better quality of goods at reasonable prices as per promised delivery dates. Delivery in time and proper quality, both help in winning the confidence of customers, improving relations with customers and promoting profitable repeat orders.
- (ii) **Fewer Rush Orders** : In an organisation, where there is effective system of production planning and control, production operations move smoothly as per original planning and matching with the promised delivery dates. Consequently, there will be fewer rush orders in the plant and less overtime than, in the same industry, without adequate production planning and control.
- (iii) **Better Control of Inventory** : A sound system of production planning and control helps in maintaining inventory at proper levels and, thereby, minimising investment in inventory. It requires lower inventory of work-in-progress and less finished stock to give efficient service to customers. It also helps in exercising better control over raw-material inventory, which contributes to more effective purchasing.
- (iv) **More Effective Use of Equipment** : An efficient system of production planning and control makes for the most effective use of equipment. It provides information to the management on regular basis pertaining to the present position of all orders in process, equipment and personnel requirements for next few weeks. The workers can be communicated well in advance if any retrenchment, lay-offs, transfer, etc. is likely to

come about. Also, unnecessary purchases of equipment and materials can be avoided. Thus, it is possible to ensure proper utilization of equipment and other resources.

- (v) **Reduced Idle Time :** Production planning and control helps in reducing idle time i.e. loss of time by workers waiting for materials and other facilities; because it ensures that materials and other facilities are available to the workers in time as per the production schedule. Consequently, less man-hours are lost, which has a positive impact on the cost of production.
- (vi) **Improved Plant Morale :** An effective system of production planning and control co-ordinates the activities of all the departments involved in the production activity. It ensures even flow of work and avoids rush orders. It avoids 'speeding up' of workers and maintains healthy working conditions in the plant. Thus, there is improved plant morale as a by-product.
- (vii) **Good Public Image :** A proper system of production planning and control is helpful in keeping systematised operations in an organisation. Such an organisation is in a position to meet its orders in time to the satisfaction of its customers. Customers satisfaction leads to increased sales, increased profits, industrial harmony and, ultimately, good public image of the enterprise.
- (viii) **Lower Capital Requirements :** Under a sound system of production planning and control, everything relating to production is planned well in advance of operations. Where, when and what is required in the form of input is known before the actual production process starts. Inputs are made available as per schedule which ensures even flow of production without any bottlenecks. Facilities are used more effectively and inventory levels are kept as per schedule neither more nor less. Thus, production planning and control helps, in minimising capital investment in equipment and inventories.

## **Limitations of Production Planning and Control**

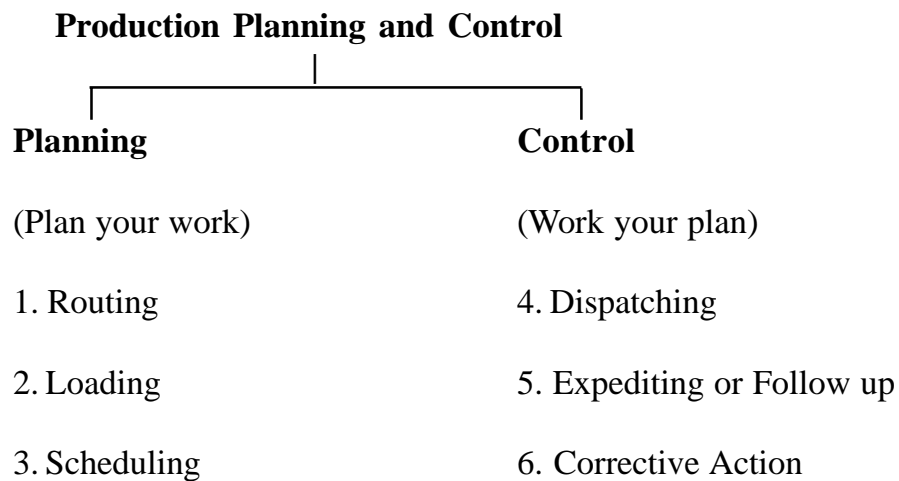
Undoubtedly, the system of production planning and control is a must for efficient production management; but in, practice, sometimes, it fails to achieve the expected results because of the following limitations :

- (i) Lack of Sound Basis :** Production planning and control is based on certain assumptions or forecasts about availability of inputs like materials, power, equipment etc. and customers orders. In case these assumptions and forecasts do not go right, the system of production planning and control will become ineffective.
- (ii) Rigidity in Plant's Working :** Production planning and control may be responsible for creating rigidity in the working of the plant. Once the production planning has been completed, any subsequent change may be resisted by the employees.
- (iii) Time consuming Process :** Production planning is a time consuming process. Therefore, under emergencies it may not be possible to go through the process of production planning.
- (iv) Costly Device :** Production planning and control is not only a time consuming process but is a costly process also. Its effective implementation requires services of specialists for performing functions of routing, scheduling, loading, despatching and expediting. Small firms cannot afford to employ specialists for the efficient performance of these functions.
- (v) External Limitations :** The effectiveness of production planning and control is sometimes limited because of external factors which are beyond the control of production manager, Sudden break-out of war, government control, natural calamities, change in fashion, change in technology, etc. are factors which have a negative impact on the implementation of production planning and control.

## Steps in Production Planning and Control

The function of production planning and control involves co-ordination and integration of the factors of production for optimum efficiency. Overall sales orders or plans must be translated into specific schedules and assigned so as to occupy all work centres but overload none. The job can be done formally, in which case elaborate charting and filing techniques are used; or it can be done informally with individual's thoughts and retention thereof supplanting tangible aids. In any case, the production planning and control function must be performed somehow by someone. The better the job that is done, the better the profit picture will be. A successful production planning and control programme minimizes the idleness of men and machines, optimizes the number of set-ups required, keeps in process inventories at a satisfactory level, reduces materials handling and storage costs and consequently permits quantity and quality production at low unit costs.

The basic phases of production planning and control are shown and discussed below :



## **1. Routing**

Production routing involves the laying down of path which work will follow and the order in which various operations will be carried out. It consists of the determination of operations through which the product must pass and the arrangement of operations in the sequence that will require a minimum of handling, transportation, storage and deterioration through exposure.

It is the job of routing personnel to determine the production routes in the organisation. A route for the movement of a manufacturing lot through the factory results from the determination of where each operation on a component part, subassembly, or assembly is to be performed. Routing may be generalised or detailed, depending upon the quality of product to be manufactured, production system in use and other factors. Generalised routing may be established either by building or by departments such as machine shop, assembly or others. Detailed routing indicates the specific work station or machine to be used for each operation.

The aim of routing is to determine an economical sequence of operations. Efficient routing permits the best utilisation of physical human resources employed in production. Routing is an essential element of production control because other production control functions are dependent on routing function. The persons who make out a list of operations must be thoroughly familiar with all the operations and various machines in the plant so that they are able to establish routes which will ensure maximum utilisation of the plant and machinery.

The routing procedure depends on considerations of type of work stations, characteristics of individual machines, needs of personnel etc. Routing in continuous industries does not present any problem because of the product type of layout where the equipment is arranged as per the sequence of operations required to be performed on the components (from raw material to the finished



products). On the other hand, in open job shops, since every time a new job is undertaken, the route sheet will have to be revised which involves a lot of work and expertise. In general, the following routing procedure is followed :

**(i) Determining What to Make and What to Buy :** The product is analysed, from manufacturing point of view, to find out how many parts or components can be manufactured in the plant and how many can be purchased from outside directly. The decision to make or buy a component depends on relative cost involved, technical consideration, purchasing policies of the firm and availability of equipment, and personnel. In general during slack periods the decision is taken to undertake maximum production to keep the men and machines busy. On the other hand, during prosperity, the sub-contracts are given for any parts to relieve overburdened facilities.

**(ii) Ascertaining the Requirements of Materials :** After the decision to manufacture is taken, the production department decides the exact quantity and quality of materials required for the manufacture of the components or the product. A parts list and a bill of materials is prepared showing name of each part, quantity, material specifications, amount of materials required, etc. The necessary materials, thus, can be procured.

**(iii) Preparation of Route Sheet :** The chief paper which gives the details of what is to be done and how it will have to be done is called a route sheet. In other words, a route sheet is a tabular form on which the path that a particular item is to follow through production is recorded. Route sheets are prepared in advance of need and filed in route file. A route sheet is to be prepared for every production order showing the individual parts to be completed for each finished individual parts to be completed for each finished product before any group can be assembled.

Route sheets will contain the following details in full :

- (a) The works order No.
- (b) Number of pieces to be made.
- (c) Symbol and classification of the part.
- (d) The lot sizes for each unit of production, if put through in lots.
- (e) List of operations for each part.
- (f) Definite sequence of operations.
- (g) Machine to be used for each operation.
- (h) Materials that is necessary for a given operation.
- (i) Standard time for each operation.

A separate route sheet is necessary for each part or component of a works order. It may be noted that it is not necessary that the number of pieces mentioned on the route sheet should be the same as required under any specified order; because in many cases some allowance has to be made for spoilage, and additional pieces may be needed for stock, or as reserves for repairs, or as spares.

While preparing a route sheet, it is essential to bear in mind that the route selected is the shortest and the most economical of all possible alternative routes.

**(iv) Determining Lot Sizes :** When the work orders are received from the customers, it is necessary to determine the lot sizes so as to keep the route free and ready for smooth operations. This must be done with due reference to length of operations, space occupied by the material while moving through the shop, and the requirements of the master schedule.

**(v) Determining Scrap Factors :** A scrap factor is the anticipated normal scrap encountered in the course of manufacturing process. The routing

department should determine the amount of possible scrap and rejection in each order or lot. Usually, a margin of 5% to 10% is kept for such rejections.

**(vi) Estimation of the cost of the Product :** The cost of the component or product is analysed and estimated through the information obtained in steps (i) to (v) above. The cost consists of material, wages, and other specific and indirect expenses.

**(vii) Preparation of Production Control Forms :** To collect detailed information relating to production control, the production department prepares the various forms such as job cards, inspection cards, move tickets, tool tickets, etc.

## **2. Loading**

Once the route has been established, the work can be loaded against the selected machine. Loading deals with the amount of work assigned to a machine or a worker. It deals with the record of work-load of different shops. The total time required to perform the operations is computed by multiplying the unit operation time given on the standard process sheet by the number of parts to be processed. The total time is then added to the work already planned for the work station. The process results in a tabulated list or chart showing the planned utilisation of machines or work stations in the plant. From the chart, it is easy to assess the spare capacity of the plant.

If the loading charts indicate sufficient spare capacity, efforts may be directed through the sales department to obtain more orders for the utilisation of spare capacity. Underload of certain departments may also arise from ineffective planning. In such a case, the remedy lies in proper planning. But if, on the other hand, there is an overload in any workshop, action on anyone or more of the following lines may be taken to relieve the bottleneck

- (a) by arranging for overtime work;
- (b) by introducing an additional shift;

- (c) by transferring operations to another shop; and
- (d) by sub-contracting of the excess load.

### **3. Scheduling**

Scheduling involves fixing priorities for different items and operations and providing for their release to the plant at the proper time. It establishes the time sequence of operations and indicates the time required for each job and operation. A schedule is a time-table of operations specifying the time and date when each job/operation is to be started and completed. Scheduling is, thus, the determination of the time that should be required to perform each operation and also the time necessary to perform the entire series, as routed making allowance for all factors concerned.

The objective of scheduling is to ensure that every job is started at the right time and it is completed before the delivery date. Scheduling and routing are inter-dependent and the two should, therefore, be integrated properly. It is difficult to prepare a schedule of production without determining the route or sequence of operations. Similarly, an efficient route for an item cannot be determined without consulting the production schedule designed for it. To be effective, scheduling should be flexible and due provision should be made for contingencies like delay in the availability of materials, breakdown of machines, absence of key personnel, etc.

### **4. Dispatching**

Dispatching may be defined as the setting of productive activities in motion through release of orders and instructions, in accordance with previously planned timings as embodied on operation sheet, route card and loading schedules. Dispatch provides official authorization and information for (i) Movement of materials to different work stations, (ii) movement of tools and fixtures necessary for each operation, (iii) beginning of work on each operation, (iv) recording of beginning and completion time, (v) movement of work in

accordance with a routing schedule, (vi) control of progress of all operations and making of necessary adjustments in the release of operations.

Dispatching requires co-ordination among all the departments concerned. This is obtained through varied degrees of centralised control. Under centralised control, dispatch clerks, centrally located, release all orders including the movement of materials and tools necessary for the operations. Under decentralised control, this responsibility is handled by each department.

In continuous manufacturing, under normal conditions, orders may be dispatched to departments a day or more in advance of operations. Each department prepares its own instructions and sends a duplicate copy to the central office. Since duplicate copies are received by the central office considerably in advance of operations, there is sufficient time for the recommendation of changes.

If it is found that certain orders are being unduly delayed, a request may be made for adjustments. However under abnormal conditions, when a company is being pressed by impatient customers, and the plant is loaded to capacity, emergency changes are more frequent. A special rush order may required that operations start immediately and that other orders originally scheduled may be held temporarily. Under these circumstances, it is apparent that centralised control plays an important role in obtaining speed and co-ordination.

## **5. Expediting or Follow Up**

Expediting or follow up is the last step in production planning and control. It involves determination of the progress of work, removing bottlenecks in the flow of work and ensuring that the productive operations are taking place in accordance with the plans. Follow up or expediting is that branch of production control procedure which regulates the progress of materials and parts through the production process. It spots delays or deviations from the production plans.

It helps to reveal defects in routing and scheduling, misunderstanding of orders and instructions under loading or overloading of work etc. All problems and deviations are investigated and remedial measures are undertaken to ensure the completion of work by the planned date.

Follow up serves as a catalytic agent to fuse the separate production activities into a unified whole. It seeks to ensure that the promise is backed up by performance and the work done is upto the pre-determined standards as to quantity, quality, time and cost. The responsibility for expediting is usually given to a separate group of persons known as 'expeditors'. These people are 'liaison men' or 'go-betweens' who obtain information on the progress of work and attempt to achieve coordination among the different departments.

## **6. Corrective Action**

Corrective action is needed to make effective the system of production planning and control. By resorting to corrective measures, the production manager maintains full control over the production activities. For instance, routing may be defective and the schedules may be unrealistic and rigid. The production manager should try to rectify the routes and lay down realistic and flexible schedules. Workload of machines and workers should also be determined scientifically. If schedules are not being met, the causes should be fully investigated. It should also be ensured that there is optimum utilisation of the plant capacity.

Sometimes, abnormal situations like strike and break-down of machinery or power may upset the work schedules. The production manager should try to make up the delays and adjust the schedules properly. Systematic investigation of activities at various stages of production may also lead the production manager to revise the production targets, loads and schedules. There is also a strong need of performance appraisal of all employees. Many a time, production

schedules are not met in time or if they are met, the goods are of substandard quality. If the causes of these are due to the poor performance of the employees, certain personnel decisions like demotion, transfer and training may be essential.

### **PRODUCTION PLANNING AND CONTROL (PPC) UNDER DIFFERENT PRODUCTION SYSTEMS**

No single system of production planning and control is good for all types of industries. The nature of PPC varies from firm to firm depending upon the type of production process. In a manufacturing industry, raw materials are covered into components, semi-finished products and finished products. But some firms are engaged in the assembling of products. An assembling industry combines together a number of components or parts to make the finished product, e.g. bicycle, typewriter, fan, scooter, etc. The application of production planning and control to various types of production has been explained below :

#### **PPC in Process Industry**

Production planning and control in process industry is relatively simple. Routing is almost automatic and uniform because standardised techniques and specialised equipment are used in production processes. The product is standardized and goods are produced for stock. Therefore, scheduling is easy and department schedules can be prepared from the master schedule on a continuing basis. Dispatching involves repetitive orders issued to ensure a steady flow of materials through the plant. In process industry, decentralised dispatching can be used so that each foreman can issue orders and instructions to each operator and machine under his charge as per the circumstances of his work-station. The sequence of operations being uniform, responsibility for quality control can be delegated to individual production units to ensure that the products manufactured conform to the specifications laid down in advance. Thus, the main task of production planning and control in process industry is

h maintain a continuous and uniform flow of work at the predetermined rate so that there is full utilisation of plant capacity and the work is completed in time. Therefore, it is known as 'flow control'.

### **PPC in Job Production Industry**

Production, planning and control is relatively difficult in job production industry. Every order is of a different type and it entails a particular sequence of operations. There is not standardised route plan and a new route has to be prepared for every order. Specific orders are assigned to different workstations according to the capacities available with them. Production, schedules are drawn up according to relative urgency of order. An order received later may have to be supplied earlier. Sometimes, it may not be possible to schedule all operations relating to an order simultaneously. Dispatching and follow up are also order-oriented. For every order fresh instructions and follow up measures have to be undertaken. Therefore, production control in job production system may be called 'Order control'.

### **PPC in Intermittent Production Industry**

In case of intermittent production, raw materials are converted into components or parts for stock but they are combined according to the customer's orders. The products are manufactured usually in large batches. Every batch differs from others but all units within a batch are identical. A number of heterogeneous finished products are manufactured within a limited range of options. Therefore, production planning and control in intermittent manufacturing is a mixture of those used in process industry and job order production. There is a standardised components and production schedules are continuous. But the routes and schedules for intermediate operations have to be changed every time. In order to avoid delays and bottlenecks in the production process, great care needs to be taken in dispatching. Before issuing orders and instructions



need for new materials and tools, overloading and underloading of particular machines/operators and other problems must be anticipated. As product are diversified and several orders are being handled simultaneously in different work-centres, follow up is a cumbersome task in intermittent manufacturing. Follow up may be organised either according to product or process. Follow up by product is suitable for process or continuous production system. It is relatively simple because there is an automatic flow of work from one operation to another and the follow up man has simply to report and remove breakdown, delays, shortage of materials and tools that obstruct the smooth flow of production. But in intermittent production system, follow up by process is used. In every department, the follow up men check the progress of work passing through that department. The follow up men do not require knowledge and information about all the departments. But they have to be more alert as the flow of work from one operation to another is not automatic. Quality has to be controlled both during the manufacture of components and during their conversion into the finished product. In practice, a combination of flow and order controls known as block control may be used. Flow control is employed to produce standardised components and order control is used for the manufacture of finished products.

### **PPC in Assembly Industry**

In an assembly industry, there is a uniform sequence of repetitive operations but the number of components and their proportion to be assembled differ from one product to another. Once the sequence of operations has been decided, the efficiency depends upon the regular and timely supply of the required components. The entire production line may be held up and machinery and men may remain idle on account of the non availability of one single component at the proper time and in the required quantity. It is, therefore, essential to determine first of all the type and quantity of various components

required at different stages in the assembling of a product. This will depend upon the nature and volume of a product to be assembled during a particular period of time. Production schedules are drawn up for each product so as to achieve the targets of production. Assembly work for different products is assigned to various machines and operators according to their capacities and suitability. Instructions are issued in such a manner that the responsibility, for a particular product is fixed on specific employees. Follow up measures need to be taken to ensure that every product is being assembled as per the specifications and schedules laid down in advance.

### **REQUIREMENTS OF EFFICIENT PRODUCTION PLANNING AND CONTROL**

A system of production planning and control is said to be efficient when it does its job well and successfully without wasting time or energy. To be efficient it must have the following prerequisites or conditions or requirements:

- (i) **Sound Organisational Structure** : An effective system of production planning and control requires a sound organisational structure. The management as a team should recognise the need for production planning and control and must be willing to delegate authority and create responsibility at all levels. In case the work schedules are centrally determined, the supervisors must recognise that this is merely an extension of functional specialisation to make it possible for them to devote more of their time to those activities for which they are best qualified. This attitude produces co-operative effort.
- (ii) **Reliable and Detailed Information** : For successful production planning and control, reliable, detailed and up-to-date information must be available to all concerned regarding the following :
  - (a) products required to be produced;

- (b) the number and types of each production machine and processing unit, together with the fees, speeds, and productive capacities.
  - (c) the manufacturing time required and the sequence of operations of each part going into the finished product;
  - (d) requirements and availability of material labour;
  - (e) requirements and availability of the proper tools, jigs, and fixtures for each part of the product to be manufactured;
  - (f) work-in-progress, etc.
- (iii) **Trained Personnel :** A competent system of production planning and control presupposes the existence of trained personnel in the use of special tools, jigs and fixtures, etc. The personnel must have the required aptitude for the work to be completed and understand the various aspects of production planning and control. They must have built-in motivation for achieving goals of the firm.
- (iv) **Standardisation :** The term ‘standardisation’ refers to the process of making things that conform to a fixed size, colour, quality, etc. for achieving an effective system of production planning and control, standardisation is required for the following :
- (a) materials purchased and fabricated;
  - (b) operations on all parts as far as design permits;
  - (c) tools and equipment as far as practical;
  - (d) procedures of operations and organisational set up including delegation of authority and fixed responsibility;
  - (e) production standards for employees and method of remuneration for employees;
  - (f) quality requirements and adequate inspection to guarantee quality maintenance;

- (g) reports on production performance in comparison with scheduled production, etc.
- (v) **Flexibility** : Something or someone that is flexible is able to change easily and adopt to different conditions and circumstances as they occur. To be successful, the system of production planning and control should have built-in flexibility so that it may adapt to changes like power failure, break down of machinery, shortage of raw materials, absence of key personnel, etc.
- (vi) **Periodic Appraisal** : An appraisal of a situation is a careful judgement about what is happening and why is happening. Since production planning and control is a continuous process, a periodic appraisal of its various aspects is required so that superfluous ones may be identified and removed. The process of continuous checking is quite helpful in keeping the system efficient and in line with the requirements of the particular organisation and its customers.

**Do Yourself :**

1. What do you understand by production planning and control? How does it help in the effective operation of a factory? Also discuss importance of production planning and control.
2. What are the objectives of production planning and control? Discuss the steps involved in production control.
3. State the requirements of an effective system of production planning and control.
4. Discuss the production planning and control under different production systems.

## **LESSON : 5**

### **PRODUCTION PROCESS ANALYSIS**

#### **INTRODUCTION**

In modern industrial age, the managers have to face many problems in the field of production such as what should be the nature of production, system of production and size of the plant ? They have to take into account the industrial environment, demand of the product, labour problems and possibilities of expansion of the plant. Production planning is done considering all the above factors. Standards for men, materials, machines and output are fixed in advance. Production planning is only a means for the effective utilisation of various resources of the plant and not an end in itself. Effective utilisation and control of plans are equally important otherwise planning activity will remain a paper work merely wasting the time and money.

Production planning does not reveal an order of various production operations and the information as disclosed in the plan. It is arranged again in a systematic order regarding sequence of operations involving men, machine and material for providing proper understanding about the constituents of the system and proper analysis. The systematic arrangement of different systems and techniques in order to carry out the production activities of an organisation may be called as production process analysis.

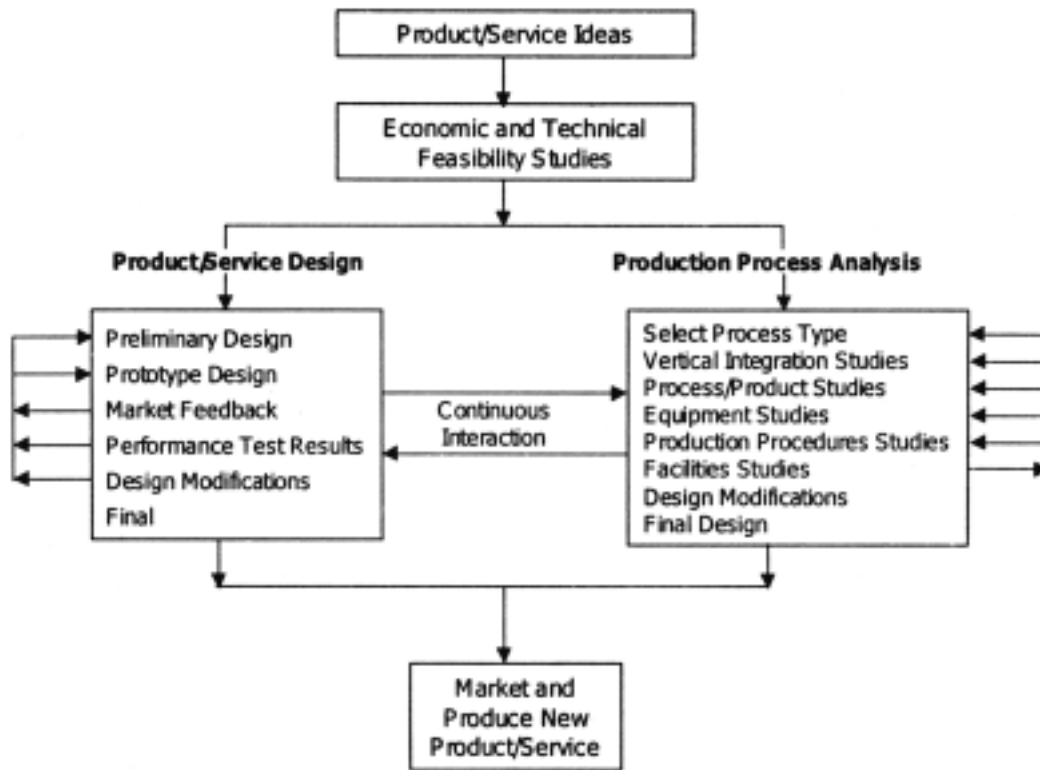
Production process analysis and design means the complete delineation and description of the specific steps in the production process and the linkages

among the steps that will enable the production system to produce products/ services of the desired quality, in the required quantity, at the time customers want them, and at the budgeted cost. Process analysis is intense for new products/ services, but replanning can also occur as capacity needs change, business or market conditions change, technologically superior machines become available, or as other changes occur. Although production processes and their technology do evolve, at anyone point in time, the essential character and structure of production processes is shaped by operations strategy.

Production processes must be planned and designed to provide the mix of competitive weapons embodied in the production plan, which reflects the operations strategy for the business. For example; if positioning strategy for a particular product line consists of producing small batches of custom-designed products and a produce-to-order inventory policy, production processes must be designed that allow the flexibility of quickly shifting to other products and economically producing products in small batches.

### **Interrelationship of product/service design and process design**

The design or redesign of products/services and the design or redesign, of production processes are interrelated. Figure 1 illustrates that there is a continuous interaction between these activities. This means that production processes must be designed to accommodate the product/service design and that products must be designed for producibility.



**Fig. 1 : Interaction Between Product/Service Design and Process Analysis.**

### **Production Process Analysis and Design Systems**

Production process analysis and design brings together knowledge about operation strategies, product/service designs, technologies of the production system, and markets, and then develops a detailed plan for producing the products/services.

Figure 2 illustrates the inputs and outputs of process analysis. The inputs to process analysis come from information about products/services and their markets, from the production system and its technologies, and from operations strategies.

INPUTS	PROCESS ANALYSIS AND DESIGN	OUTPUTS
<p><b>1. Product/Service Information</b>  Product/Service Demand  Price/Volumes  Patterns  Competitive Environment  Consumer Wants/Needs  Desired Product Characteristics</p> <p><b>2. Productions System</b>  Information  Resource Availability  Production Economics  Known Technologies  Technology that can be Acquired  Predominant Strengths  Weaknesses</p> <p><b>3. Operations Strategy</b>  Positioning Strategies  Competitive Weapons Needed  Focus of Factories and Service Facilities  Allocation of Resources</p>	<p><b>1. Select Process Type</b>  Coordinated with Strategies.</p> <p><b>2. Vertical Integration Studies</b>  Vendor Capabilities  Acquisition Decisions  Make-or-Buy Decisions</p> <p><b>3. Process/Product Studies</b>  Major Technological Steps  Minor Technological Steps  Product Simplification  Product Standardization  Product Design for Producibility</p> <p><b>4. Equipment Studies</b>  Level of Automation  Linkages of Machines  Equipment Selection Tooling</p> <p><b>5. Production Procures Studies</b>  Production Sequence  Materials Specifications  Personnel Requirements</p> <p><b>6. Facilities Studies</b>  Building Designs  Layout of Facilities</p>	<p><b>1. Technological Processes</b>  Design of Specific Processes  Linkages among Processes</p> <p><b>2. Facilities</b>  Building Design  Layout of Facilities  Selection of Equipment</p> <p><b>3. Personnel Estimates</b>  Skill Level Requirements  Number of Employees  Training Requirements  Supervision Requirements</p>

**Figure 2 : The Production Process Analysis and Design System**

Process analysis and design involves the selection of a process type, studies about the degree of vertical integration, process and product/service studies, equipment studies, production procedures studies, and facilities studies. The outputs of these studies is a complete determination of the individual technological process, steps to be used, and the linkages among the steps; the selection of equipment, design of buildings, and layout facilities; and number of personnel required, their skill levels, and supervision requirements.

**MAJOR FACTORS AFFECTING PRODUCTION PROCESS ANALYSIS DECISIONS**

Among the factors affecting production process analysis are the nature of product/service demand, degree of vertical integration, product/service and



volume flexibility, degree of automation, level of product/service quality, and degree of customer contact.

**(a) Nature of product/service demand :** Production systems exist to produce products/services of the kind that customers want, when they want them, and at a cost that allows the firm to be profitable. The place to start in analysing production systems, therefore, is the demand for products and services. Of particular importance are the patterns of demand.

#### *Patterns of Product/Service Demand*

First, production processes must have adequate capacity to produce the volume of the products/services that customers want. Forecasting methods help to estimate the customer demand for product/services. These forecasts can then be used to estimate the amount of production capacity needed in each future time period. Seasonality, growth trends, and other patterns of demand, therefore, are important determinants of the production capacity necessary to satisfy demand.

Seasonality is an important consideration in planning the appropriate type of production process for a product/service. For example, if a product's demand exhibits great variation from season to season, the production processes and inventory policies must be designed to allow the delivery of sufficient quantities of products or services during peak demand seasons, and yet still be able to produce products economically in slack demand seasons.

Similarly, the growth trends of product/service demand have important implications for analysing production processes. For example, if a service is

expected to show strong sales growth over a five-year period, provision must be made for designing production processes whose capacity can be expanded to keep pace with demand. Some types of processes can be more easily expanded than others, and the choice of the type of production process will be affected by the forecasted growth trends of product/service demand.

As with seasonality and growth patterns, random fluctuations and cyclical patterns will also have an impact on production process designs. In addition, the overall volume of the demand and the prices that can be charged for the products/services will affect the type and characteristics of the production processes.

**(b) Degree of Vertical Integration :** One of the first issues to be resolved when developing production processing designs is determining how much of a product/service the company will produce and how much will be bought from suppliers. Vertical integration is the amount of the production and distribution chain, from suppliers of components to the delivery of finished products/services to customers, that is brought under the ownership of a company. There are two types of vertical integration, forward and backward. Forward integration means expanding ownership of the production and distribution chain forward towards the market. Backward integration means expanding ownership of the production and distribution chain backward towards the sources of supply.

Generally, there are three stages of production : component, subassembly, and final assembly. For most manufacturers of finished products-such as Ford, Telco and Maruti that assemble automobiles-the major issue of vertical integration is whether they should enter into supply contracts with suppliers

of subassemblies and components, or backward integrate to produce subassemblies and components themselves. On the other hand, for firms that are primarily subassembly suppliers – the major issues of vertical integration is whether they should forward integrate and assemble and market their own finished products. In either case, the issue of whether to integrate vertically brings both opportunities and risks.

The amount of vertical integration that is right for a particular firm in one industry could be inappropriate for another firm in a different industry. For companies that would forward integrate towards the market, the predominant factor in such decisions is the ability of the company to market the products.

It should be clear from Table 1 that the decision whether to make products (backward integrate by bringing production of subassemblies and components in-house) or buy them from suppliers is not a simple decision.

**TABLE 1**

**The points of Contention in a Decision Situation**

1. The cost of making or producing subassemblies or components in-house versus buying them from suppliers.
2. The amount of investment necessary to produce subassemblies or components in-house.
3. The availability of funds to support the necessary expansion of production capacity.
4. The effect on return on assets if production of subassemblies or components is undertaken.
5. The present technological capabilities of the company to produce subassemblies or components.
6. The need to develop technological capabilities to produce subassemblies or components to secure future competitive position.
7. The availability of excellent suppliers who are willing to enter into long-term supply relationships, particularly those who can provide high-quality subassemblies and components at low prices, who are well enough funded to ensure continuity of an adequate supply, and who are able to work with the company to continuously improve product and component designs and manufacturing processes.
8. The amount of market share held by the company.

(c) **Product/Service and Volume Flexibility** : Flexibility means being able to respond fast to customers needs. Flexibility is of two forms, product/service flexibility and volume flexibility. Product/service flexibility means the ability of the production system to quickly change from producing one product/service to producing another. Volume flexibility means the ability to quickly increase or reduce the volume of products/services produced. Both of these forms of flexibility of production systems are determined in large part when the production processes are designed.

Product/service flexibility is required when business strategies call for many custom-designed products/services each with rather small volumes or when new products must be introduced quickly. In such cases production processes must ordinarily be planned and designed to include general purpose equipment and versatile employees who can be easily changed from one product/service to another. The concept of a flexible work force involves training and cross-training workers in many types of jobs. Although training costs obviously increase, the payoff is work that is perhaps more interesting for workers and a work force that can quickly shift from job to job and to other products/services with little loss in productivity.

Volume flexibility is needed when demand is subjected to peaks and valleys and when it is impractical to inventory products in anticipation of customer demand. In these cases, production processes must be designed with production capacities that can be quickly and inexpensively expanded and contracted. Manufacturing operations are ordinarily capital-intensive, which simply means

that the predominant resource used is capital rather than labour. Thus in the presence of variable product demand, capital equipment in production processes must be designed with production capacities that are near the peak levels of demand. This translates into either increased capital investment in buildings and equipments or the use of outside subcontractors and some provision for quickly expanding and contracting the work force. Over time, layoffs or the recall of workers from layoffs, use of temporary or part-time workers on short notice, and permanent overstaffing are options commonly used to achieve volume flexibility of employees.

**(d) Degree of Automation :** A key issue in analysing production processes is determining how much automation to integrate into the production system. Because automated equipment is very expensive and managing the integration of automation into existing or new operations is difficult, automation projects are not undertaken lightly.

Historically, the discussion of how much automation to use in factories and services has centered on the cost savings from substituting machine effort for labour. Today, automation affects far more than the costs of production; in fact, for many companies automation is seen as basic to their ability to become or remain competitive.

Automation can reduce labour and related costs, but in many applications the huge investment required by automation projects cannot be justified on labour savings alone. Increasingly, it is the other benefits of automation that motivate companies to invest in automation. The need to quickly produce products/

services of high quality and the ability to quickly change production to other products/services are the key factors that support many of today's automation projects. The degree of automation appropriate for production of a product/service must be driven by the operations strategies of the firm. If those strategies call for high quality, product flexibility, and fast production of products/services, automation can be an important element of operations strategy.

**(e) Level of product/service quality :** In today's competitive environment, product quality has become the chief weapon in the battle for world markets of mass-produced products. The choice of production process is certainly affected by the desired level of product quality. At every step of process design, product quality enters into most of the major decisions. For many firms the issue of how much product quality required is directly related to the degree of automation-integrated into the production process. Automated machines can produce products of incredible uniformity. And with proper management, maintenance, and attention, products of superior quality can be produced with automated production processes at low production costs.

**(f) Degree of Customer Contact :** For most services and for some manufacturers, customers are an active part of the processes of producing and delivering products and services. The extent to which customers become involved in the production systems has important implications for the production processes.

There is a wide range of degree of interaction of customers with the production system. For example, at one extreme are barbershops, hair salons, and medical

clinics. Here the customer becomes an active part of production, and the service is actually performed on the customer. In these cases the customer is the central focus of the design of production processes. Every element of the equipment, employee training, and buildings must be designed with the customer in mind. Also, courteous attention and comfortable surroundings must be provided to receive, hold, process, and release customers. In such systems, service quality, speed of performing the service, and reduced costs can be improved with automated equipment as long as the fundamental nature of the service is not materially affected.

At the other extreme of customer involvement, the design of production processes is affected little because of interaction with customers. Examples of this type of service are fast-food restaurants or back room operations at banks. In these operations, services are highly standardized, production volume of services is high, and cost, price, and speed of delivery tend to be predominant in operations strategies.

### **TYPES OF PROCESS DESIGNS**

At the earliest stages of production process planning, the organisation must decide on the basic type of production processing and finished goods inventory policy to use in producing each major product/service. The common types of production processes are product-focused, process-focused, and group technology/cellular manufacturing.

**(a) Product-Focused :** The term product-focused is used to describe a form of production process in which production departments are organized according to the type of product/service being produced. In other words, all of the production operations required to produce a product/service are ordinarily grouped into one production department.

Product-focused production process is also sometimes called line flow production or continuous production. Both of these terms describe the nature of the routes that products/services follow in production. In line flow production, products/services tend to follow direct linear paths without backtracking or sidetracking. In continuous production, products/services tend to proceed through production path without stopping.

Compared to other types of production, product-focused systems in manufacturing, usually require higher initial investment levels. This increased investment need stems from (1) the use of more expensive, fixed-position materials-handling equipment, such as overhead conveyors, and (2) the use of processing equipment that is specialized to a particular product/service, such as automatic welding machines especially designed and tooled for only one product. Additionally, the product/service flexibility of these systems tends to be rather low because they are ordinarily difficult to change over to other products/services. Offsetting these drawbacks are the advantages of low labour-skill requirements, reduced worker training, reduced supervision, and ease of planning and controlling production.



**(b) Process Focused :** The term process-focused is used to describe a form of production in which production operations are grouped according to type of processes. In other words, all production operations that have similar technological processes are grouped together to form a production department. For example, all production operations throughout a factory that involve painting (the technological process) are grouped together in one location to form a painting department.

Process-focused systems are also sometimes known as intermittent production or job shops. They are referred to as intermittent production because production is performed on products intermittently, that is, on a start-and-stop basis. Process-focused systems are also commonly referred to as job shops because products/services move from department to department in batches (jobs) that are usually determined by customer orders.

**(c) Group Technology/Cellular Manufacturing :** Group Technology/Cellular Manufacturing (GT/CM) is a form of production that has only recently been adopted in the United States. Cellular Manufacturing is subset of the broader Group Technology concept. In Group Technology, a coding system is developed for the parts made in a factory. Each part receives a multi digit code that describes the physical characteristics of the part. For example, let us say that a part is cylindrical, six inches long, one inch in diameter, and made of aluminium. The part's code would indicate these physical characteristics. By the use of a coding system for parts, the following production activities are simplified :

- i) It is easier to determine how to route parts through production because the production steps required to make a part are obvious from its code.
- ii) The number of part designs can be reduced because of part standardization. When new parts are designed, the codes of existing parts can be accessed in a computer data base to identify similar parts in the data base. New designs can be made like the existing ones.
- iii) Parts with similar characteristics can be grouped together into part families. Because parts with similar characteristics are made in similar ways, the parts in a parts family are typically made on the same machines with similar tooling.
- iv) Some parts families can be assigned to manufacturing cells for production, one part family to a cell. The organisation of the shop floor into cells is referred to as Cellular Manufacturing.

The advantages claimed for cellular manufacturing over job shops are many. Because the parts within a family in a cell require the same machines with similar tooling and require similar production operations :

- i) Machine changeovers between batches of parts are simplified, thereby reducing costs of changeover and increasing production capacity.
- ii) Variability of tasks is reduced, and training periods for workers are shortened.

- iii) There are more direct routes in production, allowing parts to be made faster and shipped quicker.
- iv) Parts spend less time waiting, in-process inventory levels are reduced.
- v) Since parts are made under conditions of less part-design variability by workers, who are more specifically trained for the parts, quality control is improved.
- vi) With shorter, more direct routes through production and with reduction of materials-handling costs, production planning and control are simpler.
- vii) As a result of reduced part variety and similarity of tooling and machines within cells, automation of cells is much simplified. The formation of cells may therefore be seen as an intermediate step in the automation of job shops.

GT/CM can also have some disadvantages. For example, duplicate pieces of equipment may be needed so that parts do not have to be transported between cells. Also, because not all parts from a job shop can be made in the GT/CM cells, producing the remaining parts in a job shop may not be as efficient once GT/CM cells have been established.

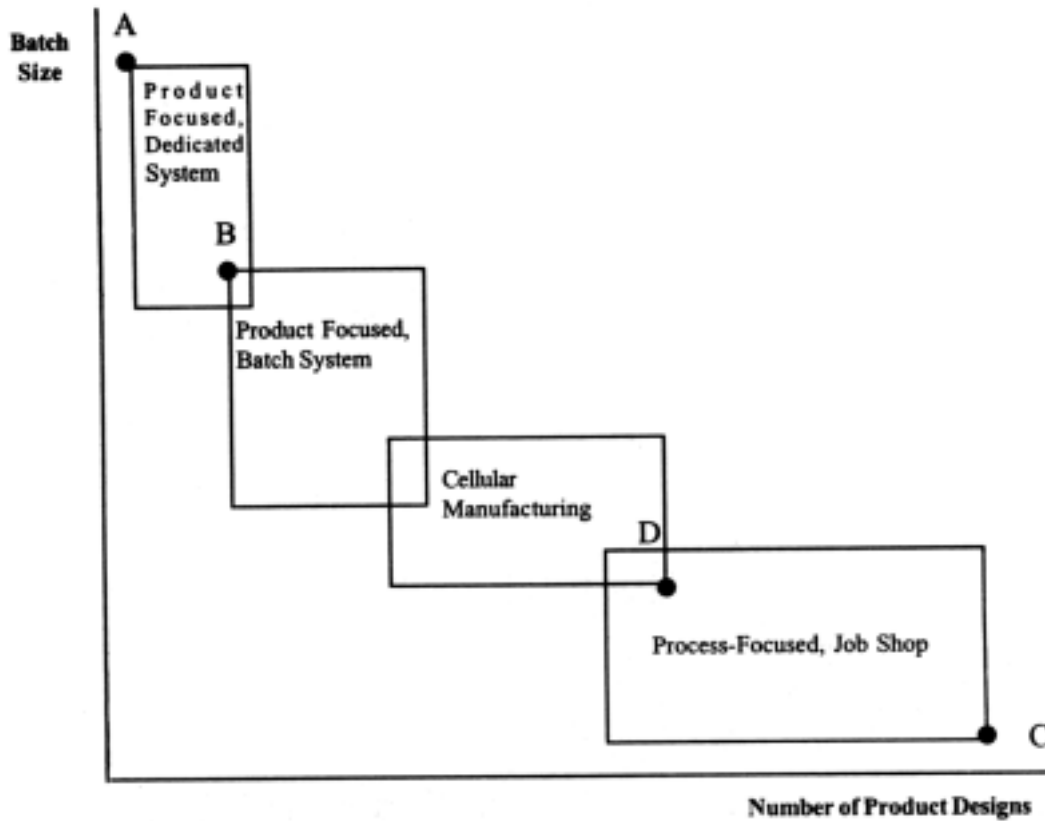
### **DECIDING AMONG PRODUCTION PROCESSES ALTERNATIVES**

In deciding on a particular type of production process for a major product line, several factors must be considered. Among these are batch size and product

variety, capital requirements, and economic analysis.

**(a) Batch Size and Product Variety :** In choosing the type of production process design, a major consideration would be the amount of product variety and the volume to be demanded of each product model. Figure 3 illustrates that the type of process design that is appropriate depends on the number of product designs and the size of the batches to be produced in a production system.

As a generalisation, as we move from Point A to Point C in Figure 3, the production cost per unit and product flexibility increase. At point A, there is a single product, and the demand for the product is very large. In this extreme case, a product-focused organisation that is dedicated to only that product would be appropriate. Production costs per unit are very low, but this type of production organisation is very inflexible because equipment specialised to the product and the specific training of the employees make it impractical to change to the production of other products. As the number of product designs increase and as the batch size of the products decreases, at some point, say point B, a product-focused, batch system becomes appropriate. Although this system is relatively inflexible, employees are trained to shift to the production of other products, and equipment is designed to be changed to other products, but with some difficulty.



**Figure 3 : Type of Process Design Depends on Product Diversity and Batch Size**

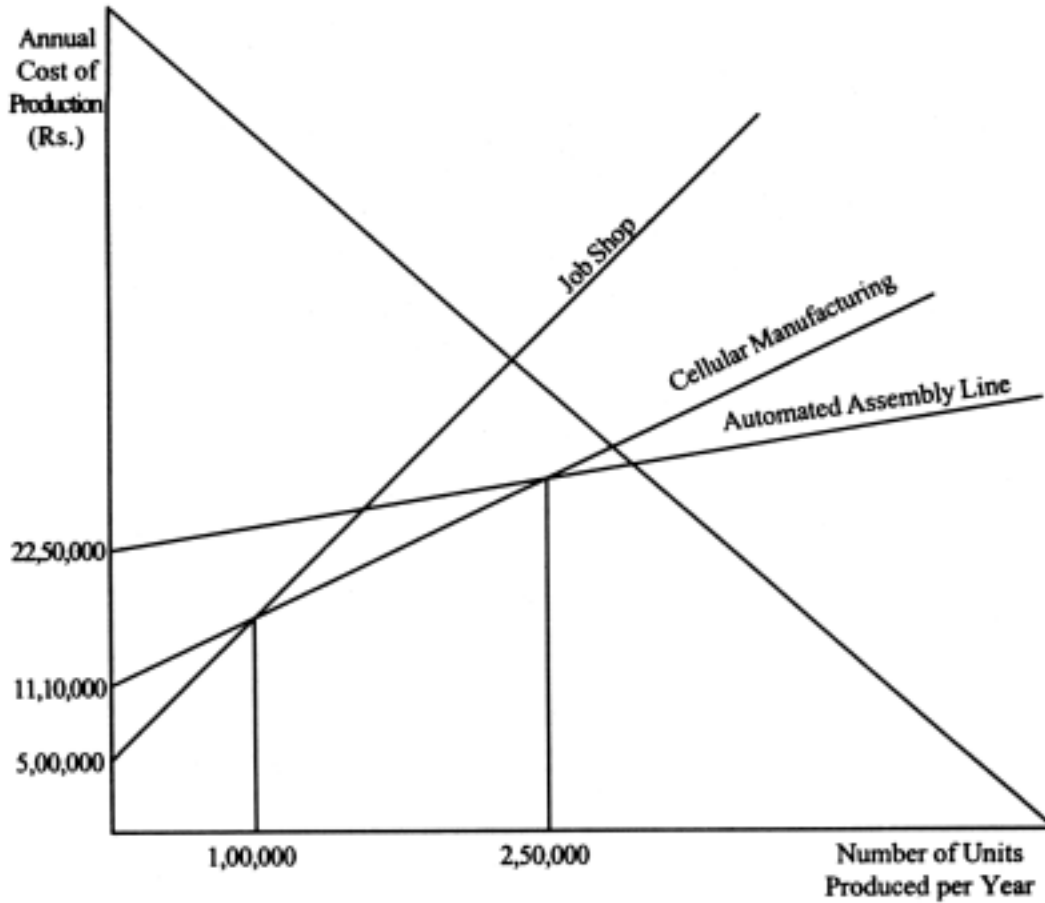
At the other extreme, Point C represents the production of many one-of-a-kind products. In this case, a job shop producing unique products in batches of a single item would be appropriate. This form of production is the ultimate in product flexibility. As the number of products decreases and as the batch size of the products increases from this extreme, at some point, say point D, cellular manufacturing of some of the parts within a job shop becomes appropriate.

Thus as business strategies are developed for each major product line, the

determination of the volume of demand that is expected for each product and the number of product models necessary to appeal to the market are important factors in choosing the type of process design.

**(b) Capital Requirements :** The amount of capital required for the production system tends to differ for each type of production processing organisation. In figure 3, in general, the amount of capital required is greatest at Point A and diminishes as we move downward to the right towards point C. The amount of capital available and the cost of capital to a firm could be important factors in choosing a type of production process design, and business strategies would have to be adjusted accordingly.

**(c) Economic Analysis :** Among the factors to be considered when deciding among the types of production processing organizations, the production cost of each alternative is important. Each type of production process requires a different amount of capital. Capital costs are ordinarily fixed charges that occur every month and represent some measure of the cost of capital to the firm. Figure 4 graphically illustrates that different forms of process design for producing a hypothetical product have different cost functions. The greater the initial cost of equipment, buildings, and other fixed assets, the greater are the fixed costs. Also, different forms of production organizations have different variable costs – those costs that vary with the volume of products produced in each month.



**Figure 4 : Cost Functions of Processing Alternatives**

As can be seen in Figure 4, the automated assembly line alternative has annual fixed costs of Rs. 22,50,000. Fixed costs are the annual costs when the volume of the product produced is zero. Also, it can be seen from Figure 4 that the variable costs for the automated assembly line are very low relative to the other forms of process design because the slope (rise over run) of its cost function is very flat. This means that annual costs do not climb very fast as annual volume of production grows. The cost function of a job shop usually exhibits very low fixed costs and very high variable costs.

The fixed and variable costs of cellular manufacturing are usually intermediate to those of the other two process designs.

An important conclusion from Figure 4 is : If capital availability is not a factor and annual production costs are the predominant consideration, the process design that is preferred depends on the production volume of the product. In the example of Figure 4, if production volume is less than 1,00,000 units, a job shop would be preferred. If production volume of between 1,00,000 and 2,50,000 units is expected, cellular manufacturing would be preferred. And if production volume of greater than 2,50,000 units is expected the automated assembly line would be preferred. If none of the alternatives provide a satisfactory return, do not select any of the processing alternatives.

### **Charts for Production Process Analysis**

These charts show different steps or events that occur during the performance of a task or series of operations. These give a detailed description step by step starting with the input of raw materials and ending with the output of the finished product. Between these two ends, other activities like transportation, storage, inspection, machine operation etc. are taken into consideration. This helps in eliminating the wasteful activities. The main charts used for process analysis are : (i) Schematic charts and (ii) Process charts.

**(a) Schematic charts :** These charts are prepared and used for comparing different alternative methods of production. In these charts, the graph depicts



how a product can be manufactured under different types of manufacturing methods using the same ingredients. The conditions of production operation in each production process are depicted on the chart thus facilitating the comparison of various production alternatives and to select the best one out of them. In process industries, the charts are also useful for preliminary layout analysis. In preparing these charts, one should collect and complete the information in a tabular form, for each alternative method of production, containing the details of equipment, raw material, labour, land, production time etc. involved in each process. The fundamental basis of selection of any process is the cost of production criterion but sometimes some other factors such as availability of equipment, land, skilled labour etc. are given weight. For each comparison the order of various columns under different methods should be the same.

**(b) Process charts :** Process chart is the diagrammatic representation of various tasks and activities in sequence of operation passing through the production process, beginning with the first operation to the last operation for the completion of product. In preparing a layout plan, these charts are of great value. The basis of operation chart is that there is always some order of operations between raw material source and the eventual consumer. The different operations during the fulfillment of these ends are often linked together.

The various operations involved in the production process can be grouped under the following categories :

- i) Flow operations : These are operations which change the state of materials without any significant change in their quantity.
- ii) Dividing operations : The flow of materials through such operations is divided into a number of constituent streams.
- iii) Combining operations : Such operations combine the different flow streams into one stream.

**Symbols used in process charts :** In preparing process charts a number of symbols are used to denote different activities or operations in a production process. In a process chart, these symbols are listed in a vertical column along with another column giving the description of various operations. Additional columns can be provided for giving additional information describing important features of the process such as distance covered by an item during various stage of production, number of items being used, the type of machine required etc. The symbols commonly used in the process charts are given as below :

<b>Symbols</b>	<b>Description of the activity, the symbol represents :</b>
O	This represents broad category of operation used in the production. Sometime, some number may be inserted inside the circle to mark some specific operation.  Inspection of items produced at any stage of production process. In order to specify the nature of inspection, some number or letter can be inserted inside the square.

- Transportation of items from one operation or location to another.
  - Δ This represents the storage activity of any item during the course of process. The nature of storage — temporary or permanent may be inserted inside triangle.
  - It shows that operation and inspection activities are carried out simultaneously.
  - D It represents delay in the process. It means that the object is 'held up and cannot proceed immediately to the next process.
- 

A process chart is of great value in the development of a layout plan. With the help of charts, theoretical description of various activities are easily translated into symbolic form and it is shown how the various activities of the process are linked together. Thus a process chart helps in visualising a process and serves as a source of improving the system.

### **SELF TEST QUESTIONS**

1. Describe the relationship between process design and product design.
2. What are the steps in process analysis? What inputs are required for process design? What are the outputs?
3. Explain the various factors which affect production process analysis decisions.

4. What is the relationship between group technology and cellular manufacturing? Under what conditions would a manager want to form manufacturing cells in a job shop?
5. Describe an schematic chart and a process chart. How are they different? Explain how they are used in production process analysis?

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## LESSON : 6

### DEMAND FORECASTING

**Need of Demand Forecasting :** Demand forecasting is predicting future demand for a product. The information regarding future demand is essential for planning and scheduling production, purchase of raw materials, acquisition of finance and advertising. It is much more important where a large-scale production is being planned and production involves a long gestation period. The information regarding future demand is essential also for the existing firms for avoiding under or over-production. Most firms are, in fact, very often confronted with the question as to what would be the future demand for their product. For, they will have to acquire inputs and plan their production accordingly. The firms are hence required to estimate the future demand for their product. Otherwise, their functioning will be shrouded with uncertainty and their objective may be defeated.

An important point of concern in all business activities is to assess the future business trend whether it is going to be favourable or unfavourable. This assessment helps the top management in taking appropriate policy decisions in advance. If sales are expected to rise substantially after, say, 10 years, it will call for measures to build adequate productive capacity well in advance so that future profit potential is not lost to the rival producers. This essentially relates to long-term planning.

On the other hand, if sales of a product are expected to go up in the very near future, it will be prudent on the part of the management to make the needed

adjustments in production schedule and take suitable steps immediately to ensure that sufficient stocks are available with given plant capacity as soon as needed. This involves short-term planning.

Irrespective of the length of future time period one is interested in, the planners and policy makers need to know the possible future trends in relation to several variables, which is made possible through forecasting. In this context, forecasting provides knowledge about future trends and deals with the methods of acquiring this knowledge.

Due to dynamic nature of market phenomenon demand forecasting has become a continuous process and requires regular monitoring of the situation.

Demand forecasts are first approximations in production planning. These provide foundations upon which plans may rest and adjustments may be made. *“Demand forecast is an estimate of sales in monetary or physical units for a specified future period under a proposed business plan or program or under an assumed set of economic and other environmental forces” planning premises outside the business organisation for which the forecast or estimate is made”*.

Sales forecast is an estimate based on some past information, the prevailing situation and prospects of future. It is based on an effective system and is valid only for some specific period. The following are the, main components of a sales forecasting system:

- (i) Market Research Operations to get the relevant and reliable information about the trends in market.
- (ii) A data processing and analysing system to estimate and evaluate the sales performance in various markets.

- (iii) Proper co-ordination of steps (i) and (ii) and then to place the findings before the top management for making final decision.

In this lesson, we will discuss the important methods of estimating and forecasting demand. The techniques of forecasting are many, but the choice of a suitable method is a matter of experience and expertise. To a large extent, it depends also on the nature of the data available for the purpose. In economic forecasting, classical methods use historical data in a rather rigorous statistical manner for making the future projections. There are also less formal methods where analyst's own judgment plays a greater part in picking, choosing and interpreting the available data than the statistical tools.

### **TECHNIQUES OF FORECASTING DEMAND**

**Survey Method :** Survey method are generally used where purpose is to make short-run forecast of demand. Under this method, surveys are conducted to collect information about consumers intentions and their future purchase-plans.

This method includes :

- (i) survey of potential consumers to elicit information on their intentions and plan;
- (ii) opinion polling of experts, i.e., opinion survey of market experts and sales representative, and through market studies and experiments.

The following techniques are used to conduct the survey of consumers and experts.

#### **Consumer Survey Methods :**

The consumer survey method of demand forecasting involves direct interview of the potential consumers. It may be in the form of :

- \* complete enumeration, or
- \* sample survey.

These consumer survey methods are used under different conditions and for different purposes. Their advantages and disadvantages are described below.

### **Direct Interview Method :**

The most direct and simple way of assessing future demand for a product is to interview the potential consumers or users and to ask them what quantity of the product they would -be willing to buy at different prices over a given period say, one year. This method is known as direct interview method. This method may cover almost all the potential consumers or only selected groups of consumers from different cities or parts of the area of consumer concentration. When all the consumers are interviewed, the method is known as complete enumeration survey method, and when only a few selected representative consumers are interviewed, it is known as sample survey method. In case of industrial inputs, interview of postal inquiry of only end-users of a conduct may be required. These are described as follows :

### **Complete Enumeration Method :**

In this method, almost all potential users of the product are contacted and are asked about their future plan of purchasing the product in question. The quantities indicated by the consumers are added together to obtain the probable demand for the product. For example, if only  $n$  out of  $m$  number of households in a city report the quantity ( $d$ ) they are willing to purchase of a commodity, then total probable demand ( $D_p$ ) may be calculated as



$$D_p = d_1 + d_2 + d_3 + \dots + d_n \quad \dots\dots\dots (1)$$

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

where  $d_1, d_2, d_3$  etc. denote demand by the individual households 1, 2, 3 etc.

This method has certain limitations. It can be used successfully only in case of those products whose consumers are concentrated in a certain region or locality. In case of a widely dispersed market, this method may not be physically possible or may prove very costly in terms of both money and time. Besides, the demand forecast through this method may not be reliable for many reasons: (i) consumers themselves may not be knowing their actual demand in future and hence may be unable or not willing to answer the query; (ii) even if they answer, their answer to hypothetical questions may be only hypothetical, not real; and (ii) their plans may change with the change in factors not included in the questionnaire

**Sample Survey Method :**

Under this method, only a few potential consumers and users selected from the relevant market through a sampling method are surveyed. Method of survey may be direct interview or mailed questionnaire to the sample-consumers. On the basis of the information. obtained, the probable demand may be estimated through the following formula:

$$D_p = \frac{H_R}{H_s} (H.A_c) \quad \dots\dots\dots (1)$$

were  $D_p$  = probable demand forecast;  $H$ =census number of households from the relevant market;  $H_s$  = number of households surveyed or sample households;  $H_R$  = number of households reporting demand for the product;  $A_c$  = average expected consumption by the reporting households (= total quantity reported

to be consumed by the reporting households» number of households).

This method is simpler, less costly, and less time-consuming than the comprehensive survey method. This method is generally used to estimate shortterm demand from business firms, government departments and agencies, and also by the households who plan their future purchase.

Sample survey method is widely used to forecast demand. This method, however, has some limitations. The forecaster therefore should not attribute reliability to the forecast more than warranted. Besides, sample survey method can be used to verify the demand forecast made by using quantitative or statistical methods. Although some authors suggest that this method should be used to supplement the quantitative method for forecasting rather than to replace it; this method can be gainfully used where market area is localized.

#### **Expert-Opinion Method:**

It is one of the most widely used and influential forecasting technique where the opinions and intuition of management is utilised. The process brings together in an organised manner, personal judgements about the process being analysed. Main reliance is on human judgement.

In this method, the executive uses his own anticipation and what he hears from others. Outside experts are also consulted and the other executive heads are also required to give their opinion in the matter. Salesmen are to provide information about customer's attitude and preferences and the activities of competitors. Thus all possible information from the opinions of various persons is combined together to change the subjective opinions into quantitative forecasts.

No doubt experts and experienced managers can be useful as guides and serve as reliable source of information, but one has to make his own decision from all the opinions. Thus in this method broad guess is made by the executive incharge of a business. There are many advantages and disadvantages of opinion technique of forecasting:

**Advantages :**

- (i) Simple and easy to understand.
- (ii) No specialised skill is required.
- (iii) Low cost.
- (iv) It is based on the information or opinion of the persons who are directly involved in the system.
- (v) It can be used in case of new products where satisfactory data is not available.

**Disadvantages :**

- (i) Opinions and intuitions are highly subjective.
- (ii) Personal estimates are likely to be biased.
- (iii) Time required to take the decision may be more.
- (iv) results can be easily distorted.
- (v) This method is not useful for long term planning.

**Delphi Method :**

Delphi method of demand forecasting is an extension of the simple expert opinion poll method. This method is used to consolidate the divergent expert opinions and to arrive at a compromise estimate of future demand. The Process is simple.

Under Delphi method, the experts are provided information on estimates of forecasts of other experts along with the underlying assumptions. The experts may revise estimates in the light of forecasts made, by other. experts. The consensus of experts about the forecasts constitutes the final forecast. It may be noted that the empirical studies conducted in the USA have shown that unstructured opinions of the experts is most widely used technique of forecast. This may appear a bit unusual in as much as this gives the impression that sophisticated techniques, e.g., simultaneous equations model and statistical methods, are not the techniques which are used most often. However, the unstructured opinions of the experts may conceal the fact that information used by experts in expressing their forecasts may be based on sophisticated techniques. The Delphi technique can be used for cross-checking the information on forecasts.

### **Market Studies and Experiments :**

An alternative method of collecting necessary information regarding demand is to carry out market studies and experiments in consumer's behaviour under actual, though controlled, market conditions. This method is known in common parlance as market experiment method. Under this method, firms first select some areas of the representative markets - three or four cities having similar features, viz., population, income levels, cultural and social background, occupational distribution, choices and preferences of consumers. Then, they carry out market experiments by changing prices, advertisement expenditure, and other controllable variables in the demand function under the assumption that other things remain the same. The controlled variables may be changed over time either simultaneously in all the markets or in the selected markets. After such changes are introduced in the market, the consequent changes in

the demand over a period of time (a week, a fortnight, or month) are recorded. On the basis of data collected, elasticity coefficients are computed. These coefficients are then used along with the variables of demand function to assess the demand for the product.

Alternatively, market experiments can be replaced by consumer clinic or controlled laboratory experiment. Under this method, consumers are given some money to buy in a stipulated store goods with varying prices, packages, displays, etc. The experiment reveals the consumers responsiveness to the changes made in prices, packages and displays, etc. Thus, the laboratory experiments also yield the same information as the field market experiments. But the former has an advantage over the latter because of greater control over extraneous factors and its somewhat lower cost.

**Limitations:** The market experiment methods have certain serious limitations and disadvantages which reduce the reliability of the method considerably.

- (i) The experiment methods are very expensive. It cannot be afforded by small firms.
- (ii) Being a costly affair, experiments are usually carried out on a scale too small permit generalization with a high degree of reliability.
- (iii) These methods are based on short-term and controlled conditions which may not exist in an uncontrolled market. Hence the results may not be applicable in the uncontrollable long-term conditions of the market.
- (iv) The changes in socio-economic conditions taking place during the field experiments, such as local strikes or lay-offs, advertising program by competitors, political changes natural calamities, may invalidate the results.

- (v) “Tinkering with price increases may cause a permanent loss of customers to competitive brands that might have been tried”.

Despite these limitations, however, market experiment method is often used to provide an alternative estimate of demand, and also “as a check on results obtained from statistical studies.”. Besides, this method generates elasticity co-efficients which are necessary for statistical analysis of demand relationships.

### **Statistical Methods :**

Basically all statistical approaches of forecasting, project historical information into the future. These are based on the assumption that future patterns tend to be extensions of past ones and that one can make useful predictions by studying the past behaviour i.e. the factors. which were responsible in the past will also be operative to the same extent in future.

Some companies have detailed sales record item wise as well as territory wise. This sales record can be utilised to make useful predictions. The information should be complete with respect to events, policies, quality of the product etc. from period to period. Such information in general is known as Time series data. The time series for any phenomenon is composed of three components (i) Trend (ii) Seasonal variation and (iii) Random fluctuations. Trend exhibits the general tendency of the data and is known as long period or secular trend. This can be either upward or downward, depending on the behaviour.

Mostly trend is used for forecasting in practice. There are many methods to determine trend. Some of the methods are:

- (i) Graphical method.
- (ii) Least square method.
- (iii) Moving average method.

(i) **Graphical Method :** In this method the period is taken on X-axis and the corresponding sales value on y-axis and the points are plotted for given data on graph paper. Then a free hand curve passing through most of the plotted points is drawn. This curve can be used to forecast the values for future. The method is explained by the following example.

**Example 1 :** The demand for a product is continually diminishing. Estimate the demand for 2004 with the help of following information:

Year	1995	1996	1997	1998	1999	2000	2001
Demand (in 1000 units)	75	70	72	69	50	54	37

**Solution :** Plot a graph for the given data to find the demand for 2004 (see fig. 1). From the graph the demand for 2004 comes out to be approximately 20,000 units.

It is an approximate method as the shape of the curve mainly depends on the choice of scale for the graph and the individual who draws the free hand curve.

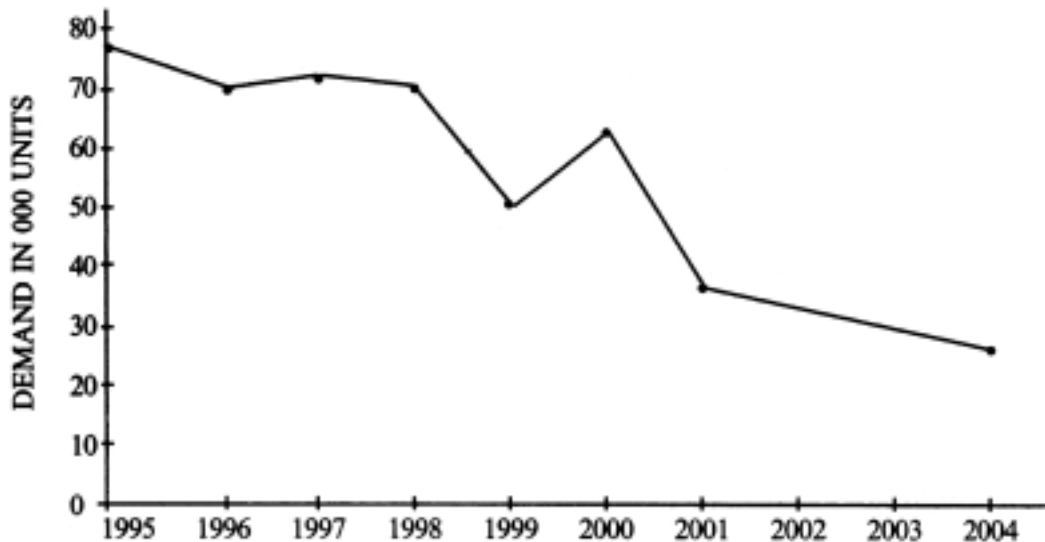


Fig. 1

(ii) Least Squares Method : This is one of the best method to determine trend. In most cases, we try to fit a straight line to the given data. The line is known as ‘Line of best fit’ as we try to minimise me sum of the squares of deviation between the observed and the fitted values of the data. The basic assumption here is that the relationship between the various factors remains unchanged in future period also.

Let Y denote the demand and X the period for a certain commodity. Then the linear relationship between Y and X is given by

$$Y = a + bX \quad \dots\dots\dots (3)$$

the nature of the relationship is determined by the values of a and b. The values of a and b can be estimated with the help of the pass information about Y and X. If x and y denote the deviations of X and Y from their respective means, then the least square estimates of a and b are given by

$$a = \frac{\Sigma y}{n}$$

$$b = \frac{\Sigma xy}{\Sigma x^2}$$

where n is the number of observations. The calculation of  $\Sigma y$ ,  $\Sigma xy$  and  $\Sigma x^2$  can be done with the help of given data on Y and X. The following example will help you in understanding this method.

**Example 2 :** The sales of a product is given below :

Years	1992	1993	1994	1995
Product Sales (in Rs.)	1,00,000	1,50,000	1,25,000	1,75,000

Fit a linear trend and forecast the sales for the year 1996.

**Solution:** Let years be denoted by X and product sales by Y. Then linear trend of year X is given by



$$Y = a + bX$$

The unknown constant 'a' and 'b' can be estimated by least square method. The calculation can be done in the following tabular form.

**Table 1**

Year X	x =	x <sup>2</sup>	Sales in Rs. '000 Y	XY
1992	-3	9	100	-300
1993	-1	1	150	-150
1994	1	1	125	125
1995	3	9	175	525
n = 4	$\Sigma x^2 = 0$	$\Sigma x^2 = 20$	$\Sigma Y = 550$	$\Sigma XY = 200$

$$\text{Now } a = \frac{\Sigma Y}{n} = \frac{550,000}{4} = 1,37,500$$

$$b = \frac{\Sigma XY}{\Sigma X^2} = \frac{200,000}{20} = 10,000$$

Hence the linear trend is

$$Y = 1,37,500 + 10,000 \left( \frac{X-1993.5}{.5} \right)$$

For X = 1996, forecast of Sales will be

$$\begin{aligned} Y &= 1,37,500 + 10,000 \left( \frac{1996-1993.5}{.5} \right) \\ &= 1,37,500 + 10,000 (5) \\ &= 1,87,500 \end{aligned}$$

**Advantages of least squares method :**

- (i) There is no need to conduct any sample survey as only past information

about sales is required.

- (ii) Method is simple and easy to understand.
- (iii) Under normal situations the method is likely to give reliable and accurate results.

**Disadvantages of least squares method:**

- (i) The method is based on some mathematical formulate which may not be understood by common man.
- (ii) The assumption that other things remaining constant may not hold good in practice.

**Exponential trend**

When sales (or any dependent variable) have increased over the past years at an increasing rate or at a constant percentage rate, then the appropriate trend equation to be used is exponential trend equation of the following forms.

- (1) Double-log trend of the form

$$Y = aT^b \quad \text{..... (1)}$$

or its double logarithmic form

$$\lg Y = \log a + b \log T$$

This form of trend equation is used when growth rate is increasing.

- (2) Polynomial trend of the form

$$Y = a + bT + cT^2 \quad \text{..... (1)}$$

In these equations a, band c are constants, Y is sales, T is time and c = 2.718.

Once the parameters of the equations are estimated, it becomes quite easy to forecast demand for the years to come.

The trend method is quite popular in business forecasting because of its simplicity. It is simple because only time-series data on sales are required.

The analyst is supposed to possess only working knowledge of statistics. Since data requirement of this method is limited, it is also expensive. Besides, trend method yields fairly reliable estimates of future course of demand.

### **Limitations :**

The trend method has, however, the following limitations.

The **first** limitation of this method arises out of its assumption that the past rate of change in the dependent variable will persist in future too. Therefore, the forecast based on this method may be considered to be reliable only for the period during which this assumption holds.

**Second**, this method cannot be used for short-term estimates. It cannot be used also where trend is cyclical with sharp turning points of troughs and peaks.

**Thirdly**, this method, unlike regression analysis, does not bring out the measure of relationship between dependent variables. Hence, it does not yield the necessary information (e.g., price and income elasticities) which can be used for future policy formulations. The analyst should bear these limitations in mind while making the use of this method.

### **(c) Box-Jenkins Method**

Box-Jenkins method of forecasting is used only for short term predictions. Besides, this method is suitable for forecasting demand with only stationary time-series sales data. Stationary time-series is one which does not reveal a long-term trend. In other words, Box-Jenkins technique can be used only in

those cases in which time-series analysis depicts only monthly or seasonal variation or variations that recur with some degree of regularity.

When sales data of various commodities are plotted, many commodities will show a seasonal or temporal variation in sales. For examples, sale of woolen clothes will show a hump during months of winter in all the years under reference. The sale of New Year Greeting Cards will be particularly very high in the last week of December every year. Similarly sale of desert coolers is very high during the summers each year. This is called seasonal variation. Box-Jenkins technique is used for predicting demand where time-series sales data reveal this kind of seasonal variations.

According to Box-Jenkins approach, any stationary time-series data can be analysed by the following three models:

- (i) auto regression model,
- (ii) moving average model, and
- (iii) auto regressive moving average model.

The three models are, in fact, the three stages of Box-Jenkins method. The auto regressive-moving average model is the final form of the Box-Jenkins model. The purpose of three models is to explain movements in the stationary series with minimised error term, i.e., the unexplained components of stationary series.

The steps and models of Box-Jankins approach are described briefly here with the purpose of acquainting the reader with this approach rather than providing the entire methodology.

## Steps in Box-Jenkins Approach

As mentioned above, Box-Jenkins method can be applied to only stationary time-series. Therefore, the first step in Box-Jenkins approach is to eliminate trend from the time-series data. Trend is eliminated by taking first differences of time-series data, i.e. subtracting observed value of one period from the observed value of the preceding year. After trend is eliminated, stationary timeseries is created.

The **second step** in the Box-Jenkins approach is to check whether there is seasonality in stationary time-series. If a certain pattern is found to repeat over time, there is seasonality in stationary time-series.

The **Third step** involves use of models to predict the sales in the intended period.

Let us now describe briefly the Box-Jenkins models which are used in the same sequence.

### (i) Autoregressive Model

In a general auto regressive model, the behaviour of a variable in a period is linked to the behaviour of the variable in future periods. The general form of the auto regressive model is given below :

$$Y_t = a_1 Y_{t-1} + a_2 Y_{t-2} + \dots + a_n Y_{t-n} + e_t \quad \dots\dots\dots (6)$$

This model states that the value of Y in period t depends on the values of Y in periods t-1, t-2, t-n. The term  $e_t$  is the random portion of  $Y_t$  that is not explained by the model. If estimated value of one or some of the coefficients.  $a_1, a_2 \dots a_n$  are different from zero, it reveals seasonality in data. This completes the second step.

The model (6), however, does not specify the relationship between the value of Y and residuals ( $e_t$ ) of previous periods. Box-Jenkins method uses moving average method to specify the relationship between  $Y_t$  and  $e_t$  values of residuals in previous years. This makes the third step. Let us now look at the moving average model of Box-Jenkins method.

**(ii) Moving Average Model**

The moving average model estimated  $Y_t$  in relation to residuals ( $e_t$ ) of the previous years. The general form of moving average model is given below :

$$Y_t = m + b_1 e_{t-1} + b_2 e_{t-2} + \dots + b_p e_{t-p} + e_t \quad \dots\dots\dots (7)$$

where m is mean of the stationary time-series and  $e_{t-1}, e_{t-2}, \dots, e_{t-p}$  are the residuals, the random components of Y in t-1, t-2, t-p periods, respectively.

(c) Method of Moving Averages: This method can be used to determine the trend values for given data without going into complex mathematical calculations. The calculations are based on some predetermined period in weeks, months, years etc. The period depends on the nature of characteristics in the time series and can be determined by plotting the observations on graph paper.

A moving average is an average of some fixed or pre-determined number of observations (given by the period) which moves through the series by dropping of top item of the previous averaged group and adding the next item below in each successive average.

The calculation depends upon the period to be odd or even.

In the case of odd order periods (3,5,7,.....) the average of the observations

is calculated for the given period and the calculated value is written in front of central value of the period e.g. for a period of 5 years, the average of the values of five years is calculated and is recorded against the third year. Thus in case of five yearly moving averages, first two years and last two years of the data will not have any average value.

If period of observations is even e.g. four years; then the average of the four yearly observations is written between second and 3rd year values. After this centering is done by finding the average of the paired values. The method is illustrated by solving example 4.

The even order periods creates the problem of centering between the periods. Due to this generally odd order periods are preferred.

The calculated values of the moving averages became the basis for determining the expected future sales.

If the underlying demand pattern is stationary i.e. at a constant mean demand level expect, of course, for the superimposed random fluctuations or noise, the moving averages method provided a simple and good estimate. In this method equal weightage is assigned to all the periods chosen for average.

The moving average method for forecasting suffers from the following defects:

- (i) records of the demand data have to be retained over a fairly long period.
- (ii) if demand series depicts trend as against the stationary level the moving average method would proving forecasts that lags the original series.

**Example 3 :** The following are the annual sales in thousands of a product during

the period 1965-1975. Find the trend of the sales using (i) 3 yearly moving averages and forecast the value for the year 1979.

Year	Sales in 000 units	Year	Sales in 000 units	Year	Sale in 000 units
1985	12	1989	18	1993	22
1986	15	1990	17	1994	25
1987	14	1991	19	1995	24
1988	16	1992	20		

**Solution :** The trend values can be calculated in the following tabular form :

**Table 12.2**

Year	Sale in 000 units	Three yearly moving total	3 yearly moving average Trend values
1985	12		
1986	15	41	$41/3 = 13.7$
1987	14	45	$45/3 = 15$
1988	16	48	$48/3 = 16$
1989	18	51	$51/3 = 17$
1990	17	54	$54/3 = 18$
1991	19	56	18.7
1992	20	61	20.2
1993	22	67	22.3
1994	25	71	23.7
1995	24		



e.g. 41 = value of 1985 + value of 1986 + 1987

= 12 + 15 + 14 = 41 written at the central period 1986 of the years  
1985, 86 and 87

### **Business Indicators :**

Business indicators refer to the time series data on important business and economic activities in key sectors of the economy. These time series are representative, in one way or the other, of the aggregate business and economic activity in the economy as a whole. It is more in the sense that the overall behaviour of such aggregate activities has been found to be systematically associated with the pattern of cyclical movements in the indicator series.

An intelligent analysis and understanding of the time duration and the amplitude of cyclical ups and downs in the selected indicators provide useful information regarding the future behaviour of overall cyclical movements. This holds only long as these are specifically related to a particular business activity.

How correctly a business indicator will help predict the immediate future conditions facing a particular business organisation depends to a large extent on the judicious choice of an indicator in terms of its relevance to the type of business in question. The selection of relevant business indicators is so important that a large amount of statistical intelligence is required to go into its final choice before any formal statistical technique is applied for purposes of analysis.

The U.S. National Bureau of Economic Research, after having carefully studied about 800 time series which could possibly be used as business indicators, have selected around 20 time series. Such series individually follow definite pattern

of cyclical movements vis-a-vis those in the general business activity. The cyclical movements in these selected series have been found to be systematically related to successive cycles in the overall business activity in a definite way. While the turning points in the case of a few precede the cyclical turning points in the general business activity, those in some others coincide, and in yet some others follow, the turning point in the latter.

The indicators that were found to precede the general business activity have come to be known as leading series (or leading indicators). The leading indicators are of crucial importance in providing information about the upward and downward movements, and the consequent peaks and troughs, in the general economic activity at least a few months in advance. This happens because by virtue of their relationship with the general economic activity, the cyclical movements in the leading series tend to occur earlier than the beginning of the turning points to the overall business and economic activity in the economy.

Business indicators that follow the movements in general business activity are termed as lagging series, while those coinciding the movements in general business activity are known as coincident series. The significance of both these series lies in confirming that turning points in the general business activity have actually started occurring. Thus, if the leading indicators have signalled an upward trend in the general business activity, the coincident series will eventually start weakening. Such a development calls for a careful observation of how all the three types of series are likely to behave in the future.

Although the cyclical indicators approach has been found to be quite beneficial in predicting the cyclical turning points. This does- not necessarily indicate the existence of any causal relationship between the two series.

**Regression Method :** Regression analysis is the most popular method of demand estimation. This method combines economic theory and statistical techniques of estimation. Economic theory is employed to specify the determinants of demand and to determine the nature of relationship between the demand for a product and its determinants. Economic theory thus helps in determining the general form of demand function. Statistical techniques are employed to estimate the values of parameters in the equation estimated.

In regression techniques of demand forecasting, the analysis estimate the demand function for a product. In the demand function, quantity to be forecast is a “dependent variable and the variables that affect or determine the demand (the dependent variable) are called as ‘independent’ or ‘explanatory’ variables. For example, demand for cold drinks in a city may be said to depend largely on ‘per capita income’ of the city and its population. Here demand for cold drinks is a ‘dependent variable’ and ‘per capita income’ and ‘population’ are the ‘explanatory’ variables.

**Simple Regression :**

In simple regression technique, a single independent variable is used to estimate a statistical value of the ‘dependent variable’, that is, the variable to be forecast. The technique is similar to trend fitting. An important difference between the two is that, in trend fitting, independent variable is ‘time’ (t) whereas in regression equation, the chosen independent variable is the single most important determinant of demand. Besides, the regression method is less mechanical than trend fitting method of projection.

For an illustration, consider the hypothetical data on quarterly consumption of sugar given in table.

**Table X : Quarterly Consumption of Sugar**

<b>Year</b>	<b>Population (millions)</b>	<b>Sugar Consumed (000) tonnes</b>
1985-86	10	40
1986-87	12	50
1987-88	15	60
1988-89	20	70
1989-90	25	80
1990-91	30	90
1991-92	40	100

Suppose we have to forecast demand for sugar for 1994-95 on the basis of 7year data given in Table. This can be done by estimating a regression equation of the form

$$Y = a + bX \quad \dots\dots\dots (8)$$

Where Y is sugar consumed, X is population and a and b are constants.

Like-trend fitting method, Eq. 8 can be estimated by using the ‘least square’ method. The procedure is the same as shown in Table X. That is, the parameters a and b can be estimated by solving the following two linear equations:

$$\Sigma Y = na + b\Sigma X \quad \dots\dots\dots (i)$$

$$\Sigma XY = \Sigma xa + b\Sigma x^2 \quad \dots\dots\dots (ii)$$

The procedure of calculating the terms in equations (i) and (ii) above is presented in Table X.

**Table X : Calculation of Terms in Linear Equations**

<b>Year</b>	<b>Population (X)</b>	<b>Sugar consumed (Y)</b>	<b>X<sup>2</sup></b>	<b>XY</b>
1985-86	10	40	100	400
1986-87	12	50	144	600
1987-88	15	60	225	900
1988-89	20	70	400	1400
1989-90	25	80	625	2000
1990-91	30	90	900	2700
1991-92	40	100	1600	4000
$\Sigma n=7$	$\Sigma X_1 = 152$	$\Sigma Y_1=490$	$\Sigma X^2 =3994$	$\Sigma X_1 Y_1 = 12000$

By substituting the values from Table into equation (i) and (ii), we get

$$490 = 7a + 152 b \quad \dots\dots (iii)$$

$$12,000 = 152a + 3994 b \quad \dots\dots (iv)$$

By solving equations (iii) and (iv), we get

$$a = 27.42$$

and  $b = 1.96$

By substituting values for a and b in Eq. (8), we get the estimated-regression equation as

$$Y = 27.44 + 1.96 X$$

Given the regression equation (8), the demand for sugar for 1994-95 can be easily projected if population for 1994-95 is known. Supposing population for

1994-95 is projected to be 70 million, the demand for sugar in 1994-95 may be estimated as

$$Y = 27.44 + 1.96 (70) = 164,640 \text{ tonnes}$$

The simple regression technique is based on the assumption that (i) independent variable will continue to grow at its past growth rate, and (ii) the relationship between the dependent and independent variables will continue to remain the same in future as in the past.

### **Multi-variate Regression :**

The Multi-variate regression equation is used where demand for a commodity is deemed to be the function of many variables or in cases in which number of explanatory variables is greater than one.

The procedure of multiple regression analysis may be briefly described here. The first step in multiple regression analysis is to specify the variables that are supposed to explain the variations in the demand for the product under reference. The explanatory variables are generally chosen from the determinants of demand, viz., price of the product, price of its substitute, consumers' income, and their taste and preference. For estimating the demand for durable consumer goods, (e.g., TV sets, refrigerators, house, etc.), the other variables which are considered are availability of credit and rate of interest. For estimating demand for capital goods (e.g., machinery and equipments), the relevant variables are additional corporate investment, rate of depreciation, cost of capital goods, cost of other inputs (e.g., labour and raw materials), market rate of interest, etc. These variables are treated as independent variables.

Once independent variables are specified, the second step is to collect timeseries data on the independent variables. After necessary data are collected, the next step is to specify the form of equation which can appropriately describe the nature and extent of relationship between the depend and independent variables.

The final step is to estimate the parameters in the chosen equations with the help of statistical techniques. The multivariate equations cannot be easily estimated manually. They have to be computerised.

### **Diffusion Index :**

Diffusion index as a technique of predicting turning points in the general business activity is an improvement over the business indicator approach in so far as it makes up the deficiency of the latter for lack of uniformity in the duration and amplitude of cyclical fluctuations in the leading series. The computation of diffusion index requires counting of the number of leading series and expressing them as a percentage of the total number of series in the leading group.

For example, if there are 20 leading series in all, and if all of them are expanding cyclically, the diffusion index is 100. If 5 series are declining cyclically, the diffusion index is 75, which means that 15 series are still expanding.

The diffusion index is interpreted as follows:

- (i) So long as this index remains above 50 per cent, a decline in the index indicates that the overall business activity is in a state of expansion. Once the index reaches the 50 per cent mark, the overall business activity is considered to have reached the peak of expansion.
- (ii) A decline in the index below 50 per cent is indicative of the process of contraction having set in. As long as the index remains below the 50 per cent mark, the overall business activity is in a state of contraction and eventually reaches the trough. Revival starts only when it rises above the 50 per cent mark.
- (iii) The 50 per cent mark is also decisive in predicting the turning points in the overall business activity. As the index tends to approach the 50 per cent mark from above, it is indicative of the beginning of the upward trend in the overall business activity.

Turning points in business cycles predicted in line with the trends in the diffusion index are reliable only so long as all the series behaving in a particular direction move cyclically more or less quite closely with one another, and that all the series have equal importance with respect to the aggregate. In practice these conditions are met fairly well.

However, the use of diffusion Index is not an easy task. It is mainly because the construction of a diffusion index requires determining whether particular series is cyclically expanding or contracting, which is an extremely difficult and laborious task.

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**Questions :**

1. Discuss meaning and significance of Demand Forecasting.
2. Discuss critically the different methods of demand forecasting.
3. Outline the trend projection method of demand forecasting.



4. What are the possible consequences if a large-scale firm places its project in the market without having estimated the demand for its product?
5. What would be the appropriate variables for estimating demand for (a) steel, (b) sugar, (c) petrol, and (d) toys by the regression method?
6. Plot the following data on a graph and find the trend equation for sales :
- |                     |      |      |      |      |      |      |      |
|---------------------|------|------|------|------|------|------|------|
| Year                | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1976 |
| Total sales (units) | 115  | 102  | 305  | 300  | 95   | 306  | 403  |
7. The following are the available data of sales for some years :
- |                            |      |      |      |      |
|----------------------------|------|------|------|------|
| Years                      | 1990 | 1991 | 1993 | 1994 |
| Sales (in lakhs of Rupees) | 50   | 70   | 60   | 80   |
- Assuming the same relationship holds true for future, forecast the sales for the year 2002 by applying least square method.
- Hint.** To make  $\Sigma X = 0$ , time deviations from 1992 may be taken.
- Ans.** 115 in Lakhs of rupees.
8. Explain the regression method of demand forecasting. Compare this method with trend method.
9. You are given the following data :
- |   |   |   |    |    |    |    |    |    |
|---|---|---|----|----|----|----|----|----|
| X | 3 | 6 | 8  | 10 | 13 | 13 | 13 | 14 |
| Y | 8 | 6 | 10 | 12 | 12 | 14 | 14 | 20 |
- Estimate the regression equation  $Y = a + bX$
10. What are the different techniques of survey method? Under what conditions are complete enumeration and sample survey methods are chosen?
11. What is Delphi method? What is the use of this method in demand forecasting?
12. Explain Business indicator method of demand forecasting.

## **LESSON : 7**

### **PRODUCTIVITY**

#### **INTRODUCTION**

“Productivity is the ratio of the input facilities to the output of goods and services – The company must achieve high total factor productivity which is the ratio of the market value of its output to the cost of all the resources required to produce the output.”

– **James Dilworth**

Policy formulation in modern times has become a very complicated and time consuming phenomenon. Business enterprises now-a-days want to plan their future strategies taking into account their past performance. There are number of measures viz, productivity, profitability, rate of return etc. to illustrate the past performance of an enterprise. Often we see productivity reported as output per hour worked, which measures only labour productivity, whereas, total factor productivity includes the cost of such factors as labour, materials, capital energy, and any other major inputs required to provide the output. But all of these indicators have some sort of direct or indirect relationships between input and output factors. But none of measures is able to determine or evaluate the overall performance of an enterprise in isolation. In this lesson, one of these factors, namely productivity has been discussed. Infact, the only way of raising the living standards of the society is to increase productivity of factors of production. Productivity can be increased by increasing output from each unit of input available.

## **MEANING OF PRODUCTIVITY**

In general sense, productivity is some sort of relationship between inputs and outputs of an enterprise. It is the quantitative relationship between what we produce and the resources used. The concept of productivity has many dimensions. It can relate to every item/activity on which money is spent to get the final product. Some of the definitions given below explain the fundamental concept of productivity.

### **DEFINITIONS**

The following definitions are given for explaining the concept of productivity :

- i. “Productivity is a measure of-how much input is required to produce a given output i.e. it is ratio of output to input.” – N. Charry
- ii. “Productivity is the ratio between the amount produced and the amount of resources used in the course of production. The resources may be any combination of materials, machine, men, and space.” – B.S. Goel
- iii. “Productivity means a balance between all factors of production that will give the maximum output with the smallest effort.” – P.F. Drucker
- iv. “The ratio between the volume of output as measured by production indices and the corresponding volume of labour input as measured by production indices and the corresponding volume of labour input as measured by employment indices.” – I.L.O
- v. “Productivity is an attitude of mind. It is a mentality of progress, of the constant improvement of that which exists. It is the certainly of being able to do better than yesterday and continuously. It is constant adaptation

of economic and social life to changing conditions. It is the continual effort to apply new techniques and methods. It is the faith in human progress.” – European Productivity Council.

Thus there can be a number of measures indicating the level of performance corresponding to each input. In general sense, productivity is measure of how much input is required to produce a given output i.e.

$$\text{Productivity} = \frac{\text{Measure of output}}{\text{Measure of input}}$$

Inputs in a business organisation can be labour, capital etc. The measure can be expressed in terms of money value or in terms of quantity. In most cases output will be goods and services produced, for which input will be men, money, equipment, power plant facilities and other items used in the process of production. Total productivity of the firm can be defined as :

$$\text{Pt.} = \frac{\text{Qt.}}{\text{L+C+R+M}}$$

Where Pt = Total productivity

L = Labour Input

C = Capital Input

R = Raw material and purchased parts input

M = Other miscellaneous goods and services

Qt = Total output

All the input and output factors are measured in some common unit. Productivity is a measure of how well the resources are utilised to achieve given objectives.

## **IMPORTANCE OF PRODUCTIVITY**

The concept of productivity is of great significance for under developed and developing countries. In both the cases there are limited resources which should be used to get the optimum output i.e. there should be tendency to perform a job by cheaper, safer and quicker ways. The aim should be optimum use of resources so as to provide maximum satisfaction with minimum efforts and expenditure.

Productivity analysis and measures indicate the stages and situations where improvement in the working of inputs is possible to increase the output. The productivity Indicators can be used for different purposes viz. comparison of performances for various organizations, contribution of different input factors, bargaining with trade unions etc.

## **FACTORS AFFECTING PRODUCTIVITY**

Productivity is taking more and more the meaning of excellence, which has to come about in all types and levels of jobs and responsibilities. Improving productivity would mean encouraging excellence. As John W. Hardner said, “An excellent plumber is infinitely more admirable than an incompetent philosopher : A commitment to excellence means to constantly strive for producing the highest possible results. It means continuous improvement. In such a case, ‘standards’ for productivity may come in the way of pursuing excellence. Because standards prescribe what is good enough’; unless a standard is not seen as rigid concept. Standards should, therefore, be for the very purpose of better future transformation. A standard should be the base-line from which further improvements can be made.

We cannot escape the fact that productivity and society are closely linked, just as the organisation and the society are inseparable. The society’s, as also

organizations' thinking determines productivity. Productivity is definitely contributed to by improved methods, procedures, techniques and systems but it is much more than that. In true sense, productivity is a state of mind which is affected by a large number of factors.

All the factors which are related to input and output components of a production process are likely to affect productivity. These factors can be divided in two main categories namely.

### **CATEGORY – I**

#### **INPUT RELATED FACTORS**

- a) **Primary factors :** These are effort and working capacity of an individual as we say that the productivity is a state of mind. One who believe in productivity can take the stock of the situation that how one will ensure the productivity.
- b) **Organisational factors :** These are related to the design and transformation process required to produce some items, the nature of training and other skills imparted to workers to perform certain operations in a production process, control and various other incentives.
- c) **Conventions and traditions of the organisation :** The activities of labour unions, medical facilities, workers and executives understanding, etc. are part of this.

### **CATEGORY – II**

#### **OUTPUT RELATED FACTORS**

- a) Research and development techniques, improvement in technology and efficient sales strategy of the organisation will lead to improvement in output.

- b) Efficient use of resources, better stores control, production control policy, maintenance of machines etc. will minimise the cost of production.
- c) Quality improvement process will ensure the minimum wastage and in-tern better productivity.

The factors affecting the productivity can also be divided into four major classes viz,

- a) Technological
- b) Managerial
- c) Labour; and
- d) External factors

The technological factors can increase the output per unit of input substantially. These can be defined in terms of technology employed, tools and raw material used, etc.

Managerial factors can be located in organizational structure, scheduling of work, financial management, layout, innovations, personnel policies and practices, work environment, material management etc.

Labour factors are, characterised by the degree of skills of the workforce, health, attitude towards management, training, discipline etc. Greater the congruence between the skills of work force and technology employed better would be the productivity.

External factors are innumerable and identifiable in the environment with which an organisation has to interact e.g. the power and transport facilities, tariffs and taxes etc. have important bearing on the levels of productivity.

## **HOW TO IMPROVE THE PRODUCTIVITY**

Productivity can be increased in a number of ways. It can be increased either by reducing the input for the same level of output or by increasing the output with the same level of input or by combination of both. This can be achieved by elimination of waste, by using improved technology, better production design and management efforts. There can be increase in productivity by reducing downtime of maintenance, reduction in material input, better quality of goods, improved utilization of resources, reduction in working capital requirements, reduction in inventory size, improvement in manpower skills through training etc. Out put can be increased by better leadership management. When employees are better motivated, output can be increased.

Decision making is a key factor which affects productivity. Better decisions obtained through adequate and timely information systems definitely will improve effectiveness and efficiency of the organizations.

Productivity can be considerably improved by improving the performance of various factors affecting productivity. The measure to improve productivity can be :

- i) Better planning and training of employees, improved jobs and communication and effective management through CPM/PERT methods.
- ii) Use of time and motion studies to study and improve work performance. It enables to assess the quantum of work which can be used for planning at control.
- iii) Better transportation and material handling system.
- iv) By providing work incentives and other benefits to workers.
- v) Workers involvement in decision making and working of organizations.



- vi) Improvement in technology of production process and nature of raw material and its quality.
- vii) Simplification, standardisation and specialisation techniques.
- viii) Better and efficient utilization of resources at the disposal of the enterprise.
- ix) Use of linear programming and other quantitative techniques for better decision making.
- x) ABC analysis to identify more important items and then apply inventory control to reduce capital investment.
- xi) Value engineering to reduce material content by good design.

### **METHODS FOR MEASUREMENT OF PRODUCTIVITY**

There are a number of ways to measure productivity. The main criteria of measuring productivity are :

- a) In terms of input performance by calculating changes in output per unit of input.
- b) On the basis of output performance by calculating change in input per unit of output.

Following are some of the methods in common use :

$$(I) \quad \text{Labour Productivity} = \frac{\text{Amount of Output}}{\text{Amount of Labour}}$$

Where output can be measured in total quantity produced and labour can be measured in total man-hours required to produce that output. Output and labour can also be measured in terms of their value in money units.

$$\begin{aligned}
\text{(II) Capital Productivity} &= \frac{\text{Turn over}}{\text{Capital Employed}} \\
\text{(III) Profit Productivity} &= \frac{\text{Profit}}{\text{Investment}} \\
\text{(IV) Energy Productivity} &= \frac{\text{Output}}{\text{Quantity of Energy used}} \\
\text{(V) Overall Productivity} &= \frac{\text{Output}}{\text{Labour + Capital + Other inputs}}
\end{aligned}$$

Each kind of measure needs some specific kind of information. The appropriate measure can be selected on the basis of the information available and the objective of measurement. In fact, the measure of productivity indicates the performance of input namely labour and capital in an enterprise. Increase in output is not an indication of increase in productivity. Production is an absolute measure and productivity is a relative measure.

## **VI) INPUT – OUTPUT ANALYSIS METHOD**

Input–output analysis is a method to study the interdependence of input and output factors of a production system. It tries to locate the equilibrium between input and output factors. If  $Y$  denotes the final demand of an industry and  $A$  is the matrix of inputs, then the output for each industry can be determined by the relation.

$$X = (I - A)^{-1}Y$$

**(146)**

Where I is the identity matrix and X is the matrix of estimated outputs. (I-A) is known as technology matrix.

Input output analysis can be used to study the productivity of an enterprise. The index of productivity can be defined as :

$$\frac{Q_1 (I-A_1) P_o}{Q_o (I-A_o) P_o}$$

Where  $P_o$   $Q_o$  is the value of output in base year and  $Q_1 P_o$  is the output value in current year based on base year prices. (I-A<sub>1</sub>) is technology matrix in current year and (I-A<sub>o</sub>) is the technology matrix in base year.

### **Productivity and Work study :**

A team from International Labour organisation demonstrated to the management that given adequate supervision with the same plant and equipment the existing staff can secure distinct improvements in productivity. Labour is an important output and plays significant role in attaining desired level of productivity. The productivity of an organisation can be improved by improving the performance of labour. It is observed that increased incentives had to better performance. This co-ordinates the objectives of individuals into industry's objectives sometimes without any genuine increment of effort on the part of the worker, his output may increase just by learning new methods. By introducing work study methods, and evaluation of new methods and procedures of doing work, productivity can improved. However, work study is not exclusively directed upon the operator. It gives due attention to other inputs also.

## **EXERCISE QUESTIONS**

1. What do you mean by productivity? What is its importance in present times ?
2. Define productivity. Discuss the methods of measuring the productivity.
3. Explain main factors affecting productivity.
4. Write a detailed note on productivity and methods for measuring the productivity.
5. Discuss the factors on which productivity depends.

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## **LESSON : 8**

### **TIME AND MOTION STUDY**

Production is vital to competitors in the marketplace. Companies must keep their prices reasonable and competitive, and they must be able to respond quickly to changes in demand. The productivity of both labour and capital is important in keeping companies competitive. In recent years the rate of productivity improvement in several industrialized nations has exceeded that of the United States, and many U.S. Companies have lost part of their market. Both manufacturing and service companies throughout the world are working to increase their rates of productivity, which in turn has improved the current and projected rate of improvement in the country's overall productivity. At the individual worker level the productivity of labour is measured in terms of a time standard, sometimes simply called a standard that expresses output per unit of time. Work standards are determined through some means of work measurement such as time study standard data, historical records, work sampling, employee self timing or motion study. The discussion in the present lesson will be on time and motion study only.

#### **TIME STUDY**

Time study methods were originally proposed by Frederick Taylor and were later modified to include a performance rating adjustment. They have now

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

Fundamentally, time study or stopwatch time study is performed by timing a worker as the job is performed, summing the times for the necessary elements of the job, adjusting this time if an abnormal work pace was observed, and then adding time for personal and rest breaks.

The purpose of time study is to determine as to how much time is required to perform a job that would be considered as average time or normal time. The process of time study itself is the process of systematically recording, analyzing and synthesizing the times required to perform a motion or a series of motions relevant to the given job. Time study was pioneered by Frederick Taylor, known as the father of scientific management, when he began a systematic study of how the workers performed their jobs in 1881. In one of his studies of 120 girls who were working 10 hours a day inspecting ball bearings for bicycles, he was able to reduce the work force down to 35 girls and the time of work to 8 hours a day, with appreciable improvement in inspection accuracy for the same amount of output. This he was able to achieve by studying the job scientifically and by improving upon the methods of operations.

### **Steps Involved in a Time Study**

The time study approach to work measurement uses a stopwatch or

other timing device to determine the time required to complete given tasks. Assuming a standard is being set, the worker must be trained and must use the prescribed method while the study is being conducted. The following are the steps involved in conducting a time study:

### **1. Selecting the Job**

Analysts who perform time study should select an operator who is properly trained and uses the proper work method. They should tell the worker that they want to observe and time the job through a considerable number of cycles and should try to allay any fears or suspicions the worker may have. After an analyst has observed the job sufficiently to identify the necessary work involved, he or she lists the necessary work elements and begins to record, the amount of time each element requires. Dividing the work into elements can be helpful for several reasons :

- (a) The list of elements and their times helps describe the work method and shows how the time for performing the job is distributed among the elements. Longer work elements often are the targets for methods improvement efforts because they account for the greatest portion of the total.
- (b) A worker's rate of performance may not be the same for all elements of a job. The time study analyst must adjust the operator's time to

represent the time that the average worker would take. If the operator is much faster than the average worker for some work elements, these elements should be given a different performance rating than those performed more slowly.

- (c) Machine-paced elements should be separated from those that are under the control of the operator.
- (d) Some elements may not be repeated every cycle but may recur every tenth cycle, every sixteenth cycle, or at some other interval.
- (e) Times for similar work elements from several jobs may be compared to help keep standards uniform.
- (f) Element times can be collected and cataloged into “standard data” that can possibly be combined to arrive at standards for other jobs without the need for time study.

To illustrate, we will use a typing job which includes the following elements :

- Read rough draft.
- Correct errors.
- Set up typewriter.
- Type letter.
- Proofread letter.



- Correct errors.
- Type envelope
- Get signature.
- Mail letter.

Let us assume that the method has been determined for doing each of these elements and we are now ready to study the time required for each one.

Figure 1 is a typical time study chart used to record the data taken during a time study. Along the left side of the sheet is each element in the job. Along the top in each cycle or observation which is made. The time study person would observe several cycles of work being performed and record the time for each element from a stopwatch. As a result, the times shown in Figure 1 are recorded.

## **2. Determining The Number of Cycles to Time**

The number of cycles that should be timed increases with the degree of accuracy desired for the standard and with the variability of the observed times. After 10 or 15 cycles have been timed and some preliminary calculations have been made, the total number of cycles that should be timed can be determined by use of a formula or graph., Extreme time values, both high and low, for any element should be discarded and not used in estimating the variability of data because they might represent erroneous readings.

Sheet : 1 of 1													Date : 10/9/00											
Operation : Prepare letter													Part No. :											
Operator's Name : Karam Singh													Part Name											
Observer : Lal Singh													Shift : 1											
Begin : 9:30													Finish : 3:30		Units Finished : 10		Time in min. :							
Elements													1	2	3	4	5	6	7	8	9	10	Rating	Normal Time
1. Read rough Draft													.73	.85	.97	.65	.78	.84	.69	.74	.95	.88	95	.77
2. Correct errors													.10	.40	.21	.35	.25	.37	.41	.43	.48	.31	100	.35
3. Setup typewriter													.51	.63	.42	.30	.67	.51	.56	.40	.38	.41	105	.50
4. Type letter													1.65	2.03	2.15	1.50	2.20	1.80	1.93	1.75	1.76	1.85	110	2.05
5. Proofread letter													.60	.65	.50	.55	.67	.73	.69	.59	.68	.71	100	.64
6. Correct Errors													.85	.90	.93	.70	.97	.71	.83	.76	.87	.91	105	.88
7. Type envelope													.60	.51	.54	.56	.63	.65	.68	.48	.46	.61	110	.63
8. Get signature													-	-	-	-	-	-	-	-	-	-	-	-
9. Mail letter													.21	.20	.19	.18	.23	.21	.22	.23	.21	.19	110	.21
Allowances :													Total normal										6.03	
Personal and Fatigue													10%										× 1.15	
Delays													5% ] 15% Allowance										Standard	
																							6.93	

**Figure I : Time Study Observation Sheet**

## Formula For Sample Size

Assuming that a normal probability distribution applies, a confidence interval may be constructed that has a given probability (that is, “confidence”) that the interval will contain the actual mean time to perform the task. A 95 per cent confidence interval means that intervals developed by this procedure will contain the actual mean in about 95 per cent of the cases, so the probability is 0.95 that the actual mean is estimated within the desired accuracy  $A$ , expressed as a decimal fraction of the actual mean. The equation for the required number of observations is

$$N = \left( \frac{Zs}{A\bar{x}} \right)^2$$

where  $n$  = total number of observations that should be taken to provide desired accuracy

$\bar{x}$  = mean of the times already collected

$A$  = accuracy desired expressed as decimal fraction of the true value

$Z$  = standardized normal deviate that has  $(1-\text{confidence})/2$  as the area remaining in the tail of the distribution beyond the value of  $Z$

$s$  = estimated standard deviation of distribution of element times, based on observations already made.

A time-study analyst would observe several cycles, say 10 or 15, and compute  $n$  on the basis of the data obtained at that stage of the study. Sampling would then be continued until  $n$  observations were obtained. If the element

times are to be used to develop a catalog of times required to perform given parts of the cycle, the calculation of  $n$  should be based on data for the most constraining element - the one that yields the largest value of  $n$  (that is, the one with the largest coefficient of variation).

Suppose we are interested in estimating the actual mean time to perform element 5 of the task represented in Figure. Assume that we wish to provide 95 per cent confidence that the true mean time to perform element 5 is estimated within 10 per cent accuracy. To simplify the calculations, only the first six observations are used, even though at least two or three times this number of observations probably would be used in an actual study. The observed times for the six observations are shown in table I. The calculations used to estimate the sample size required to yield 10 per cent accuracy with 95 per cent confidence are also shown. This sample size is 8 observations.

**Table-I**  
**Observed Element Times for Six Observations**

Observation	Observed Element Time $x_1$	$X^2$
1	0.60	0.3600
2	0.65	0.4225
3	0.50	0.2500
4	0.55	0.3025
5	0.67	0.4489
6	0.73	0.5329
	<b>3.70</b>	<b>2.3168</b>

$$\bar{x} = \frac{\sum x}{n} = \frac{3.70}{6} = 0.6167$$

$$s = \sqrt{\frac{\sum x^2 - (\sum x)^2/n}{n-1}} = \sqrt{\frac{2.3168 - 3.70^2/6}{5}} = 0.0838$$

$$n = \left( \frac{Zs}{Ax} \right)^2 = \left[ \frac{1.96(0.0838)}{0.10(0.6167)} \right]^2 = 8$$

### 3. Adjustment for Worker's Pace

The objective of a time study is to arrive at a standard that is suitable for the normal employee; yet the employee who was timed may not have been working at a normal rate of speed. An adjustment called performance rating, pace rating, leveling, or normalizing is made to adjust the observed times to the time required by someone working at a "normal" pace. Rating is the process of comparing the worker's rate of performance with the observer's concept of a normal work rate. Notice that each element of the task in Figure I was assigned a rating before the normal time was computed. The normal pace is not some optimal rate that only the best workers can achieve. Generally a standard is established so that most employees can achieve it without overexertion. A normal work pace should be one at which qualified workers can work all day without undue fatigue.

Even though it is a company's prerogative to determine what it considers a normal pace, it is important that the company be consistent in its rating so as to provide equitable expectations for all its employees.

#### 4. Computing Normal Time

The normal time for a job is the time it should take a qualified worker to perform the essential elements of a job while working at a normal pace. The actual time is the amount of time taken by the particular worker who was studied, at the pace he or she worked during the study. The normal time (NT) can be found by multiplying the observed actual time (AT) for the essential elements of the job by the overall performance rating for the job as a ratio to the normal efficiency rating (usually 100 per cent).

$$NT = AT \times \frac{\text{performance rating}}{\text{normal efficiency rating}} \quad [I]$$

A worker who was working 15 per cent faster than what is considered a normal pace would be given a performance rating of 115 per cent. Equation [I] would add 15 per cent of this worker's time to determine the time that would be expected for the job when a worker was working at the normal pace. If we assume that an analyst had measured an actual time of 4.23 minutes for this job, the normal time would be

$$NT = 4.23 \times 1.15 = 4.86 \text{ minutes}$$

Working at the normal pace, a worker would be expected to take 4.86 minutes to perform the job.

#### 5. Computing Standard Time

Even though it would take only 4.86 minutes to perform the above

job at normal pace, a company would be unrealistic to allow only this amount of time for each job cycle. Workers need rest breaks during the day, and some delays are bound to occur. Standard times that are used for scheduling and pricing products should include time for unavoidable delays, personal time, and rest time to relieve fatigue. Personal, fatigue, and delay allowances are added as a percentage of the normal time so that the standard time (ST) is found by equation II.

$$ST = NT (1 + \text{allowances}) \quad \text{[II]}$$

Where the allowances are expressed as a decimal fraction of the normal time. Some guidelines for personal and fatigue allowances are shown in Figure II.

### **Delays**

Delays may occur on a job through no fault of the operator. He or she may have to wait for a crane to come and remove a work item from the machine and place another on it, for a computer to respond, or experience some other unavoidable delay. A company should incorporate time for unavoidable delays in standards. Conversely, time for avoidable delays should not be included in a standard. The percentages that should be allowed for unavoidable delays can be determined by a method called work sampling or ratio delay studies.

**Figure-II**

**Percentages to be added to the normal time for an element to make allowances for its work conditions**

1.	Constant allowances	
	(a) Personal allowance .....	5
	(b) Basic fatigue allowance .....	4
2.	Variable allowances	
	A. Standing allowance.....	2
	B. Abnormal position allowance	
	(a) Slightly awkward .....	0
	(b) Awkward (bending) .....	2
	(c) Very awkward (lying, stretching) .....	7
	C. Use of force or muscular energy (lifting, pulling, pushing)	
	Weight lifted, pounds	
	5 .....	0
	10 .....	1
	15 .....	2
	20 .....	3
	25 .....	4
	30 .....	5
	35 .....	7
	40 .....	9
	45 .....	11
	50 .....	13
	60 .....	17
	70 .....	22



D.	Bad light		
	(a) Slightly below recommended .....	0	
	(b) Well below .....	2	
	(c) Quite inadequate.....	5	
E.	Atmospheric conditions (heat and humidity) – variable .....	0-10	
F.	Close attention		
	(a) Fairly fine work .....	0	
	(b) Fine or exacting .....		2
	(c) Very fine or exacting .....	5	
G.	Noise level		
	(a) Continuous .....	0	
	(b) Intermitted – loud .....	2	
	(c) Intermittent – very loud .....		5
	(d) High-pitched – loud .....	5	
H.	Mental strain		
	(a) Fairly complex process .....	1	
	(b) Complex or wide span of attention .....	4	
	(c) Very complex .....	8	
I.	Monotony		
	(a) Low .....	0	
	(b) Medium .....	1	
	(c) High .....	4	
J.	Tediousness		
	(a) Rather tedious .....	0	
	(b) Tedious .....	2	
	(c) Very tedious .....	5	

Source : Benjamin W. Niebel, Motion and time study, 8th Edition  
(Homewood, III. Irwin, 1988).

### **Uses of Time Study**

The utility of the Time Study comes in :

- (i) determining the work content and thereby setting wages and incentives;
- (ii) arriving at cost standards per unit of output for the various jobs used for cost control and budgeting for deciding on sales price;
- (iii) comprising the work efficiency of different operators;
- (iv) arriving at job schedules for production planning purposes;
- (v) manpower planning;
- (vi) aiding in the method study
  - (a) at appropriately sequence the work of an operator and the machines or that of a group of workers,
  - (b) to highlight time consuming elements, and
  - (c) to compare costs of alternative methods.
- (vii) product design by providing basic data on costs of alternative materials and methods required to manufacture the product.

### **MOTION STUDY**

One of the great husband-and-wife teams of science and engineering, Frank and Lillian Gilbreth early in the 1900s collaborated on the development of motion study as an engineering and management technique. Frank Gilbreth

was much concerned until his death in 1924, with the relationship between human beings and human effort.

While the motion study work of the Gilbreths is commonly linked with Frederick Taylor's time studies and grouped within the various "laws and principles" of scientific management, in actuality there is much difference between the two. The components of what originated as the "Taylor system" and later became scientific management, changed how workers were paid, introduced a new division of labor, and expanded and strengthened the role of management. The use of stop watches to measure and set the proper times for tasks was important, but only as part of the overall system. The Gilbreths' motion studies were more focused on how a task was done, and how best to eliminate unneeded, fatiguing steps in any process.

Frank Gilbreth's well-known work in improving brick-laying in the construction trade is a good example of his approach. From his start in the building industry, he observed that workers developed their own peculiar ways of working and that no two used the same method. In studying bricklayers, he noted that individuals did not always use the same motions in the course of their work. These observations led him to seek one best way to perform tasks.

He developed many improvements in brick-laying. A scaffold he invented permitted quick adjustment of the working platform so that the worker would be at the most convenient level at all times. He equipped the scaffold with a shelf for the bricks and mortar, saving the effort, formerly required by the workman to bend down and pick up each brick. He had the bricks stacked on wooden frames, by low-priced labourers, with the best side and end of each brick always in the same position, so that the bricklayer no longer had to turn

the brick around and over to look for the best side to face outward. The bricks and mortar were so placed on the scaffold that the brick-layer could pick up a brick with one hand and mortar with the other. As a result of these and other improvements, he reduced the number of motions made in laying a brick from 18 to 4 1/2.

As the Gilbreths expanded the scope of their motion study from the trade of bricklaying -to the manufacturing process as a whole, so did the influence of Lillian Gilbreth expand within their work. Her training in the nascent field of industrial psychology informed much of the Gilbreths' recognition of the role of the worker in any work reorganization. Unlike Taylor, who held an antagonistic and patronizing view of the laborer of the day, both Gilbreths were more sympathetic to their concerns. Frank Gilbreth had belonged to a union, and was disposed to consider that the cooperation of the worker was necessary if any "scientific" reorganization was to succeed. It is in large measure due to Lillian's influence and training that the Gilbreths' form of scientific management always had a more developed view of the worker, and his or her interests, than Taylor's simplistic view of a worker as driven solely by pay.

Frank Gilbreth's early motion study technique, used during his analysis of bricklaying, relied on a visual study of the work, laid out in detailed pictures and notes. Very soon, however, Gilbreth was using photography as a documenting tool to aid his visual memory. From there he began to use a stereoscope camera to record the differing positions of workers as they completed a task. It was only a short step from sequences of stereoscopic images to using motion picture film and cameras to record the entire sequence of a work activity.

The Gilbreths' only complete installation of scientific management, at the New England Butt Company during 1913-14, relied heavily on the use of cameras to record work process in order to eliminate unnecessary and inefficient movement. The resulting "micro-motion" films, as Frank Gilbreth dubbed them, served two purposes. One was as the visual record of how work had been done, and the Gilbreths and their team studied these films in order to make improvements.

The micro-motion films also served the purpose of training workers; after instituting new procedures for work practices, the Gilbreths would then film a number of workers performing the same task. They would winnow these films down to the best workers, or select individual clips representing a particularly "best way" to perform one step in the work process. These films would be screened both for workers and management, and narrated by Frank Gilbreth, went a ways towards securing the cooperation of the workers.

One can only imagine the effect of the Gilbreth operation on a group of workers in a factory during the second decade of the twentieth century. Motion picture technology, though widespread, and available as cheap entertainment, is certainly not known for taking as its subject common laborers and their tasks. But there, appearing on the factory floor, are motion picture cameras, and technicians, and Frank Gilbreth, director. Compared to Frederick Taylor's solitary man with a stopwatch, the Gilbreths' enterprise seems more like a circus. If both systems were designed to return the same result - more efficient work in less time - the Gilbreth system had the advantage of treating the worker far differently. Peter Leibhold, project specialist at the Smithsonian's National Museum of American History, theorizes that the effect of all this was to make the worker feel like a "star."

After Frank Gilbreth's death, Dr. Lillian Gilbreth continued the work and extended it into the home in an effort to find the "one best way" to perform household tasks. She has also worked in the area of assistance to the handicapped, as, for instance, her design of an ideal kitchen layout for the person afflicted with heart disease. She is widely recognized as one of the world's great industrial and management engineers and has traveled and worked in many countries of the world.

The objectives of motion study are :

- To eliminate all non-productive, ineffective and superfluous motions.
- To develop and substitute more effective and productive patterns of movements.
- To modify tools, shapes of work locations, lighting and other factors to help in optimizing the effects of motions.

The rules of human motions as presented by Gilbreth are as follows:

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**Use the Human Body the Way it Works Best**

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1. Work should be performed by machines if machines are more suitable or if the work is unsafe for humans.
2. Tools and materials should be placed in fixed locations in a sequence that permits a natural rhythm of motions and close together so movements are short and eye fixations are minimized.
3. Hands should begin and complete motions together when possible, and both should not be idle except during rest times.

4. Simultaneous arm motions should be in opposite directions with symmetric patterns.
5. Smooth continuous areas of motion are preferable to straight-line movements involving abrupt changes in direction.
6. Motions should be confined to the lowest classification to involve as few muscle groups as are required to perform the job satisfactorily. The ascending order of motion classifications is :
  - (a) Fingers only
  - (b) Fingers and wrists
  - (c) Fingers, wrists, and lower arms
  - (d) Fingers, wrists, lower and upper arms
  - (e) Hands, arms, and body

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**Arrange the Workplace to Improve Performance**

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7. Worker safety is a primary consideration in workplace design.
8. Chairs, tables, ventilation, illumination, and all features of the workplace should be suitable for the task and the worker.
9. Gravity feed chutes or other automatic conveyance devices should be used where appropriate to deliver objects close to the point of use.
10. Tools, materials, and controls on equipment should have set locations, close to the point of use and arranged to permit the best sequence and paths of motion.

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### **Use Equipment to Improve Human Productivity**

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11. Computers, automation, and mechanical assistance should be employed where they can improve productivity.
12. Vises or clamps can be used to hold work precisely and relieve the hands for performing more valuable work than simply holding.
13. Mechanical guides might be used to reduce the time, effort, and attention required to position work.
14. Automatic controls and foot-actuated devices should relieve the hands for higher-value work or to reduce fatigue, where practicable.
15. Mechanical systems should be designed to require minimal operator motion and only reasonable amounts of force to use them.

#### **Do yourself :**

1. Explain the relationship between time study and motion study.
2. What is meant by time study? Explain the steps involved in conducting a time study.
3. Discuss motion study. Highlight the rules of motion given by Gilbreth.



## **LESSON : 9**

### **QUALITY CONTROL**

#### **Introduction**

Quality is some prescribed or desired characteristics present in raw material, semi-finished or finished items. It is a relative term and is generally used with reference to the end use of the product viz. fitness for purpose, degree of preference, degree of excellence, fulfillment of the promises made to the customer, quality of design, etc.

In every manufacturing organization there are always some standard specifications laid down either by the producer for the consumer and it is important that the finished product meet established specifications. A good quality item is one which conform to the specifications. Producer is responsible for the production and marketing of his product. His fundamental objective is to manufacture the product of desired quality in the most economical manner with minimum risk of being rejected by the consumer. Products superior or inferior than the specifications are not acceptable to the producer. Because the superior products will need more expenditure and the inferior ones will not be acceptable to the consumer. In both situations there will be a loss to the producer.

Similarly, consumer always wants to purchase the goods of desired quality. When consumer knows that he is getting goods of desired specifications, he buys the product with confidence and the market for the product expands.

But every manufacturing process is a repetitive process depending both on controllable and uncontrollable factors. Due to this there is bound to be some deviations in the quality of the product. This deviation in the quality of the product can be due to internal as well as external factors of the system viz. machines, material, etc. Thus there is always a necessity that the deviations in the quality of the product should be discovered and corrected.

**Quality Control :** The process of verification or correction in the quality of the product when the deviations in the quality are found to be more than expected is called quality control.

According to A. Y. Feigarbaum, “Quality-control is an effective system for integrating the quality development, quality maintenance and quality improvement efforts of the various groups in an organization, so as to enable production of goods and services at the most economical levels which allow full customer satisfaction”.

### **OBJECTS OF QUALITY CONTROL :**

The fundamental purpose of Quality Control is to maintain the quality standard of the manufactured product at an optimum cost. However some of the characteristics of quality control objectives can be listed as :

- (i) assessment of quality standards at different stages of the production process i.e. at the stages of raw materials, in process products and final product;
- (ii) to recommend for the remedial or corrective action when the process goes out of control;

- (iii) to suggest suitable improvements in the quality of the product, if any, without affecting the cost of production. This may lead to increase in the demand of the product as the product become more acceptable to consumer;
- (iv) quality control operations introduce quality consciousness in the organization and generates confidence, goodwill and reputation for the manufacturer; and
- (v) reliability regarding the quality of the product is improved and there is reduction in cost through reduction of the losses due to defects.

## **QUALITY MANAGEMENT**

Quality assessment is a probe of the level of quality being achieved. Quality Control starts with quality assessment, and includes action taken to do away with unacceptable quality. A typical QC programme is based on periodic inspection, later followed by feedback of results, and the adjustments made where found necessary. Quality Assurance is quality control, but with an emphasis on quality in the design of the products, processes and jobs and in the selection of personnel and higher training. Total Quality Control (TQC) refers to a total commitment to quality in all its aspects, to commitment of quality in all functional areas of work and makes use of behavioural techniques like QC's (quality circles), zero defect programmes etc.

Quality assurance is a modern day concept. SQC-Statistical Quality Control came on the scene in 1924. Quality Circles (QC's) are very popular these days. QC is a group of employees whose task is to identify problems, formulate solutions, and present their results to management with suggestions for

implementation. Just recently, we had an-international convention of Quality Circle Forum - an organization devoted to this cause - in India.

### **QUALITY ORGANIZATION :**

Quality is not only the concern of the manufacturing department. Quality is everyone's business. Each department has to contribute to quality. Quality is built into the product at the product concept stage and is ubiquitous all throughout its life. Poor quality can occur because of organizational problems anywhere, or even outside the organization. Top management's commitment to quality is a proper beginning. Quality improvement is to be viewed as a positive effort. Continuous training is thus a key to Quality Control. Quality function can be organised in several alternative methods, keeping the above principle in mind.

### **CONTROL OF QUALITY :**

Today, in the modern era of industrialisation, products are being produced on a large scale to take advantage of mass scale production. Things like tooth brushes, tooth-pastes screws, nuts, bolts, cloth, sugar etc. are produced in huge quantities everyday. But one screw is not exactly the same as another in all respects. There are bound to be some variations in the size or composition of a product. For example, if screws of length 1.5cm are produced, some screws will be slightly longer than 1.5cm., say 1.59 cm., or 1.6 cm. etc. and some screws will be slightly smaller than 1.5 cm, say 1.49 or 1.4 cm. etc. Variations within certain limits are tolerable, as they are unavoidable, but if they are too large, the product becomes useless. Maintaining the quality of a product means keeping its size and composition within the tolerance limits (upper and lower).

**Cause of variation :** The factors which cause variations in the size or composition of a product can be classified into two classes :

- (i) Chance variation, and
- (ii) Assignable cause of variation

Chance variation arises due to a large number of factors which are out of everybody's control. These chance causes of variation can neither be discerned nor removed. Chance causes arise from so many very small sources that even if

a few were found and something done about them, the overall effect would' be negligible. These types of variations may take place due to a slight variation in the electric current supplied to the machine, or a slight variation in the machine.

Assignable causes of variations are disturbances that can enter the system undetected until large penalties are paid for poor quality of production that has occurred. For example, there may be variations due to negligence of the operator or due to disturbance in the process or some faults of a machine. Variations caused by these factors are generally high and are intolerable. When such causes are present quality of a product is lost and we say that the process is out of control.

**Functions of Quality Control:** The functions of quality control include the following:

- (i) To see that the product or service is designed in such a way so that it meets customers' specifications. It is the function of design and engineering division.

- (ii) To maintain discipline amongst the employees and to boost their morale :  
The quality of a product in a particular unit also depends on the people working in that unit and therefore sincere efforts should be made to raise or atleast to maintain the level of discipline and morale.
- (iii) To see that the materials, parts, components, tools, equipment etc. of standard quality only are purchased and used. Use of substandard materials, parts, tools etc. results in more score or defective products. Moreover, it increases the cost of production. If a material worth Rs. 50 is inspected before is sent for further processing, it saves Rs. 500 at the final stage, because the cost of labour and overheads spent on the same during the production cycle is saved, if it is found at the initial stage that the material is defective.
- (iv) To make the employees quality conscious by fixing their responsibility at various stages of production : A particular employee can be held responsible for a certain defect, if the stage of defect is identified. A worker may have worked with full responsibility but there may be a fault in a machine also. Therefore the responsibility of a defect found out afterwards must be determined very carefully.
- (v) To reduce the proportion of scrap, waste and spoilage during the process:  
The causes for all these three during the process should be studied carefully and the points or stages of such losses should be identified, so that corrective action can be taken to reduce the losses arising out of scrap, waste and spoilage.

Today, according to JUSE's Junji Noguchi, quality control in Japan has six principal features :

**Company-wide Quality Control :**

All parts of a firm cooperate to control quality, which has been broadened in meaning to include productivity and efficiency. Companies assist suppliers to achieve necessary QC levels.

**QC Audit :**

Top management examines QC effectiveness in the firm, its affiliates or suppliers, JUSE and other organisations conduct external audits, as with the Deming Prize competition.

**Education and Training :**

Most major companies hold regular in-house QC courses that are required for all personnel from the Board of Directors downwards, as well as selective specialized classes. JUSE offers programmes for management and workers.

**QC Circles :**

Small voluntary groups undertake work-related projects to improve quality.

**Application of Statistical Methods :**

Workers, management and engineers communicate and solve production and QC problems with such statistical tools as pareto charts, cause and effect diagrams, check sheets, satisfaction, scatter diagrams and Shewari control charts.

### **Nationwide QC Activities :**

Annually there are regional and national conferences held for management and workers so that QC problems common to one or more industries can be explored and a solution found.

### **CONTROL OF QUALITY STAGES :**

On the basis of the study of quality control functions, we can say that to control the quality of a product, the quality is required to be controlled at various stages of production i.e. (i) at a design stage, (ii) at a purchasing stage, (iii) at a production stage and (iv) after a product is sold (product-support services).

**(i) Control at design stage :** Design and engineering department determines design/specifications/standards for raw materials, components, parts, tools, equipment, processes or methods of production etc. The information regarding quality and quantity of products required by the customers to satisfy their needs is provided by market research or sales department, which is being transformed into the product specifications. Product specifications or design should be based on the needs of the costumers; otherwise it will prove to be useless, even if it is outstanding. An error or a fault at this stage affects the quality of the final product adversely and the cost of production may also increase due to more scrap or spoilage or defective material.

**(ii) Control at Purchasing stage :** The responsibility for the procurement of materials, components, parts, tools, equipment etc. of standard specifications, in a required quantity at a reasonable price rests with the purchase department. Efficient procurement gives better results. The 'quality of the final product depends on the efficiency shown in procurement. It does not mean that the materials, parts, components etc., procured must be of the best quality because



the best quality will cost more and a customer prefers that product, out of so many available, which he considers best for the money he is willing to spend.

Thus cost is also to be considered, while procuring materials, parts, components etc. Sometimes, the suppliers do not supply materials, parts, components, tools etc. as per the specifications and delivery program, even though they are capable of doing so. Therefore, the suppliers should be selected after proper evaluation and after considering their reliability. Moreover, the quality control system or equipment of the suppliers should also be checked to determine their ability to supply quality materials regularly in required quantity.

Quality control people should see that strict control is exercised at the purchasing stage and storage facilities are proper.

**(iii) Control at production stage (during production process) :**

Production department is responsible for the production of quality products as per the specifications. determined by the design and engineering department. Now during the production operations, materials, parts, components, etc. are converted into finished products, which must be fit for the intended use. The quality of a product is affected by the manufacturing processes, tools and equipment and also testing and measuring instruments and methods used. The manufacturing processes or methods must be faultless and carefully designed. The equipment and tools for production as well as instruments for testing and measuring should be maintained properly and carefully and checked periodically to assure the quality of the final product. Measuring and testing instruments of standard and well known manufacturers should only be used to maintain great accuracy. Instruments with precision, accuracy and sensitivity should be used. Employees should be trained properly to use such instruments.

(iv) **Control at delivery and after-sales-service stage** : Careful handling, proper storage and systematic packing save the products from rain, dust, sunlight, temperature etc. and maintain the quality of the products. A product, which leaves the factory in a good condition may get spoiled or damaged due to careless handling or improper storage and packing. If the customers on receipt of the products, find them in damaged conditions due to poor packing or for the other reasons, they get dissatisfied with the company. Complaints from the customers should be entertained promptly. It is very important to analyse and study the complaints data to find out major reasons of complaints. On the basis of such analysis proper corrective action can be taken.

#### **METHODS USED TO ASSURE OR TO CONTROL THE QUALITY :**

Quality of a product can be assured or controlled by :

1. **Inspection method** – 100% inspection or a sample inspection.
2. **Statistical Quality Control Method** :

#### **Inspection :**

Inspection is the process of examining an object for identification or checking it for verification of quality and quantity in any of its characteristics. It is an important tool for ascertaining and controlling the quality of product. In the words of Alford and Batty, “Inspection is the art of applying tests, preferably by the aid of measuring appliances to observe whether a given item or product is within the specified limits of variability or not.” According to Sprigel and Lansburg, “Inspection is the process of measuring the qualities of a product or services in terms of established standards”. The standards can be in terms of strength, hardness, shape, etc.

The purpose of inspection is to see that items are produced within the specified limits of variability. Inspection in its broadest sense is the art of comparing materials, product, or performances with established standards. By means of inspection one can take a decision to accept or reject certain item. The items are accepted if these conform with the given specifications otherwise rejected.

**Functions of Inspection :** The following are some of the important functions of inspection :

- (i) Maintenance of specified standards of the quality of products.
- (ii) Devising means for conducting inspection at lower cost.
- (iii) Segregating spoilt work which may be salvaged by re-operation.
- (iv) Maintaining inspection equipment in good condition.
- (v) Detection of defects at source to reduce scraps and defective work.
- (vi) Furnishing advice to operators when production difficulties arise.
- (vii) Reporting source of manufacturing troubles to management.

**Objectives of inspection:** Fundamental objectives of inspection are:

- (i) to safeguard the quality of the finished products by comparing raw materials, workmanship and final product with some set standards. It prevents further work being done on semi-finished product already detected as spoiled;
- (ii) the defective “items are located and the factors responsible for this discrepancy in the quality of the product are then identified to take corrective measures. This results in enhancing the prestige and confidence of the organization in the eyes of the consumer;

- (iii) the reduction in the risk and possibility of items not accepted by consumer saves the producer as well as the consumer from losses if any and also reduces the cost of production; and
- (iv) to detect sources of weakness and trouble in the finished product and thus check the work of designers.

**Essential steps for inspection :** There are five main steps in inspection :

- (i) Characteristics about which the quality of the items is to be inspected should be carefully established.
- (ii) A decision regarding when and where the inspection should take place is to be taken.
- (iii) To find that how many items are to be inspected i.e. 100% or sampling inspection. Here the level of accuracy desired and the nature of the production process are taken into consideration.
- (iv) The sampling scheme for the selection of items from the lots should be selected.
- (v) Specification limits for the acceptance and rejection of items should be formulated.

**Where to inspect?** Inspection may take place right in the processing area or at a separate inspection station. The choice of location depends on the process flows and on the problems of scheduling the inspection function which must be treated as yet another operation in the total process. The first line of defence is the worker who can avoid making defects. Then come in inspectors who are usually trained separately from the workers to obtain benefits of specialisation. They are taught to use gauges, test instruments, micrometers and procedures at which they become increasingly proficient. Some items inspection tools

cannot be placed in the production line. Then the work may have to leave the normal flow to go to an inspection station. During a production process there are many stages where inspection can be done. The choice depends mainly on the convenience of the organization as well as its approach towards the maintenance of the products quality. In general, inspection can be carried out at following locations :

- (i) Items can be Inspected either at the vendor's place or at the purchaser's premises.
- (ii) Semi-finished items are inspected during the production process.
- (iii) Inspection of finished products.
- (iv) Post-sales quality evaluation.

**Purchaser or Vendor place inspection :**

Here the inspection is carried out mainly to ascertain the quality of raw material. The quality of the finished goods in general depends on the quality of raw materials and proper precaution at this stage will minimise the chances of rejection at later stages. Here 100% inspection is done to ensure that raw-material supplied is in accordance with the specifications laid down in purchase order.

It is always said that prevention is better than cure. Verification of quality standards in the beginning ensures interrupted production schedule because in the case of observing some substandard material at a later stage may result a delay in the supply of fresh material and thus a breakdown or stoppage in production process may happen. The outcome is idle machines and labour. This type of inspection strategy also provides a sound basis for negotiating regarding quality of the raw material with the supplier.

### **In-Process Inspection :**

In this era of automation, in-process inspection has become an important and inevitable activity of the production strategy. Producing the items up to mark is the first objective of every organization. To accomplish this goal the defective items, if any, should be located as quickly as possible, so that the remedial steps are taken to avoid scrapping of future products. The in-process inspection can be classified as :

- (i) Trail run inspection
- (ii) First-off inspection
- (iii) Inspection by self control
- (iv) Decentralised/floor/patrolling inspection.
- (v) Centralised or crib inspection.

**(i) Trail run inspection :** Here the tool/machine is checked against its drawing and specification before commencement of operation. A trail run is made with a single piece. If piece conforms with specifications then the production is allowed to be carried on otherwise remedial measures are taken.

**(ii) First-off inspection :** The items produced in the first production run are inspected and examined with respect to specifications thoroughly and carefully. The method is concerning with checking the setup of the machine. Here the reasons for discrepancy in actual and specified standards are located and corrected. This inspection reduces the chances of scrap at later stages when the production is in full swing.

**(iii) Inspection by self control :** This kind of inspection is done mainly by the operators, controlling the operations at different levels of the production process. The operators are conversant with the desired quality specifications

and they are vested with the responsibility to check the process against the laid standards from time to time during the course of their work. This approach is based on the well known concept that catching a defect after it has occurred is poor second best. Here the remedial step can be taken at once and thus reduces the chances of scrap. Secondly operator's time is utilized more efficiently.

The only drawback of the method is that as the same person being-responsible for operation as well as inspection, the chances of human bias are likely to be more. To avoid this provision of inspection by some independent person should also be made.

**(iv) Decentralised/floor Inspection :** Here the semi-finished goods are inspected either on the machines or in the production line. The possibility of handling the items is considerably reduced and the discrepancy or defects if any are located immediately.

**(v) Centralised or crib inspection :** Under this scheme there can be single inspection unit for the whole plant or each section can have an inspection unit to inspect the items produced by its unit. The items are shifted to the inspection units for necessary inspection. The inspection staff in such situation is Likely to be more experienced and skilled in their work Also the department can use more sophisticated and reliable instruments and techniques to measure the quality of the items. Thus centralised inspection is likely to be more reliable and accurate. But in this case there are more chances of material handling and there may be some situations e.g. large size or heavy items where shifting of items may not be simple and lead to other complications.

The basic idea is centralised inspection is separation of inspection from manufacturing. Generally the inspection cribs are placed parallel with flow of

work through machines in the shop.

*Advantages of centralised inspection are :*

- (i) There is accurate counting of good and bad items.
- (ii) No chance of collusion between production men and inspectors.
- (iii) Machine sites are free from work awaiting inspection giving operators more freedom for movement.
- (iv) Priorities of inspection may be planned according to loads on the production department.
- (v) More sophisticated instruments for inspection can be used.

*Disadvantages :*

- (i) Errors are not revealed quickly.
- (ii) Requires more materials handling.
- (iii) May result in bottlenecks due to delay in inspection of items.
- (iv) There may be larger work in process inventory.
- (v) Defects of a job are not known before it is completed. Thus remedial steps cannot be timely taken on the spot.

Thus the choice of centralised or decentralised inspection strategy depends on the nature of the product, volume of the work, quality consciousness of the enterprise, and the production process. The main purpose of inspection is to locate the defect as soon as it occurs and to see that it is not repeated in future operations. Moreover the quality control operations are to be performed and planned economically. In some cases a combination of centralised and decentralised inspection policy is also pursued.



### **Final Inspection :**

The finished products are inspected and tested to verify the quality standards. The items found to be defective are not marketed. Thus only items of desired specification goes into the hands of consumer. Naturally there are more chances of scrap in this method of inspection as the rejected items cannot be corrected at this stage or it may be quite expensive to do so. But this type of inspection provides valuable information and guidelines about the comparison of different process, assessment of various imposition procedures and the evaluation of defective work etc. Here Producer risk is more and consumer risk is minimised.

### **Post-sales Quality Evaluation :**

There is always a possibility that any item approved in terms of its quality standards may not render satisfactory and reliable service to the customer. There can be regular complaints about this from the consumer or sometimes the consumer may insist to return or ask for replacement of the item during the guarantee period. In such cases the items rejected by the consumers should be thoroughly inspected to locate the reasons for defects and suggestions should be made for necessary improvements. This can be done by providing after sales service to the customer.

### **STATISTICAL QUALITY CONTROL :**

**Introduction :** Statistical quality control, abbreviated as S.Q.C. is one of the most important applications of the statistical techniques in industry. These techniques are based on the theory of probability and sampling and are being extensively used in almost all industries such as aircraft, armament, automobile,

textile, plastic, rubber, petroleum, electrical equipment, telephones, transportation, chemical, medicine and so on. In fact it is impossible to think of any industrial field where statistical techniques are not used.

The basic problem in any production process is not the quantity of the product but the quality of the product. The producer is basically interested to see that the product is of acceptable quality, i.e., it conforms to certain prescribed standards or specifications. For successful marketing of the product, it is imperative that the end products must conform to the standards or expectations laid down by the customers. Statistical Quality Control (S.Q.C.) aims at achieving this target by keeping the various steps of the process (from the arrival of the materials through each of their processing to the final delivery of goods) within control. In nutshell the principles of quality control by statistical techniques cover almost all aspects of production, viz., quality of materials, quality of manpower's, quality of machines and quality of management.

#### **Uses of SQC :**

Statistical Quality Control is a very important technique which is used to assess the causes of variation in the quality of the manufactured product. It enables us to determine whether the quality standards are being met without inspecting every unit produced in the process. It primarily aims at the isolation of the change and assignable causes of variation and consequently helps in the detection, identification and elimination of the assignable causes of erratic fluctuations whenever they are present. A production process is said to be in a state of statistical control if it is operating in the presence of chance causes only and is free from assignable causes of variation.

### **Process and Product Control :**

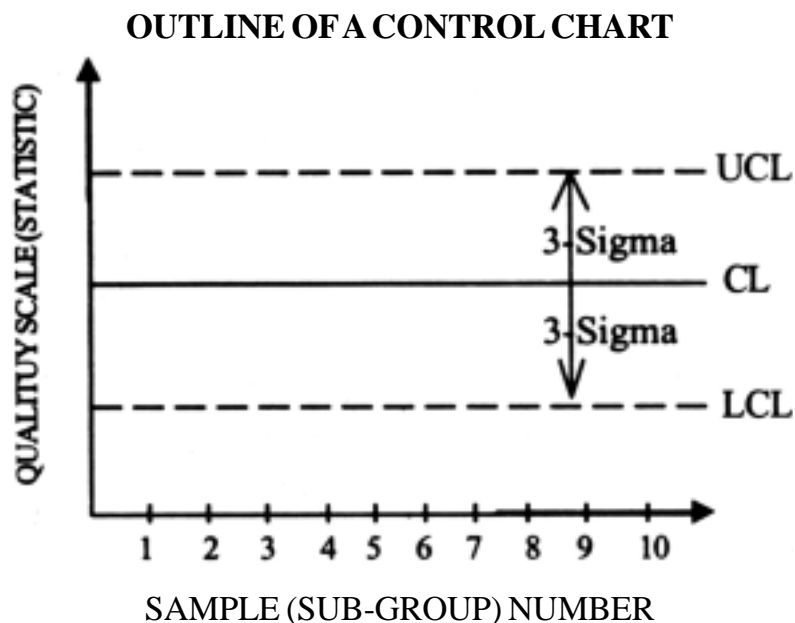
As already stated the main objective in any production process is to control and maintain a satisfactory quality level for its product. In other words, it should be ensured that the product conforms to specified quality standards, i.e., it should not contain a large number of defective items. This is termed as '*process control*' and is achieved through the technique of 'Control Charts' pioneered by W.A. Shewhart in 1924. On the other hand, by product control we mean controlling the quality of the product by critical examination at strategic points and this is achieved through '*Sampling Inspection Plans*' pioneered by Dodge and Roming. Product control aims at guaranting a certain quality level to the consumer regardless of what quality level is being maintained by the producer. In other words, it attempts to ensure that the product marked for sale does not contain a large number of defective items.

### **Control Charts :**

One of the most important tools of production management and the control of quality in the manufactured product is the 'Control Chart' technique. Based on the theory of probability and sampling, it enables us to detect the presence of assignable causes or erratic variations in the process. These causes are then identified and eliminated and the process is established and controlled at desired performances. As already pointed out, a process in statistical control implies that there are no apparent chaotic and assignable causes of variation and it will remain in control provided the conditions of manufacture remain same. Such a process does not call for any corrective action on the part of the management because the entire variation in the product is due to chance causes which are beyond the control of human hand.

The control charts provide us a very simple but powerful graphic method of finding if a process is in statistical control or not. Its construction is based on plotting  $3\sigma$  limits and a sequence of suitable sample statistics, e.g. mean ( $\bar{x}$ ), range (R), standard deviation (s), fraction defective (p), etc., computed from independent samples drawn at random from the product of the process. These sample points depict the frequency and extent of variations from specified standards. Any sample point going outside  $3\text{-}\sigma$  control limits is an indication of the lack of statistical control, i.e., presence of some assignable causes of variation, which must be traced, identified and eliminated. A typical control chart consists of the following 3 horizontal lines : together with a number of sample points as exhibited in the fig. 10.1.

- (i) Upper Control Limit (UCL),
- (ii) Lower control Limit (LCL), and
- (iii) Central Line (CL),



**Fig. 10.1**

In the control chart Upper Control Limit (UCL) and Lower Control Limit (LCL) are usually plotted as dotted lines and central line (CL) is plotted as a bold (dark) line.

**Tools for Statistical Quality Control :** (i) Process control and (ii) Product control. The process control is achieved through '*Control chart*' techniques pioneered by W.A. Shewhart and product control is achieved through 'Sampling Inspection Plans' pioneered by Dodge and Roming. Commonly used control charts are :

1. Control Charts for Variables ( $\bar{X}$ , R,  $\sigma$  charts)
2. Control Charts for Attributes (p, np and c charts).

Control charts for variables are designed to achieve and maintain a satisfactory quality level for a process whose product is amenable to quantitative measurements like the thickness, length or diameter of a screw or nut, weight of the bolts, tensile strength of yam or steel pipes, resistance of a wire, etc. The observations on such units can be expressed in specific units of measurements. In such cases the quality control involves the control of variation both in measures of central tendency and dispersion of the characteristic. Control charts for variables are :

- (i) Control chart for mean ( $\bar{X}$ ).
- (ii) Control chart for range (R).
- (iii) Control chart for standard deviation ( $\sigma$ ).

**Control Chart for mean ( $\bar{X}$ ) :** This is primarily designed to control the variation in the process average. The construction of  $\bar{X}$  chart involves the following steps :

**1. Measurement :** The first step in the construction of  $\bar{x}$  chart is to take measurements on the sample units selected at random from the product of the process.

**2. Selection of Samples or Sub-Groups :** In order to draw valid conclusions from the control chart it is essential that all the samples are drawn at random so that each unit in the lot has an equal chance of being selected in the sample, In practice, samples of size 4 to 5 are usually selected. The frequency of inspection depends basically on the nature of the process, i.e., the quality of the product. Usually 25 samples of size 4 each or 20 samples of size 5 each are sufficient to provide reliable estimate of the process average and dispersion.

**3. Calculation of Mean ( $\bar{X}$ ) and Range (R) for each Sample :** Suppose we draw  $k$  independent random samples each of fixed size  $n$  from the lot to study if the process is in a state of statistical control or not Let  $\bar{X}_1, \bar{X}_2, \dots, \bar{X}_k$ , be the means of the observations on the 1st, 2nd, .... kth sample respectively and let  $R_1, R_2, \dots, R_k$ , be the values of corresponding ranges for the  $k$  samples. Now we define  $\bar{\bar{x}}$ , the mean of these  $k$  sample means and the means of the  $k$  sample ranges so that :

$$\bar{\bar{x}} = \frac{1}{k} (\bar{x}_1 + \bar{x}_2 + \bar{x}_3 + \dots + \bar{x}_k) = \frac{1}{k} \sum \bar{x}$$

$$R = \frac{1}{k} (R_1 + R_2 + \dots + R_k) = \frac{1}{k} \sum R$$

**4. Computation of Control Limits :** Let us suppose that the process mean is  $\mu$  and standard deviation is  $\sigma$ . In this case, the statistic under consideration is the sample mean  $\bar{x}$  whose sampling distribution is given by :

$$E(\bar{x}) = \mu \text{ and standard error (S.E. of } \bar{x}) = \sigma / \sqrt{n}$$

where, n is the sample size.

Hence the 3cr control limits for x-chart are :

$$E(\bar{X}) \pm 3 \text{ S.E.}(\bar{X}) = \mu \pm 3 \sigma / \sqrt{n} = \mu \pm A \sigma$$

Where  $A = 3/\sqrt{n}$  is a constant whose values have been tabulated for different values of n from 1 to 25 and are given in the Appendix-X.

If  $\mu$  and  $\sigma$  are not known, then

$$UCL \bar{X} = \bar{\bar{x}} + A_2 R$$

$$LCL \bar{X} = \bar{\bar{x}} - A_2 R$$

Where  $A_2 = 3/(d_2 \sqrt{n})$  is a constant depending on sample size n.

**5. Construction of  $\bar{X}$  Chart :** The control chart for mean is drawn on a graph paper by taking the sample number along the horizontal scale, (x-axis) and the statistic  $\bar{x}$  along the vertical scale (y-axis). Sample points (sample means  $\bar{x}_1, \bar{x}_2, \dots, \bar{x}_k$ ) are then plotted as points (dots) against the corresponding sample number. These points may or may not be joined. The central line is drawn as a bold (dark) horizontal line at  $\mu = \mu'$  (if  $\mu$  is Known) or at  $\bar{\bar{x}}$  (if  $\mu$  is not known). This UCL  $\bar{x}$  and LCL  $\bar{x}$  are plotted as dotted horizontal lines at the computed values.

**Control chart for Range (R-Chart) :** R-chart is constructed for controlling the variation in the dispersion (variability) of the product. The 1st three steps in its construction are primarily the same as that of  $\bar{x}$  chart, viz.,

1. Measurements
2. Sample size and frequency of sampling.

3. Computation of  $\bar{R}$ .
4. **Computation of Control Limits :** The  $3\text{-}\sigma$  control limits for R-chart are given by :

$$\left. \begin{aligned} \text{UCL}_R &= n \sigma \\ \text{LCL}_R &= D_1 \sigma \end{aligned} \right\} 10.1$$

if the process standard deviation is known. If  $\sigma$  is unknown, then these limits are given by :

$$\left. \begin{aligned} \text{UCL}_R &= D_4 \bar{R} \\ \text{LCL}_R &= D_3 \bar{R} \end{aligned} \right\} 10.2$$

where  $D_1, D_2, D_3$  and  $D_4$  are constants depending on the sample size  $n$  and have been computed and tabulated for different values of  $n$  from 2 to 25. These are given in Table-X in the Appendix. Since range can never be negative,  $\text{LCL}_R$  must be  $\geq 0$ . In case it comes out to be negative, it is taken as a zero.

5. **Construction of R-chart :** As in case of  $\bar{x}$ -chart, the sample or subgroup number is taken along horizontal scale and the statistic (Range) is taken along vertical scale. The sample points  $R_1, R_2, \dots, R_n$  are then plotted as points (dots) against the corresponding sample numbers.

The central line is taken as bold horizontal line at  $\bar{R}$  and  $\text{UCL}_R$  and  $\text{LCL}_R$  are plotted as dotted horizontal lines at the computed values given by (10.1) or (10.2).

**Example 10.1 :** You are given the values of sample means ( $\bar{x}$ ) and the ranges



(R) for ten samples of size 5 each. Draw mean and range chart and comment on the state of control of the process;

Sample No.	1	2	3	4	5	6	7	8	9	10
x	43	49	37	44	45	37	51	46	43	47
R	5	6	5	7	7	4	8	6	4	6

You may use the following control chart constants :

For  $n = 5$ ,  $A_2 = 0.58$ .  $D_3 = 0$  and  $D_4 = 2.115$ .

**Solution Mean Chart :** From the above data, we get

$$\bar{\bar{x}} = \frac{\Sigma \bar{x}}{10} = 44.2$$

$$\bar{R} = \frac{\Sigma R}{10} = 5.8$$

As given above, for  $n = 5$  we have

$$A_2 = 0.58, D_2 = 0 \text{ \& } D_4 = 2.115$$

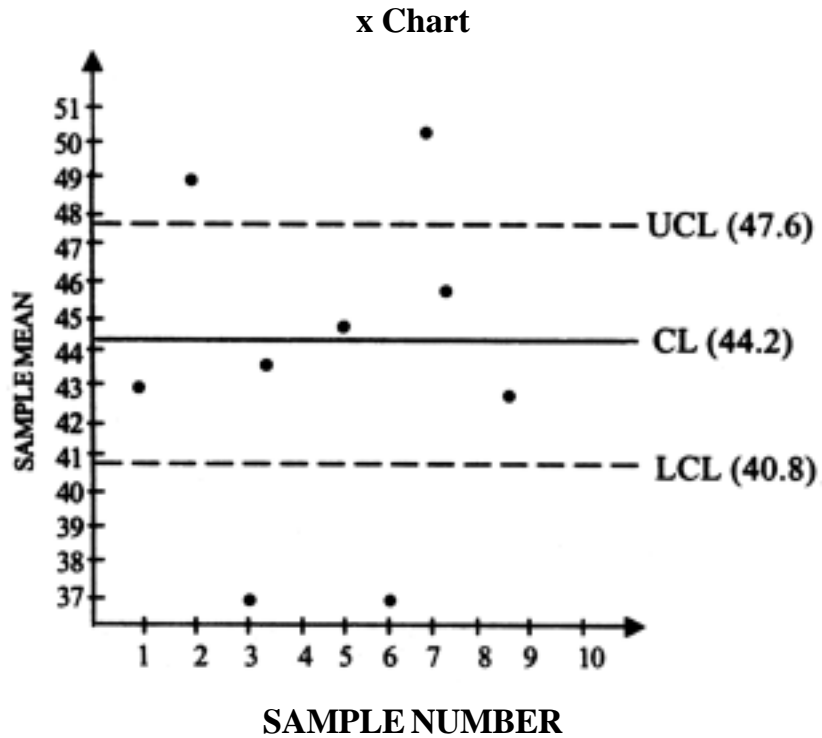
$3\sigma$  control limit for  $\bar{x}$  chart are :

$$\begin{aligned} \text{UCL } \bar{x} &= \bar{\bar{x}} + A_2 \bar{R} \\ &= 44.2 + 0.58 \times 5.8 = 47.567 \end{aligned}$$

$$\begin{aligned} \text{LCL } \bar{x} &= \bar{\bar{x}} - A_2 \bar{R} \\ &= 44.2 - 0.58 \times 5.8 = 40.836 \end{aligned}$$

$$\text{CL } \bar{x} = \bar{\bar{x}} = 44.2$$

The control chart for mean is shown by figure 10.2



**Fig. 10.2**

From the chart, we see that the sample points (sample means) corresponding to 2nd, 3rd, 6th & 7th samples lie outside the control limits. Hence the process is out of control. This implies that some assignable causes of variation are operating which should be detected and corrected.

**Range Chart (R-Chart).**  $3\sigma$  control limits for R-chart are given by :

$$UCL_R = D_4 \bar{R} = 2.115 \times 5.8 = 12.267$$

$$LCL_R = D_3 \bar{R} = 0 \times 5.8 = 0$$

$$CL_R = \bar{R} = 5.8$$

R-chart is given in Fig. 10.3 :

### R-Chart

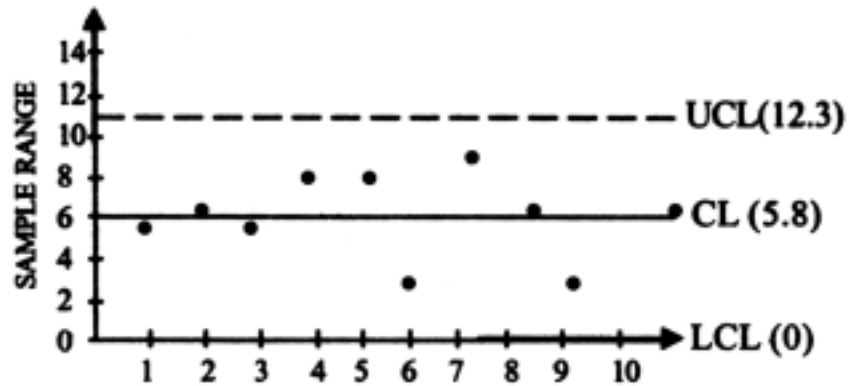


Fig. 10.3

Since all the sample points (sample ranges) fall within the control limits, R-chart shows that process is in statistical control.

Although R-chart depicts control, the process cannot be regarded to be in statistical control since x chart shows lack of control.

**Example 10.2 :** The following data give the measurements of the axle of bicycle wheel 12 samples were taken so that each sample contains the measurements of 4 axles. The measurements which were more than 5 inches are given here. Obtain control limits for x and R charts and comment whether the process is under control or not.

139 140 142 136 145 146 148 145 140 140 141 138  
 140 142 136 137 146 148 145 146 139 140 137 140  
 145 142 143 142 146 149 146 147 141 139 142 144  
 144 139 141 142 146 144 146 144 138 139 139 138

[For  $n = 4$ ,  $A_2 = 0.73$ ,  $D_3 = 0$ ,  $D_4 = 2.28$ ]

**Solution :**

Sample Sample	Sample values				Total	Sample	
No. (1)	(0.0001 inch) (2)				(3)	Mean (x) (4) = (3) ÷ 4	Range (R) (5)
1.	139	140	145	144	568	142.00	6
2.	140	142	142	139	563	140.75	3
3.	142	136	143	141	562	140.50	7
4.	136	137	142	142	557	139.25	6
5.	145	146	146	146	583	145.75	1
6.	146	148	149	144	587	146.75	5
7.	148	145	146	146	585	146.25	3
8.	145	146	147	144	582	145.50	3
9.	140	139	141	138	558	139.50	3
10.	140	140	139	139	558	139.50	1
11.	141	137	142	139	559	139.75	5
12.	138	140	144	138	560	140.00	6
					<b>Total</b>	<b>Σx = 1705.50</b>	<b>ΣR = 49</b>

From the above table we get :

$$\bar{\bar{x}} = \frac{1}{12} \Sigma \bar{x} = \frac{1705.50}{12} = 142.125$$

$$\bar{R} = \frac{1}{12} \Sigma R = \frac{49}{12} = 4.08$$

We are given that for n = 4, A<sub>2</sub> = 0.73, D<sub>2</sub> = 0 and D<sub>4</sub> = 2.28

$\bar{X}$  Chart 3σ control limits are given by :

$$UCL_{\bar{x}} = \bar{\bar{x}} + A_2 \bar{R} = 142.25 + 0.73 \times 4.08 = 145.10$$

$$LCL_{\bar{x}} = \bar{\bar{x}} - A_2 \bar{R} = 142.25 - 0.73 \times 4.08 = 139.15$$

$$CL_{\bar{x}} = \bar{\bar{x}} = 142.125$$

Since the sample Point (means) corresponding to sample numbers 5, 6, 7 and 8 lie outside the control limits, the  $\bar{x}$  chart indicates lack of control in process average  $\mu$ . This suggests the presence of some assignable causes of chaotic variations which must be detected and corrected.

**R-Chart** : 3- $\sigma$  control limits are given by :

$$UCL_R = D_4 \bar{R} = 2.28 \times 4.08 = 9.3024$$

$$LCL_R = D_3 \bar{R} = 0 \times 4.08 = 0$$

$$CL_R = \bar{R} = 4.08$$

Since  $\bar{x}$ -chart shows lack of control, the process cannot be regarded in statistical control although R-chart exhibits statistical control.

### **Control Charts for Attributes :**

As an alternative to  $\bar{x}$  and R or  $\bar{x}$  and s charts we have the control charts for attributes which are used :

- (i) When we deal with quality characteristics which cannot be measured quantitatively. In such cases the inspection of units is accompanied by classifying them as acceptable or non acceptable, defective or non defective.
- (ii) When we deal with characteristics which are actually observed as attributes although they could be measured quantitatively, e.g., go and not-go gauge test results.

**Control charts for attributes are :**

- (a) Control chart for fraction defective, i.e., p-chart.
- (b) Control chart for number of defectives, i.e., np-chart or d-chart.
- (c) Control chart for number of defects per unit, i.e. c-chart.

**Control Chart for Fraction Defective or p-Chart :**

Control chart for fraction defective is used when sample unit as a whole is classified as good or bad i.e. defective or non-defective. We define,

$$\text{Fraction defective (p)} = \frac{\text{Total No. of defective units (d)}}{\text{Total No. of units (n)}}$$

The sampling distribution of the statistic 'p' is given by

$$E(p) = P$$

$$\text{and S.E. (p)} = \sqrt{\frac{PQ}{n}}$$

3  $\sigma$  control limits for p-chart are given by :

$$E(p) \pm 3 \text{ S.E. (p)} = P \pm 3 \sqrt{\frac{PQ}{n}}$$

If p' is the given or known value of p, then

$$UCL_p = p' + 3 \sqrt{P'Q'/n}$$

$$LCL_p = p' - 3 \sqrt{P'Q'/n}$$

**Construction of p-chart :** As in the case of x and R charts we take the sample number along the horizontal scale and the statistic 'p' along the vertical scale. The sample fraction defectives  $p_1, p_2 \dots p_k$  are plotted against the corresponding sample numbers as points (dots), The central line is drawn as a dark horizontal line at p and  $UCL_p$  and  $LCL_p$  are plotted as dotted horizontal lines at the computed values given by (10.40).

**Example 10.3 :** If the average fraction defective of a large sample of a product is 0.1537, calculate the control limits. (Given that sub group size is 2,000).

**Solution :** Here we have a case of fixed sample size  $n = 2,000$  for each sample. Also the average fraction defective is given to be :

$$\bar{p} = 0.1537 \quad \bar{q} = 1 - \bar{p} = 0.8463$$

Hence the  $3\text{-}\sigma$  control limits for p-chart are given by :

$$\bar{p} \pm 3 \sqrt{\bar{p}\bar{q}/n}$$

$$= 0.1537 \pm 3 \sqrt{\frac{0.1537 \times 0.8463}{2,000}} = 0.1537 \pm 3 \sqrt{0.13008/2,000}$$

$$= 0.1537 \pm 3 \sqrt{0.000065} = 0.1537 \pm 3 \times 0.00806$$

$$= 0.1537 \pm 0.02418$$

$$\therefore \text{UCL}_p = 0.1537 + 0.02418 = 0.17788$$

$$\text{LCL}_p = 0.1537 - 0.02418 = 0.12952$$

$$\text{CLP} = 0.1537$$

**Example 10.4 :** The following figures give the number of defectives  $m$  in 20 samples, each sample containing 2,000 items.

425, 430, 216, 341, 225, 322, 280, 306, 337, 305, 356, 402, 216, 264, 126, 409, 193, 326, 280, 389.

Calculate the values for central line and the control limits for p-chart (reaction Defective Chart).

Draw the p-chart and comment if the process can be regarded in control or not?

**Solution :** Here we have fixed sample size  $n = 2,000$  for each sample. If we defined  $d$  = Number of defectives in a sample of size  $n$  and  $p$  = sample fraction defective,

$$\text{then } p = \frac{d}{n} = \frac{d}{2,000}$$

which are obtained in the following table

### CALCULATIONS FOR p-CHART

S.No.	d	$p = \frac{d}{2,000}$	S.No.	d	$p = \frac{d}{2,000}$
1.	425	0.2125	11	356	0.1780
2.	430	0.2150	12	402	0.2010
3.	216	0.1080	13	216	0.1080
4.	341	0.1705	14	264	0.1220
5.	225	0.1125	15	126	0.0630
6.	322	0.1610	16	409	0.2045
7.	280	0.1400	17	193	0.0965
8.	306	0.1530	18	326	0.1630
9.	337	0.1685	19	280	0.1400
10.	305	0.1525	20	389	0.1945
<b>Total</b>	<b>3,187</b>			<b>2,961</b>	

The total number of defectives out of  $20 \times 2,000 = 40,000$  items in 20 samples is

$$\begin{aligned} \Sigma d &= 425 + 430 + 216 + \dots + 389 \\ &= 3187 + 2961 = 6148 \end{aligned}$$

Hence an estimate of process fraction defective  $p$ , provided by the average sample fraction defective is given by :

**(200)**



$$\bar{p} = \frac{\Sigma d}{\Sigma n} = \frac{6,148}{40,000} = 0.1537$$

$$\bar{q} = 1 - p = 0.8463$$

3  $\sigma$  control limits for p-chart are

$$\begin{aligned} & \bar{p} \pm \sqrt{\bar{p} \bar{q} / n} \\ & = 0.1537 \pm 3 \sqrt{0.1537 \times 0.8463 / 2000} \\ & = 0.1537 \pm 3 \sqrt{0.000065} \\ & = 0.1537 \pm 0.0242 \end{aligned}$$

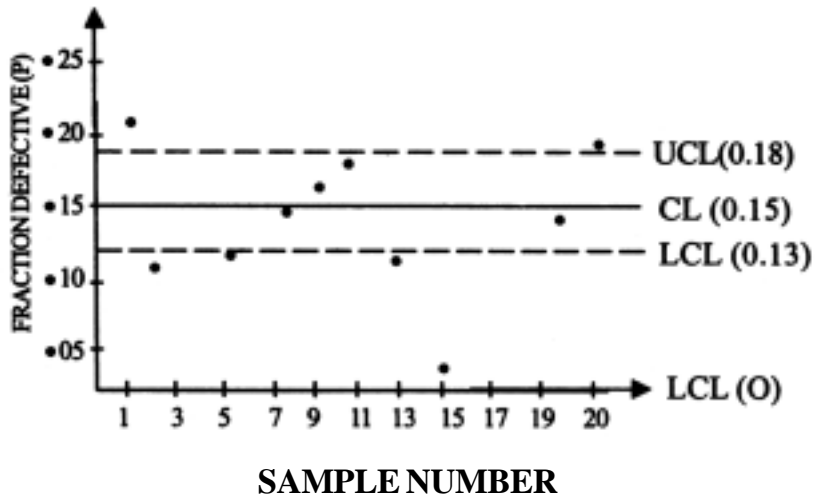
$$\therefore UCL_p = 0.1537 + 0.0242 = 0.1779$$

$$LCL_p = 0.1537 - 0.0242 = 0.1295$$

$$CL_p = P = 0.1537$$

The control chart for fraction defective is given in figure 10.4.

#### CONTROL CHART FOR FRACTION DEFECTIVE (p-CHART)



**Fig. 10.4**

Since a number of sample points lie outside the control limits the process is not in a state of statistical control. This indicates the presence of some assignable

causes of variation which must be detected, identified and corrected.

**Control Chart for Number of Defectives or np-Chart :**

If the sample size is constant for all the samples, say, n then the sampling distribution of the statistic,

$d = \text{No. of defectives in the sample} = np, \dots$  is given by :

$$E(d) = nP$$

$$\text{S.E.}(d) = \sqrt{nPQ}$$

Hence the  $3\sigma$  limits for the d-chart or np-chart are given by

$$E(d) \pm 3 \text{ S.E.}(d) = nP \pm 3 \sqrt{nPQ}$$

If  $P'$  is the known or specified value of  $P$  then

$$\left. \begin{aligned} \text{UCL} &= nP' + 3 \sqrt{n P' Q'} \\ \text{LCL} &= np' - 3 \sqrt{n P' Q'} \end{aligned} \right\} 10.5$$

$$\text{CL} = np'$$

**Example 10.5 :** An inspection of 10 samples of size 400 each from 10 lots revealed the following number of defective units :

17, 15, 14, 26, 9, 4, 19, 12, 9, 15.

Calculate control limits for the number of defective units. Plot the control limits and the observations and state whether the process is under control or not.

**Solution :** Here we have samples of fixed size  $n = 400$ . The total number of defectives in. a sample of  $10 \times 400 = 4,000$  items in 10 samples is

$$\Sigma d = 17 + 15 + 14 + 26 + 9 + 4 + 19 + 12 + 9 + 15 = 140$$

An estimate of the process fraction defective  $P$  is given by :

$$\bar{p} = \frac{\Sigma d}{\Sigma n} = \frac{140}{4,000} = 0.035$$

$$\bar{q} = 1 - \bar{p} = 0.965$$

So the 3- $\sigma$  control limits for d-chart or np-chart are

$$\begin{aligned} n\bar{p} \pm 3\sqrt{n\bar{p}\bar{q}} \\ &= 400 \times 0.035 \pm 3\sqrt{400 \times 0.035 \times 0.965} \\ &= 14 \pm 3 \times \sqrt{13.51} \\ &= 14 \pm 11.02679 \end{aligned}$$

Hence

$$UCL_d = 14 + 11.02679 = 25.02679$$

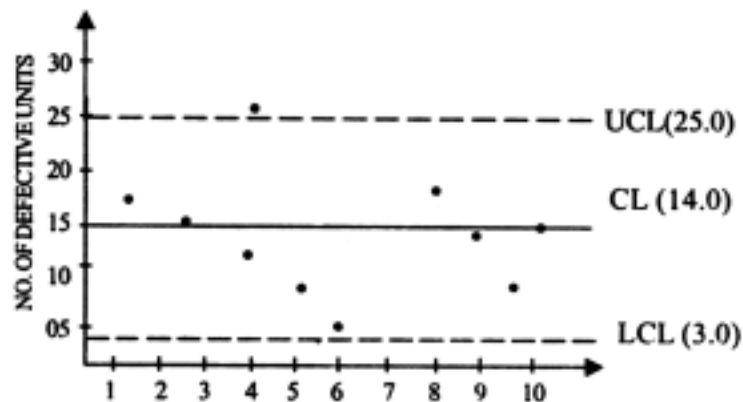
$$LCL_d = 14 - 11.02679 = 2.97321$$

$$CL_d = n\bar{p} = 14$$

The control chart for the number of defective units is obtained on plotting the number of defectives against the corresponding sample number and by fig. 10.5.

### CONTROL CHART FOR NO. OF DEFECTIVE UNITS

(np or d-CHART) – Fig. 10.5.



### Control Chart for Number of Defects er Unit (C-Chart).

Since one point corresponding to 4th sample lies outside the control limits, the process is not in a state of statistical control.

Every defective unit contains one or more of the defects. For instance, a defective casting may further be examined for blow holes, cold shuts, rough surface, weak structure, etc. The c-chart is used when we count the number of defects per unit rather than classifying a unit as good or-bad, i.e., defective or non-defective. Let us inspect k independent random samples, each of same size. Sample size for c-chart may be a single unit like a radio, or a group of units or it may be a unit of fixed time, length, area, etc. Let  $c_1, c_2, \dots, c_k$  be the number of defects observed in the 1st, 2nd, ..., kth, sample inspected respectively. If we regard the statistic c distributed as a Poisson variate with parameter  $\lambda$  then we know that.

$$E(c) = \lambda \text{ and S.E.}(c) = \sqrt{\lambda}$$

Hence the 3- $\sigma$  control limits for the c-chart become :

$$\begin{aligned} UCL_c &= E(c) + 3 \text{ S.E.}(c) = \lambda + 3\sqrt{\lambda} \\ LCL_c &= E(c) - 3 \text{ S.E.}(c) = \lambda - \sqrt{\lambda} \\ CL_c &= E(c) = \lambda \end{aligned} \quad \left. \vphantom{\begin{aligned} UCL_c \\ LCL_c \\ CL_c \end{aligned}} \right] 10.6$$

If  $\lambda$  is not known then we use its unbiased estimate  $\bar{c}$  provided by the given samples, i.e.,

$$\hat{\lambda} = \bar{c} = \frac{\sum c}{k} = \frac{c_1 + c_2 + \dots + c_k}{k}$$

In such a case ( $\lambda$ -unknown), the control limits for c-chart are given by :

$$\begin{aligned} UCL_c &= \bar{c} + 3\sqrt{\bar{c}} \\ LCL_c &= \bar{c} - 3\sqrt{\bar{c}} \\ CL_c &= \bar{c} \end{aligned} \quad \left. \vphantom{\begin{aligned} UCL_c \\ LCL_c \\ CL_c \end{aligned}} \right] 10.7$$

Since c, the number of defects per unit cannot be negative, if  $LCL_c$  computed from above formula comes out to be negative, then it is taken as zero.

The sample points  $C_1, C_2, \dots, c_k$  are plotted as points (dots) by taking the sample statistic  $c$  along the vertical scale and the sample number along the horizontal scale. The central line (CL) is drawn as bold horizontal line at  $\bar{c}$  or  $\bar{c}$  and  $UCL_c$  and  $LCL_c$  are plotted as dotted lines at the computed values given by (10.6) or (10.7).

**Example -10.6 :** During an examination of equal length of cloth, the following are the number of defects observed :

2, 3, 4, 0, 5, 6, 7, 4, 3, 2

Draw a control chart for the number of defects and comment whether the process is under control or not ?

**Solution :** Let the number of defects per unit (equal length of cloth) be denoted by  $c$ . Then the average number of defects in the 10 sample units is given by :

$$\begin{aligned} \bar{c} &= \frac{\sum c}{K} = \frac{2 + 3 + 4 + \dots + 2}{10} \\ &= \frac{36}{10} = 3.6 \end{aligned}$$

The  $3\text{-}\sigma$  control limits for  $c$ -chart are given by :

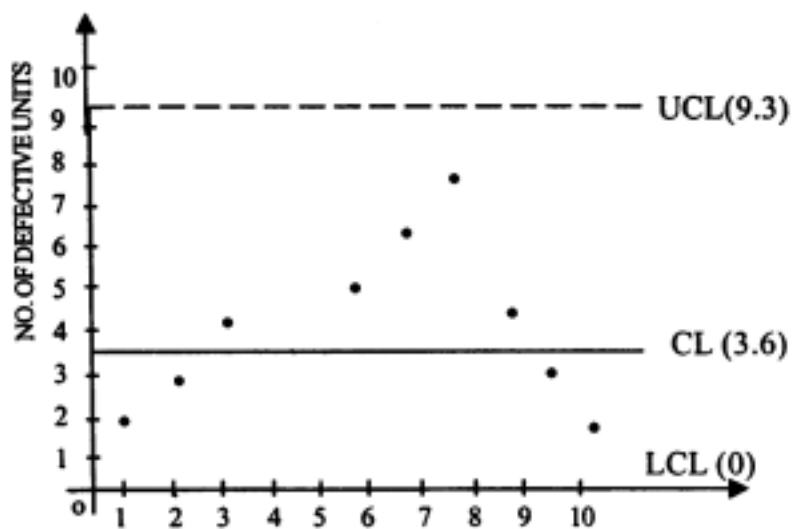
$$\begin{aligned} UCL_c &= \bar{c} + 3 \times \sqrt{\bar{c}} \\ &= 3.6 + 3 \times \sqrt{3.6} \\ &= 3.6 + 3 \times 1.8974 \\ &= 3.6 + 5.6922 \\ &= 9.2922 \\ LCL_c &= \bar{c} - 3 \times \sqrt{\bar{c}} \\ &= 3.6 - 5.6922 \\ &= -2.0922 = 0. \end{aligned}$$

since the number of defects per unit cannot be negative.

$$CL_C = \bar{c} = 3.6$$

The c-chart i.e., the control chart for the number of defects is obtained on plotting c values against the corresponding sample number, together with the control limits and is given by figure 10.6.

c-CHART



SAMPLE NUMBER (FIG. 10.6)

Since all the sample points are within the control limits, the process is in statistical control.

### Acceptance Sampling :

When materials are purchased in a large quantity or articles are produced on a large scale, there may be few defective items in each lot of materials, parts, components etc. purchased or the finished products manufactured by complete inspection of the whole lot i.e. by 100% inspection acceptance and use of

production of defective items can be avoided. But because of the following reasons, 100% inspection (piece to piece inspection) is not done :

1. It proves to be uneconomical as compared to the cost of inspection with the value and importance of the product.
2. 100% inspection is a time-consuming procedure and requires more labour.
3. 100% inspection makes the inspectors careless. To satisfy the boss as well as themselves, they generally throw out few items now and then from the materials and products received for inspection. They consider inspection as throwing out or rejecting some times now and then. Their carelessness may result in the rejection of a good lot or acceptance of a bad lot. Under such circumstances 100% inspection does not guarantee that there will be no defective items in materials, components, parts and products, inspected. Hence, such inspection becomes useless.

Therefore, to assure better quality on one hand and to come out of the difficulties as mentioned above, acceptance sampling method i.e. method sampling inspection is used. When the decision regarding acceptance or rejection of an entire lot of products or materials or parts or components is taken on the basis of number of defectives. In a sample, it is called acceptance sampling. Here, decision is taken without going through 100% inspection of the entire lot. Acceptance sampling reduces the work of inspection and the quality standards. The maximum limit of the number of defectives in a sample, to consider it acceptable, is determined first, and on the basis of this limit, decision regarding acceptance or rejection is taken. If the number of defects in a sample is less than the prescribed number, the lot is accepted and if the number of defects

is more than the prescribed number, the lot is rejected. Acceptance sampling is used to determine whether (i) to accept or reject a particular lot of materials etc. purchased or (ii) to pass or not to pass a particular batch of finished products for despatch to the customers or (iii) to pass or not to pass a particular lot of materials in process.

Acceptance sampling is mostly attribute inspection rather than variable inspection. And even more than in the case of operation control charts, acceptance sampling is a matter of calculated risks, because it deals with large quantities of already finished products. There is always a slight chance that bad lots will be passed or that good lots will be rejected. Always, when there are large quantities of products, there are going to be at least a few defective pieces in every lot. Thus acceptance sampling does not eliminate the risks of getting the good lots rejected and bad lots accepted or passed. Both buyer and seller understand that there will be some defective products and contracts are drawn accordingly. In fact, the number of expected defective products will be reflected in the price. If the buyer wants the products he buys to have a very low percentage of defective, he pays more than if he is less demanding.

With acceptance sampling unlike with control charts, it is not necessary to make our own tables of sample sizes and rejection numbers of our inspectors. Statisticians have whole sets of them, all figured out and published in booklets. We can, however, figure out our own plan, if those published do not suit our needs. Statistics books explain how to do this.

### **Types of acceptance sampling :**

Acceptance sampling is of two types :

- 1. Attribute acceptance sampling :** Here decision regarding acceptance or rejection is based on number of defectives found in a sample. A sample is



taken from a lot and good items and defective items are separated. Then the number of defective items is compared with the allowable limit stated in a sampling plan. If the number of defective items is less than the allowable limit, the lot is accepted, otherwise rejected. This type of sampling is used widely, because of its simplicity.

**2. Variable acceptance sampling :** Here decision regarding acceptance or rejection is based on 'average' (mean) and 'spread' of a number of individual measurements specifying the quality characteristics of a sample. Here a sample is taken, quality characteristics of each unit are measured, and average is worked out. The average value worked out is compared with the allowable value stated in a sampling plan, to decide whether to accept or reject a lot.

#### **Types of sampling plan :**

Sampling plan may be of three types. It may be (i) a single sampling plan or (ii) a double sampling plan or (iii) a multiple (continuous) sampling plan.

**(i) Single sampling plan :** In such a type of plan, decision to accept or reject a lot is taken on the basis of the results of the first sample. Here, generally a large sample is used. When the lots are extremely good or bad or contain high proportion of good or bad items, decision can be taken on the basis of even a small sample. A large sample unnecessarily increases the cost of inspection in such a case.

Each of the sample items ( $n$ ) are either acceptable or defective. Such a sampling plan is known as sampling by attributes.

**(ii) Double sampling plan :** Sometimes it becomes difficult to decide, on the basis of first sample, whether a lot is good or bad. This happens in case

of borderline cases. Number of defectives may be very close to the upper control limit. Under such circumstances, it becomes necessary to inspect another sample. A second sample, therefore, is drawn, inspected, added to the first sample and then on the basis of the combined result, decision regarding acceptance or rejection of the lot is taken. This is called double sampling plan, because here two samples are taken to arrive at the decision. The following procedure is followed under this plan :

1. Take first sample. Find out the number of defectives in that sample. Compare the number with two acceptance numbers  $C_1$  and  $C_2$ .
2. If the number of defectives is less than  $C_1$ , accept the lot and if it is more than  $C_2$ , reject the lot.
3. If the number of defectives is between  $C_1$  and  $C_2$ , take a second sample. Find out the number of defectives in the combined sample. Compare the number with two acceptance numbers  $C_1$  and  $C_2$ .
4. If the number of defectives is less than  $C_2$ , accept the lot and if it exceeds  $C_2$ , reject the lot.

**Multiple sampling plan :**

Under this plan, several samples are taken until a decision to accept or reject a lot is reached. It is known as sequential sampling plan also. It should be noted that if the first new items are found defective, the lot could be rejected without further inspection.

Whichever may be the sampling plan, selection of a sample is made at random, so that all the items in a lot have an equal chance of selection in a sample. Acceptance sampling plan specifies the sample size (number of items in a

sample) for a specific lot size and the number of allowable defects in the sample, on the basis of which decision regarding acceptance or rejection of the entire batch or lot is made.

### **Operating Characteristics Curves :**

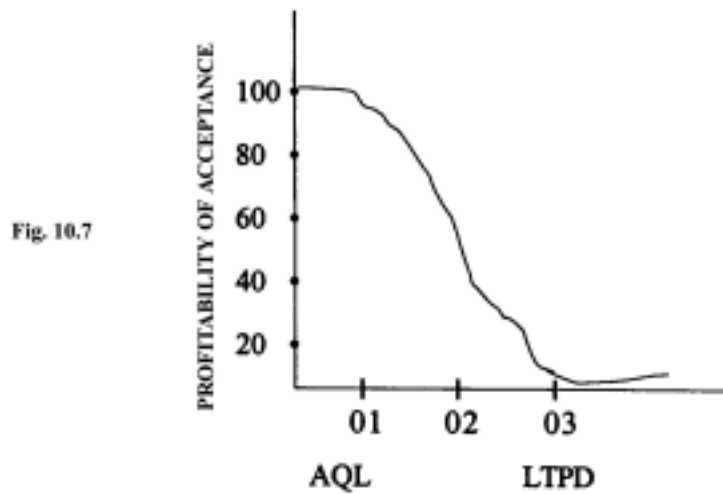
Every acceptance sampling plan has an 'operating characteristics' (OC) curve that shows how it works.

Suppose that we first set up a plan and then look at its OC curve. We'll start by deciding the producer's risk. (Sometimes called the  $\alpha$  or alpha risk). This is the risk that the producer takes that a very good lot might, by chance, be rejected. It is called the acceptable quality level (AQL) and is, generally, set at 5 per cent. This means that quite good lot will pass 95 per cent of the time.

Next we will set the consumer's risk, or the lot tolerance per cent defective (LTPD). (This is sometimes called the lot tolerance fraction defective LTFD. It is also sometimes called the  $\beta$  or beta risk). The consumer's risk is generally set at 10 per cent, which means that the consumer wants a plan which will reject lots with the maximum proportion of defectives (the LTPD) 90 times out of every 100 such lots.

The plan that will accomplish the objectives we want is an instruction to the inspector guiding him how many to include in his sample and also the maximum number of defectives that will let the lot pass. If the lot is 10,000 or more than he should inspect a sample of 400 and reject all lots whose sample contains eight or more rejects. With seven or fewer defectives he accepts the lot. But if the lot is only 1,000, we get the same quality assurance by having inspect a sample of only 275 and accepting the lot if the inspector finds no more than

five defects. If the whole lot is 200, he should inspect 125 and accept if he finds two or fewer rejects. Our plan', therefore, for each size lot, tells the inspector how big a sample to take and how good it has to be.



**Size of required acceptable**

Universe	Sample	Defectives
$\infty$	400	7
10,000	400	7
1000	275	5
200	125	2

Fig. 10.7 is the particular plan's operating characteristics curve. On this chart, the horizontal line at the bottom is an'. If line. 'If a lot submitted has 1, 2, 3, 4 etc., per cent defectives, then we can read up to the curve and across to the left to see what the chances are that we will accept such a lot. Lots which actually contain 1 per cent defectives will pass about 95 per cent of the time.

Lots with 2 per cent defectives will pass 40 per cent of the time. Lots containing 3 per cent defectives will get by only 10 per cent of the time and poorer lots have very little chance of getting by.

Every acceptance inspection plan has its own operating characteristic curve the shape of the line depends on the quality we want and the extent to which we want to be certain that we will get this quality. The slope of the curve depends upon the size of the sample and on its proportion of the parent lot. For any given size lot, the larger the sample, the steeper the curve.

### **Degrees of Defects in Acceptance Sampling**

Many products can have major or minor defects or both at the same time. If so, we might like our receiving inspectors to be using two or more inspection plans at the same time and on the same sample. We might, for instance, allow no defects at all in the sample for critical or major defects. The curvature of a spring for an automobile door lathe might be critical. If it curves too much and puts on too much pressure, it might break and let the car door swing open. So if one finds even one defective in the sample one would reject the lot.

### **Quality Control Circles – Not Productivity Circles**

QC circles are an important contributor to Japan's success in improving product quality and in achieving technological innovation. Established two decades ago, when foremen and workers were first taught quality control concepts, today more than 1,00,000 circles are registered at QC circle headquarters in JUSE.

These circles can have a significant impact on a firm - there are 1,800 at Toyo Kogyo, involving half of the total 27,000 workers and can be found in almost every department from personnel to sales.

QC circles enable Japanese companies to harness the creative talent and intellectual energy of all their employees in order to compete more effectively. At the same time, in a society that emphasizes consensus, circles give individuals with ideas an institutionalized way to change their working environment without rocking the boat. Comments JUSE's Noguchi, "QC circles are based on the idea that everyone would like to use his brain in addition to his labour". "Adds Mazda's Watanabe, "People appreciate growth through work."

Basically, a QC is a small group of employees – the advantage number of nine who volunteer to meet regularly in order to undertake work related projects designed to advance the company, improve working conditions and spur mutual self-development, by using QC concepts. Originally circles formed around foremen. Now circles coalesce from groups of co-workers or even individuals who share recreational interests. Many companies encourage circle leadership to rotate within the group.

**Questions :**

1. Explain the importance of statistical quality control in industry.
2. List at least five places in a production process where inspection should be considered.
3. What is inspection? What are the major objectives or the functions of inspection?
4. In quality control, what is meant by a process being in control?
5. Define quality control and tell how it differs from inspection?
6. What do you understand by Acceptance Sampling?
7. What is a control chart ? Describe how a control chart is constructed and interpreted?

8. Describe the method of drawing X and R charts. State the formulae you would use in both the cases.
9. The following are the figures for the number of defectives in 22 lots- each containing 2000 number bells.

425, 430, 216, 341, 225, 322, 280, 306, 337, 305, 356, 402, 206, 264, 126, 409, 193, 326, 280, 389, 457, 420.

Draw the control chart for fraction defectives and comment on the state of control in the process.

10. Thirty sample of 5 items each were taken from the output of a machine and critical dimension measured. The mean of the 30 samples was 0.655 inch and their average range was 0.0036 inch. Compute the upper and the lower control limits for the X and R-charts. You may use the following factors for finding the control limits :

n	$A_1$	$D_3$	$D_4$	$A_2$
5	1.596	0	2.115	0.577

11. Given below are the values of sample means and ranges and 10 samples of size each.

Sample No. :	1	2	3	4	5	6	7	8	9	10
$\bar{X}$ :	43	49	37	44	45	37	51	46	43	47
R :	45	6	5	7	7	4	8	6	4	6

Draw the mean and range charts and comment on the state of control of the process. (Given  $A_2 = 0.58$ ,  $D_3 = 0$ ,  $D_4 = 2.115$  for  $n = 5$ )

12. The following table gives the number of defects observed in 6 woolen carpets manufactured with great care and regarded as satisfactory. Construct the control chart for the number of defects.

Carpets No. :	1	2	3	4	5	6
No. of defects :	3	5	6	4	1	5

(215)

**APPENDIX-X  
QUALITY CONTROL CHART**

X-chart			d-chart				R-chart						
Sample size Factors for Control-limits			Factors control limits				Factors for central line						
n	A	A <sub>1</sub>	A <sub>2</sub>	c <sub>2</sub>	B <sub>1</sub>	B <sub>2</sub>	B <sub>3</sub>	B <sub>4</sub>	d <sub>1</sub>	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>
2	2.121	3.760	1.880	0.5642	2	1.843	0	3.267	1.128	0	3.686	0	3.267
3	1.732	2.394	1.023	0.7236	0	1.858	0	2.568	1.593	0	4.358	0	2.575
4	1.500	1.880	0.729	0.7979	0	1.808	0	2.266	2.059	0	4.698	0	2.282
5	1.342	1.596	0.577	0.8407	0	1.756	0	2.089	2.328	0	4.981	0	2.15
6	1.225	1.410	0.483	0.8686	6.026	1.711	0.030	1.970	2.534	0	5.076	0	2.004
7	1.134	1.277	0.419	0.8882	0.105	1.672	0.118	1.882	2.704	0.205	5.203	0.078	1.924
8	1.061	1.175	0.373	0.9027	0.167	1.638	0.185	1.815	2.847	0.387	5.307	0.136	1.864
9	1.000	1.094	0.337	0.9139	0.219	1.609	0.236	1.761	2.970	0.546	5.394	0.184	1.816
10	0.949	1.028	0.308	9.227	0.262	1.584	0.284	1.716	3.078	0.687	5.869	0.223	1.777
11	0.905	0.973	0.285	0.9800	0.299	1.561	0.321	1.679	3.173	0.812	5.435	0.256	1.744
12	0.866	0.925	0.266	0.9359	0.331	1.541	0.354	1.648	3.258	0.924	5.592	0.284	1.716
13	0.832	0.884	0.249	0.9410	0.359	1.523	0.382	1.618	3.336	1.026	5.646	0.308	1.622
14	0.802	0.848	0.235	0.9453	0.384	1.507	0.400	1.594	3.407	1.121	5.693	0.329	1.671
15	0.775	0.816	0.223	0.9490	0.406	1.492	0.428	1.572	3.472	1.207	5.737	0.348	1.652
16	0.750	0.788	0.212	0.9523	0.427	1.478	0.448	1.552	3.532	1.285	5.779	0.364	1.636
17	0.728	0.762	0.203	0.9551	0.445	1.465	0.466	1.534	3.588	1.359	5.817	0.379	1.621
18	0.707	0.738	0.194	0.9576	0.461	1.454	0.482	1.518	3.640	1.420	5.854	0.392	1.608
19	0.688	0.717	0.184	0.9599	0.477	1.443	0.497	1.503	3.689	1.490	5.888	0.404	1.596
20	0.671	0.697	0.110	0.9619	0.491	1.433	0.510	1.490	3.735	1.544	5.922	0.418	1.586
21	0.655	0.679	0.173	0.9638	0.504	1.424	0.523	1.477	3.788	1.606	5.950	0.425	1.575
22	0.640	0.662	0.167	0.9655	0.510	1.415	0.534	1.466	3.819	1.559	5.979	0.434	1.566
23	0.626	0.647	0.162	0.9670	0.527	1.407	0.545	1.455	3.858	1.710	5.006	0.443	1.557
24	0.612	0.632	0.157	0.9684	0.538	1.339	0.555	1.445	3.859	1.759	6.031	0.452	1.548
25	0.600	0.619	0.153	0.9696	0.548	1.392	0.565	1.435	3.931	1.804	6.058	0.059	1.541



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# Bachelor of Business Administration

## BBA - 303

### PRODUCTION MANAGEMENT

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