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DR. BABASAHEB AMBEDKAR
OPEN UNIVERSITY
(established by government of gujarat)

MBA02C205
Semester 2

PRODUCTION OPERATION

Message for the Students

Dr. Babasaheb Ambedkar Open (University is the only state Open University, established by the Government of Gujarat by the Act No. 14 of 1994 passed by the Gujarat State Legislature; in the memory of the creator of Indian Constitution and Bharat Ratna Dr. Babasaheb Ambedkar. We Stand at the seventh position in terms of establishment of the Open Universities in the country. The University provides as many as 54 courses including various Certificate, Diploma, UG, PG as well as Doctoral to strengthen Higher Education across the state.

On the occasion of the birth anniversary of Babasaheb Ambedkar, the Gujarat government secured a quiet place with the latest convenience for University, and created a building with all the modern amenities named 'Jyotirmay' Parisar. The Board of Management of the University has greatly contributed to the making of the University and will continue to this by all the means.

Education is the perceived capital investment. Education can contribute more to improving the quality of the people. Here I remember the educational philosophy laid down by Shri Swami Vivekananda:

> ***"We want the education by which the character is formed, strength of mind is Increased, the intellect is expand and by which one can stand on one's own feet".***

In order to provide students with qualitative, skill and life oriented education at their threshold. Dr. Babaasaheb Ambedkar Open University is dedicated to this very manifestation of education. The university is incessantly working to provide higher education to the wider mass across the state of Gujarat and prepare them to face day to day challenges and lead their lives with all the capacity for the upliftment of the society in general and the nation in particular.

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With all these efforts, Dr. Babasaheb Ambedkar Open University is in the process of being core centre of Knowledge and Education and we invite you to join hands to this pious *Yajna* and bring the dreams of Dr. Babasaheb Ambedkar of Harmonious Society come true.

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MBA

SEMESTER-2

PRODUCTION OPERATION

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PRODUCTION OPERATION

SEMESTER-2

Block

1

BLOCK

2

UNIT : 1 INTRODUCTION TO PRODUCTION & OPERATIONS MANAGEMENT

1.1 INTRODUCTION

Production/operations management is the process, which combines and transforms various resources used in the production/operations subsystem of the organization into value added product/services in a controlled manner as per the policies of the organization. Therefore, it is that part of an organization concerned with transforming a range of inputs into the required (products/services) with the requisite quality level.

The set of interrelated management activities, which are involved in manufacturing certain products, is called as **production management**. If the same concept is extended to services management, then the corresponding set of management activities is called as **operations management**.

1.2 HISTORICAL EVOLUTION OF PRODUCTION AND OPERATIONS MANAGEMENT

For over two centuries, operations and production management has been recognised as animportant factor in a country's economic growth.

The traditional view of manufacturing management began in eighteenth century when **Adam Smith** recognized the economic benefits of specialization of labour. He recommended breaking of jobs down into subtasks and recognises workers to specialized tasks in which they would become highly skilled and efficient. In the early twentieth century, F.W. Taylor implemented Smith's theories and developed scientific management. From then till 1930, many techniques were developed prevailing the traditional view. Brief information about the contributions to manufacturing management is shown in the Table 1.1.

TABLE 1.1 Historical summary of operations management

Date	*Contribution*	*Contributor*
1776	Specialization of labour in manufacturing	Adam Smith
1799	Interchangeable parts, cost accounting	Eli Whitney and others
1832	Division of labour by skill; assignment of jobs by skill; basics of time study	Charles Babbage
1900	Scientific management time study and work study developed; dividing planning and doing of work	Frederick W. Taylor Frank B. Gilbreth
1900	The motion of study of jobs	
1901	Scheduling techniques for employees, machines jobs in Manufacturing	Henry L. Gantt F.W. HarrisElton Mayo
1915	Economic lot sizes for inventory control	W.A. Shewart
1927	Human relations; the Hawthorne studies	
1931	Statistical inference applied to product quality: quality control charts	H.F. Dodge & H.G. Roming P.M. Blacker and others.John Mauchlly and
1935	Statistical sampling applied to quality control: inspection sampling plans	J.P. Eckert
1940	Operations research applications in World War II	G.B. Dantzig, Williams &others
1946	Digital computer	A. Charnes, W.W.
1947	Linear programming	Cooper& others
1950	Mathematical programming, on-linear and stochastic processes	Sperry Univac
1951	Commercial digital computer: large-scale computations available.	L. Cummings, L. Porter W. Skinner J. Orlicky and
1960	Organizational behaviour: continued study of people at work	G. Wright
1970	Integrating operations into overall strategy and policy, Computer applications to manufacturing, Scheduling and control, Material requirement planning (MRP)	W.E. Deming and J. Juran.
1980	Quality and productivity applications from Japan: robotics, CAD-CAM	

Production management becomes the acceptable term from the 1930s to the 1950s. As F.W. Taylor's works became more widely known, managers developed techniques that focused on economic efficiency in manufacturing. Workers were studied in great detail to eliminate wasteful efforts and achieve greater efficiency. At the same time, psychologists, socialists and other social scientists began to study people and human behaviour in the working environment. In addition, economists, mathematicians, and computer socialists contributed newer, more sophisticated analytical approaches.

With the 1970s emerged two distinct changes in our views. The most obvious of these, reflected in the new name **operations management** was a shift in the service and manufacturing sectors of the economy. As service sector became more prominent, the change from 'production' to 'operations' emphasized broadening our field to service organizations. The second, more suitable change was the beginning of an emphasis on synthesis in management practices rather than just analysis.

Production function is that part of an organization concerned with transforming a range of inputs into the required outputs (products) having the requisite quality level.
Production is defined as *"the step-by-step conversion of one form of material into another form through a chemical or mechanical process to create or enhance the utility of the product to the user."* Thus production is value-additionon process. At each stage of processing, there will be value addition.
Edwood Buffa defines production as '*a process by which goods and services are created*'. Some examples of production are: manufacturing custom-made products like, boilers with a specific capacity, constructing flats, some structural fabrication works for selected customers, etc., and manufacturing standardized products like, car, bus, motor cycle, radio, television, etc.

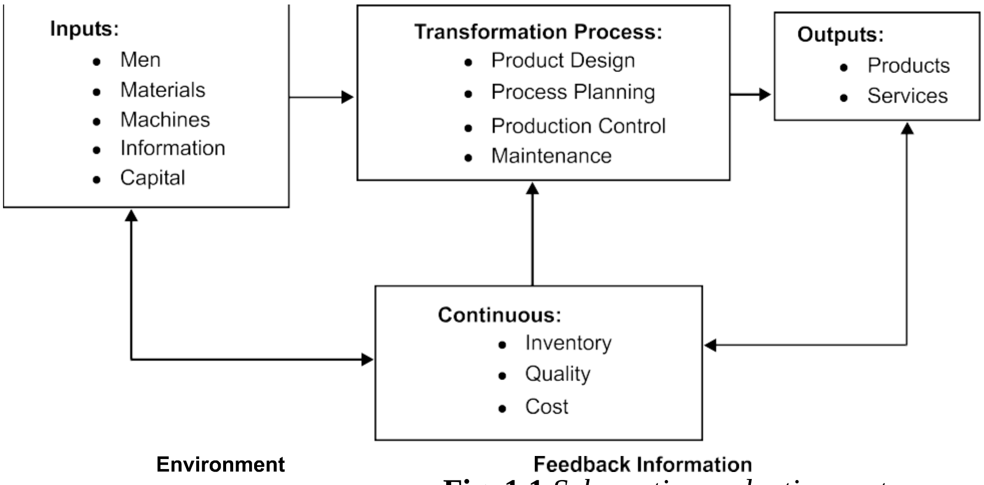


Fig. 1.1 *Schematic production system*

1.4 PRODUCTION SYSTEM

The production system of an organization is that part, which produces products of an organization. It is that activity whereby resources, flowing within a defined system, are combined and transformed in a controlled manner to add value in accordance with the policies communicated by management. A simplified production system is shown above.

The production system has the following characteristics:

1. Production is an organized activity, so every production system has an objective.
2. The system transforms the various inputs into useful outputs.
3. It does not operate in isolation from the other organization system.
4. There exists feedback about the activities, which is essential to control and improvesystem performance.

1.4.1 Classification of Production System

Production systems can be classified as Job Shop, Batch, Mass and Continuous Productionsystems.

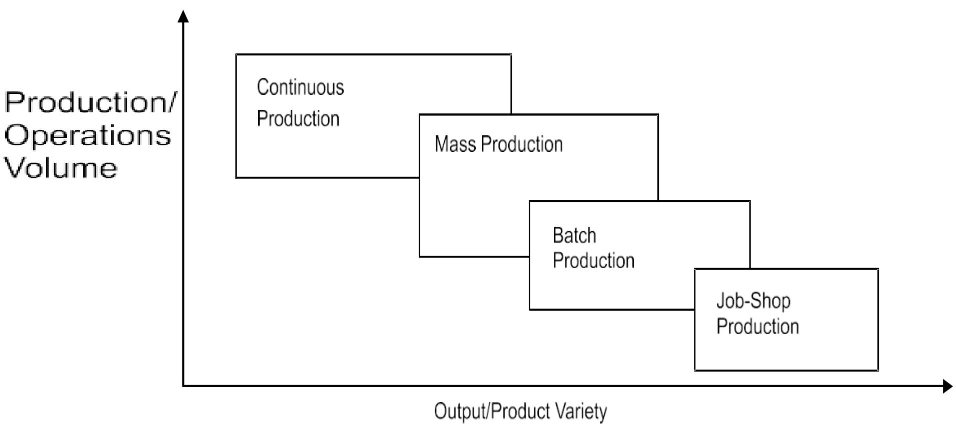


Fig. 1.2 *Classification of production systems*

JOB SHOP PRODUCTION

Job shop production are characterised by the manufacturing of one or few quantities of products designed and produced as per the specification of customers within prefixed time and cost. The distinguishire of this is the low volume and high variety of products.

A job shop comprises general-purpose machines arranged into different departments. Each job demands unique technological requirements and demands processing on machines in a certain sequence.

- **Characteristics**

The Job-shop production system is followed when there is:

1. High variety of products and low volume.
2. Use of general-purpose machines and facilities.
3. Highly skilled operators who can take up each job as a challenge because of their uniqueness.
4. Large inventory of materials, tools, parts.
5. Detailed planning is essential for sequencing the requirements of each product, capacitiesfor each work centre and order priorities.

- **Advantages**

The following are the advantages of job shop production:

1. Because of general purpose machines and facilities, various products can be produced.
2. Operators will become more skilled and competent, as each job gives them learningopportunities.
3. Full potential of operators can be utilised.
4. Opportunity exists for creative methods and innovative ideas.

- **Limitations**

The following are the limitations of job shop production:

1. Higher cost due to frequent set-up changes.
2. Higher level of inventory at all levels and hence higher inventory cost.
3. Production planning is complicated.
4. Larger space requirements.

2. **BATCH PRODUCTION**

Batch production is defined by American Production and Inventory Control Society (APICS) *“as a form of manufacturing in which the job passes through the functional departments in lots or batches, and each lot may have a different routing.”* It is characterised by the manufacture of the limited number of products produced at regular intervals and stocked awaiting sales.

Characteristics

The batch production system is used under the following circumstances:

1. When there is shorter production runs.
2. When plant and machinery are flexible.
3. When plant and machinery set up is used for the production of the item in a batch and a change of set up is required for processing the next batch.
4. When manufacturing lead time and cost are lower as compared to job order production.

Advantages

The following are the advantages of batch production:

1. Better utilisation of plant and machinery.
2. Promotes functional specialisation.
3. Cost per unit is lower as compared to job order production.
4. Lower investment in plant and machinery.
5. Flexibility to accommodate and process a number of products.
6. Job satisfaction exists for operators.

Limitations

Following are the limitations of batch production:

1. Material handling is complex because of irregular and longer flows.
2. Production planning and control is complex.
3. Work in process inventory is higher compared to continuous production.
4. Higher set-up costs due to frequent changes in set-up.

3. MASS PRODUCTION

The manufacture of discrete parts or assemblies using a continuous process is called mass production. This production system is justified by very large volume of production. The machines are arranged in a line or product layout. Product and process standardization exists, and all outputs follow the same path.

- **Characteristics**

Mass production is used under the following circumstances:

1. Standardization of product and process sequence.
2. Dedicated special purpose machines having higher production capacities and output rates.
3. Large volume of products.
4. Shorter cycle time of production.
5. Lower in process inventory.
6. Perfectly balanced production lines.
7. Flow of materials, components and parts is continuous and without any back tracking.

8. Production planning and control is easy.
9. Material handling can be completely automatic.

Advantages

Following are the advantages of mass production:

1. Higher rate of production with reduced cycle time.
2. Higher capacity utilisation due to line balancing.
3. Less skilled operators are required.
4. Low process inventory.
5. Manufacturing cost per unit is low.

- **Limitations**

Following are the limitations of mass production:

1. Breakdown of one machine will stop an entire production line.
2. Line layout needs major change with the changes in the product design.
3. High investment in production facilities.
4. The cycle time is determined by the slowest operation.

4. CONTINUOUS PRODUCTION

Production facilities are arranged as per the sequence of production operations from the operation of the first operation to the finished product. The items are made to flow through the sequence of operations through material handling devices such as conveyors, transfer devices, etc.

- **Characteristics**

Continuous production is used under the following circumstances:

1. Dedicated plant and equipment with zero flexibility.
2. Material handling is fully automated.
3. Process follows a predetermined sequence of operations.
4. Component materials cannot be readily identified with the final product.
5. Planning and scheduling are a routine action.

- **Advantages**

Following are the advantages of continuous production:

1. Standardization of product and process sequence.
2. Higher rate of production with reduced cycle time.
3. Higher capacity utilisation due to line balancing.
4. Manpower is not required for material handling as it is entirely automatic.
5. Person with limited skills can be used on the production line.
6. Unit cost is lower due to the high volume of production.

- **Limitations**

The following are the limitations of continuous production:

1. Flexibility to accommodate and process a number of products does not exist.
2. Very high investment for setting flow lines.

3. Product differentiation is limited.

1.5 PRODUCTION MANAGEMENT

Production management is a process of planning, organizing, directing and controlling the activities of the production function. It combines and transforms various resources used in the production subsystem of the organization into value-added product in a controlled manner as per the policies of the organization.

E.S. Buffa defines production management as, **"Production management** *deals with decision making related to production processes so that the resulting goods or services are produced according to specifications, in the amount and by the schedule demanded and out of minimum cost.*"

1.5.1 Objectives of Production Management

The objective of the production management is 'to produce goods services of right quality and quantity at the right time and right manufacturing cost'.

1. RIGHT QUALITY

The quality of the product is established based on the customers needs. The right quality is not necessarily the best quality. It is determined by the cost of the product and the technical characteristics as suited to the specific requirements.

2. RIGHT QUANTITY

The manufacturing organization should produce the products in the right number. If they are produced in excess of demand, the capital will block up in the form of inventory and if the quantity is produced in short of demand, it leads a to shortage of products.

3. RIGHT TIME

Timeliness of delivery is one of the important parameters to judge the effectiveness of the production department. So, the production department has to make the optimal utilization of input resources to achieve its objective.

4. RIGHT MANUFACTURING COST

Manufacturing costs are established before the product is actually manufactured. Hence, all attempts should be made to produce the products at pre-established cost, so as to reduce the variation between actual and the standard (pre-established) cost.

Operating system converts inputs in order to provide outputs which a customer requires. It converts physical resources into outputs, the function of which is to satisfy customer wants *i.e.*, to provide some utility for the customer. In some organization, the product is a physical good (hotels) while in others it is a service (hospitals). Bus and taxi services, tailors, hospitals and builders are examples of operating systems.

1.6 OPERATING SYSTEM

Everett E. Adam & Ronald J. Ebert define operating system as, "*An operating system(function) of an organization is the part of an organization that produces the organization's physical goods and services.*"

Ray Wild defines operating system as, "*An operating system is a configuration of resources combined for the provision of goods or services.*"

1.6.1 Concept of Operations

An operation is defined in terms of the mission it serves for the organization, the technology it employs and the human and managerial processes it involves. Operations in an organization can be categorized into manufacturing operations and service operations. Manufacturing operations is a conversion process that includes manufacturing yields a tangible output: a product, whereas, a conversion process that includes service yields an intangible output: a deed, a performance, an effort.

1.6.2 Distinction between Manufacturing Operations and Service Operations

The following characteristics can be considered for distinguishing manufacturing operations withservice operations:

1. Tangible/Intangible nature of the output
2. Consumption of output
3. Nature of work (job)
4. Degree of customer contact
5. Customer participation in the conversion
6. Measurement of performance.

Manufacturing is characterized by tangible outputs (products), outputs that customers consume overtime, jobs that use less labour and more equipment, little customer contact, no customer participation in the conversion process (in production), and sophisticated methods for measuring production activities and resource consumption as product are made.

Service is characterized by intangible outputs, outputs that customers consume immediately, jobs that use more labour and less equipment, direct consumer contact, frequent customer participation in the conversion process, and elementary methods for measuring conversion activities and resource consumption. Some services are equipment based namely rail-road services, telephone services and some are people based namely tax consultant services, hair styling.

1.7 OPERATIONS MANAGEMENT

1.7.1 A Framework for Managing Operations

Managing operations can be enclosed in a frame of general management function as shown in Fig. 1.3. Operation managers are concerned with planning, organising, and controlling the activities which affect human behaviour through models.

- **PLANNING**

Activities that establish a course of action and guide future decision-making are planning. The operations manager defines the objectives for the operations subsystem of the organization, and the policies, and procedures for achieving the objectives. This stage includes clarifying the role and focus of operations in the organization's overall strategy. It also involves product planning, facility designing and using the conversion process.

- **ORGANIZING**

Activities that establish a structure of tasks and authority. Operation managers establish a structure of roles and the flow of information within the operations subsystem. They determine the activities required to achieve the goals and assign authority and responsibility for carrying them out.

CONTROLLING

Activities that assure the actual performance in accordance with planned performance. To ensure that the plans for the operations subsystems are accomplished, the operations manager must exercise control by measuring actual outputs and comparing them to planned operations management. Controlling costs, quality, and schedules are the important functions here.

- **BEHAVIOUR**

Operation managers are concerned with how their efforts to plan, organize, and control affect human behaviour. They also want to know how the behaviour of subordinates can affect management's planning, organizing, and controlling actions. Their interest lies in decision-makingbehaviour.

- **MODELS**

As operation managers plan, organise, and control the conversion process, they encounter many problems and must make many decisions. They can simplify their difficulties using models like *aggregate planning models* for examining how best to use existing capacity in short-term, *break-even analysis* to identify break even volumes, *linear programming and computer simulation* for capacity utilization, *decision tree analysis* for long-term capacity problem of facility expansion, *simple median model* for determining best locations of facilities etc.

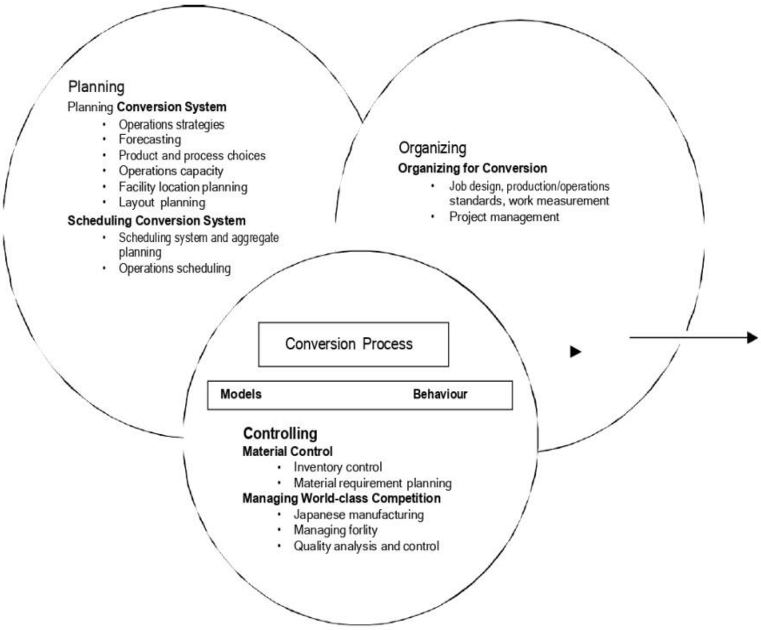


Fig. 1.3 *General model for managing operations*

1.7.2 Objectives of Operations Management

Objectives of operations management can be categorised into customer service and resource utilization.

CUSTOMER SERVICE

The first objective of operating systems is the customer service to the satisfaction of customer wants. Therefore, customer service is a key objective of operations management. The operating system must provide something to a specification which can satisfy the customer in terms of cost and timing. Thus, primary objective can be satisfied by providing the 'right thing at a right priceat the right time'.

These aspects of customer service—specification, cost and timing—are described for four functions in Table 1.2. They are the principal sources of customer satisfaction and must, therefore, be the principal dimension of the customer service objective for operations managers.

TABLE 1.2 Aspects of customer service

Principal function	Principal customer wants	
	Primary considerations	**Other considerations**
Manufacture	Goods of a given, requested or acceptable specification	*Cost*, *i.e.*, purchase price or cost of obtaining goods. *Timing*, *i.e.*, delivery delay from order or request to receipt of goods.
Transport	Management of a given, requested or acceptable specification	*Cost*, *i.e.*, cost of movements. *Timing*, *i.e.*, 1. Duration or time to move. 2. Wait or delay from requesting to its commencement.
Supply	Goods of a given, requested or acceptable specification	*Cost*, *i.e.*, purchase price or cost of obtaining goods. *Timing*, *i.e.*, delivery delay from order or request to receipt of goods.
Service	Treatment of a given, requested or acceptable specification	*Cost*, *i.e.*, cost of movements. *Timing*, *i.e.*, 1. Duration or time required for treatment. 2. Wait or delay from requesting treatment to its commencement.

Generally, an organization will aim reliably and consistently to achieve certain standards and operations manager will be influential in attempting to achieve these standards. Hence, this objective will influence the operations manager’s decisions to achieve the required customer service.

RESOURCE UTILISATION

Another major objective of operating systems is to utilize resources for the satisfaction of customer wants effectively, *i.e.*, customer service must be provided with the achievement of effective operations through efficient use of resources. Inefficient use of resources or inadequate customer service leads to commercial failure of an operating system.

Operations management is concerned essentially with the utilization of resources, *i.e.*, obtaining maximum effect from resources or minimising their loss, under utilization or waste. The extent of the utilization of the resources’ potential might be expressed in terms of the proportion of available time used or occupied, space utilization, levels of activity, etc. Each measure indicates the extent to which the potential or capacity of such resources is utilized. This is referred as the objective of resource utilization.

Operations management is also concerned with the achievement of both satisfactory customer service and resource utilization. An improvement in one will often give rise to deterioration in the other. Often both cannot be maximized, and hence a satisfactory performance must be achieved on both objectives. All the activities of operations management must be tackled with these two objectives in mind, and many of the problems will be faced by operations managers because of this conflict. Hence, operations managers must attempt to balance these basic objectives.

Table 1.3 summarizes the twin objectives of operations management. The type of balance established both between and within these basic objectives will be influenced by market considerations, competitions, the strengths and weaknesses of the organization, etc. Hence, the operations managers should make a contribution when these objectives are set.

TABLE 1.3 The twin objectives of operations Management

The customer service objective. To provide agreed/adequate levels of customer service (and hence customer satisfaction) by providing goods or services with the right specification, at the right cost and at the right time.	The resource utilization objective. To achieve adequate levels of resource utilization (or productivity) e.g., to achieve agreed levels of utilization of materials, machines and labour.

1.8 MANAGING GLOBAL OPERATIONS

The term 'globalization' describes businesses' deployment of facilities and operations around the world. Globalization can be defined as a process in which geographic distance becomes a factor of diminishing importance in the establishment and maintenance of cross border economic, political and socio-cultural relations. It can also be defined as worldwide drive toward a globalized economic system dominated by supranational corporate trade and banking institutions that are not accountable to democratic processes or national governments.

There are four developments, which have spurred the trend toward globalization. These are:

1. Improved transportation and communication technologies;
2. Opened financial systems;
3. Increased demand for imports; and
4. Reduced import quotas and other trade barriers.

When a firm sets up facilities abroad it involves some added complexities in its operation. Global markets impose new standards on quality and time. Managers should not think about domestic markets first and then global markets later, rather it could be thought globally and act locally. Also, they must have a good understanding of their competitors. Some other important challenges of managing multinational operations include other languages and customs, different management style, unfamiliar laws and regulations, and different costs.

Managing global operations would focus on the following key issues:

- To acquire and properly utilize the following concepts and those related to global operations,supply chain, logistics, etc.
- To associate global historical events to key drivers in global operations from differentperspectives.
- To develop criteria for conceptualization and evaluation of different global operations.
- To associate success and failure cases of global operations to political, social, economicnd technological environments.
- To envision trends in global operations.
- To develop an understanding of the world vision regardless of their country of origin, residence or studies in a respectful way of perspectives of people from different races, studies, preferences, religion, political affiliation, place of origin, etc.

1.9 SCOPE OF PRODUCTION AND OPERATIONS MANAGEMENT

Production and operations management concern the conversion of inputs into outputs, using physical resources, to provide the desired utilities to the customer while meeting the other organisational objectives of effectiveness, efficiency and adaptability. It distinguishes itself from other functions such as personnel, marketing, finance, etc., by its primary concern for ‘conversionby using physical resources.’ Following are the activities which are listed under production and operations management functions:

1. Location of facilities
2. Plant layouts and material handling
3. Product design
4. Process design
5. Production and planning control
6. Quality control
7. Materials management
8. Maintenance management.

1. LOCATION OF FACILITIES

Location of facilities for operations is a long-term capacity decision which involves a long term commitment about the geographically static factors that affect a business organization. It is an important strategic level decision-making for an organization. It deals with the questions such as 'where our main operations should be based?'

The selection of location is a key-decision as large investment is made in building plant and machinery. An improper location of plant may lead to waste of all the investments made in plant and machinery equipments. Hence, location of plant should be based on the company's expansion lan and policy, diversification plan for the products, changing sources of raw materials and many other factors. The purpose of the location study is to find the optimal location that will results in the greatest advantage to the organization.

2. PLANT LAYOUT AND MATERIAL HANDLING

Plant layout refers to the physical arrangement of facilities. It is the configuration of departments, work centres and equipment in the conversion process. The overall objective of the plant layout is to design a physical arrangement that meets the required output quality and quantity most economically.

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

'Material Handling' refers to the 'moving of materials from the storeroom to the machine and from one machine to the next during the process of manufacture'. It is also defined as the'art and science of moving, packing and storing products in any form'. It is a specialized activity for a modern manufacturing concern, with 50 to 75% of the cost of production. This cost can be reduced by proper section, operation and maintenance of material handling devices. Material handling devices increase the output, improve quality, speed up the deliveries, and decrease the cost of production. Hence, material handling is a prime consideration in the designing new plant and several existing plants.

3. PRODUCT DESIGN

Product design deals with the conversion of ideas into reality. Every business organisation must design, develop and introduce new products as a survival and growth strategy. Developing the new products and launching them in the market is the biggest challenge faced by organizations. The entire process of need identification to physical manufactures of the product involves three functions: marketing, product development, and manufacturing. Product development translates the needs of customers given by marketing into technical specifications and designing the various features into the product to these specifications. Manufacturis responsible fory of selecting the processes by which the product can be manufactured. Product design and development provide link between marketing, customer needs and expectations and the activities required to manufacture the product.

4. PROCESS DESIGN

Process design is a macroscopic decision-making of an overall process route for converting raw material into finished goods. These decisions encompass the selection of a process, choice of technology, process flow analysis and layout of the facilities. Hence, the important decisionsin process design are to analyse the workflow for converting raw material into finished product and to select the workstation for each included in the workflow.

5. PRODUCTION PLANNING AND CONTROL

Production planning and control can be defined as the process of planning the production in advance, setting the exact route of each item, fixing the starting and finishing dates for each item, to give production orders to shops and to follow up the progress of products according to orders.

The principle of production planning and control lies in the statement 'First Plan Your Work and then Work on Your Plan'. Main functions of production planning and control includes planning, routing, scheduling, dispatching and follow-up.

- **Planning** is deciding in advance what to do, how to do it, when to do it and who is to doit. Planning bridges the gap from where we are, to where we want to go. It makes it possiblefor things to occur which would not otherwise happen.
- **Routing** may be defined as the selection of path which each part of the product will follow, which being transformed from raw material to finished products. Routing determines the most advantageous path to be followed from department to department and machine to machine tillraw material gets its final shape.
- **Scheduling** determines the programme for the operations. Scheduling may be defined as 'the fixation of time and date for each operation' as well as it determines the sequence of operations to be followed.

- **Fig. 1.4** *Scope of production and operations management*

Dispatching is concerned with starting the processes. It gives necessary authority so as to start a particular work, which has already been planned under 'Routing' and 'Scheduling'. Therefore, dispatching is 'release of orders and instruction for the starting of production for any item in acceptance with the route sheet and schedule charts'.

The function of **follow-up** is to report daily work progress in each shop in a prescribed proforma and investigate the causes of deviations from the planned performance.

6. QUALITY CONTROL

Quality Control (QC) may be defined as 'a system used to maintain a desired level of quality in a product or service. It systematically controls various factors that affect the quality of the product. Quality control aims at prevention of defects at the source, relies on effectivefeedback system and corrective action procedure.

Quality control can also be defined as 'that industrial management technique by means of which product of uniform acceptable quality is manufactured'. It is the entire collection of activities whichensures that the operation will produce the optimum quality products at minimum cost.

The main objectives of quality control are:

- To improve the company's income by making the production more acceptable to thecustomers *i.e.*, by providing long life, greater usefulness, maintainability, etc.
- To reduce company's cost through the reduction of losses due to defects.
- To achieve interchangeability of manufacture in large-scale production.
- To produce optimal quality at reduced price.
- To ensure satisfaction of customers with productions or services or high quality level, tobuild customer goodwill, confidence and reputation of manufacturer.
- To make inspection prompt to ensure quality control.
- To check the variation during manufacturing.

7. MATERIALS MANAGEMENT

Materials management is that aspect of management function which is primarily concerned with the acquisition, control and use of materials needed and flow of goods and services connected with the production process having some predetermined objectives in view.

The main objectives of materials management are:

- To Minimise material cost.
- To purchase, receive, transport and store materials efficiently and to reduce the related cost.

- To cut down costs through simplification, standardisation, value analysis, import substitution, etc.
- To trace new supply sources and develop cordial relations with them toensure continuous supply at reasonable rates.
- To reduce investment tied in the inventories for other productive purposes and todevelop high inventory turnover ratios.

8. MAINTENANCE MANAGEMENT

In modern industry, equipment and machinery are a very important part of the total productive effort. Therefore, their idleness or downtime becomes very expensive. Hence, should the plant machinery must be properly maintained.

The main objectives of maintenance management are:

1. To achieve minimum breakdown and to keep the plant in good working condition at thelowest possible cost.
2. To keep the machines and other facilities in such a condition that permits them to be usedat their optimal capacity without interruption.
3. To ensure the availability of the machines, buildings and services required by other sectionsof the factory for the performance of their functions at optimal return on investment.

❖ Check Your Progress

Section A

1. What do you mean by 'Production'?
2. What do you mean by production system?
3. Mention the different types of production systems.
4. What is job shop production?
5. What is batch production?
6. What is mass production?
7. What is continuous production?
8. Mention any four advantages of job shop production.
9. Mention any four limitations of job shop production.
10. Mention any four advantages of batch production.
11. Mention any four limitations of batch production.
12. Mention any four advantages of mass production.
13. Mention any four limitations of mass production.
14. Mention any four advantages of continuous production.
15. Mention any four limitations of continuous production.
16. Define production management.
17. Mention any four objectives of production management.
18. Define operating system.
19. How do you manage operations?
20. What do you mean by operations?

21. What do you mean by manufacturing operations?
22. What do you mean by service operations?
23. What do you mean by 'globalization'?

Section B

1. Briefly explain the production system and its characteristics.
2. What is job shop production? What are its characteristics, advantages and limitations?
3. What is batch production? What are its characteristics, advantages and limitations?
4. What is mass production? What are its characteristics, advantages and limitations?
5. What is continuous production? What are its characteristics, advantages and limitations?
6. Explain in brief the objectives of production management.
7. Explain in brief the objectives of operations management.
8. Distinguish between manufacturing operations and service operations.
9. Explain the key issues to be considered for managing global operations.

Section C

1. Explain the different types of production systems.
2. Explain the framework of managing operations.
3. Explain the scope of production and operations management.

Skill Development

Visit a fast-food restaurant like Pizza hut, Pizza corner to understand the concept of thischapter by getting the information for the following questions.

1. Identify the type of production system followed.
2. Check how production system is managed.
3. Find out utilization of the resources namely manpower, capacity and material.
4. How the customer services is rendered [feedback system exist or not]

CASELET

SHEENA

Sheena had worked for the same Fortune 500 Company for most 15 years. Although the company had gone through some tough times, things were starting to turn around. Customer orders were up, and quality and productivity had improved dramatically from what they had been only a few years earlier due company-wide quality improvement program. So, it comes as a real shock to Sheena and about 400 of her co-workers when they were suddenly terminated following the new CEO's decision to downsize the company.

After recovering from the initial shock, Sheena tried to find employment elsewhere. Despite her efforts, after eight months of searching, she was no closer to finding a job than the day she started. Her funds were being depleted and she was getting more discouraged. There was one bright spot, though: She was able to bring in a little money by mowing lawns for her neighbours. She got involved quite by chance when she heard one neighbour remark that now that his children were on their own, nobody was around to cut the grass. Sheena almost jokingly asked him how much he'd be willing to pay. Soon Sheena was mowing the lawns of five neighbours. Other wanted her to work on their lawns, but she didn't feel she could spare any more time from her job search.

However, as the rejection letters began to pile up, Sheena knew she had to make an important decision in her life. On a rainy Tuesday morning, she decided to go into business for herself, taking care of neighbourhood lawns. She was relieved to give up the stress of job hunting and excited about the prospects of being her own boss. But she was also fearful of being entirely on her own. Nevertheless, Sheena was determined to make a go of it.

At first, business was a little slow, but once people realized Sheena was available, many asked her to take care of their lawns. Some people were simply glad to turn - the work over to her; others switched from professional lawn care services. By the end of her first year in business, Sheena knew she could earn a living this way. She also performed other services such as fertilizing lawns, weeding gardens, and trimming shrubbery. The business became so good that Sheena hired two part-time workers to assist her; even then, she believed she could expand further if she wanted to.

Questions

1. In what ways are Sheena's customers most likely to judge the quality of her lawn care services?

2. Sheena is the operations manager of her business. Among her responsibilities are forecasting, inventory management, scheduling, quality assurance, and maintenance.

(a) What kinds of things would likely require forecasts?

(b) What inventory items does Sheena probably have? Name one inventory decision she has to make periodically.

(c) What scheduling must she do? What things might occur to disrupt schedules and cause Sheena to reschedule?

(d) How important is quality assurance to Sheena's business? Explain.

(e) What kinds of maintenance must be performed?

3. What are some of the trade-offs that Sheena probably considered relative to:

(a) Working for a company instead of for herself?
(b) Expanding the business?

4. The town is considering an ordinance that would prohibit putting grass clippings at the curb for pickup because local landfills cannot handle the volume. What options might Sheena consider if the ordinance is passed? Name two advantages and two drawbacks of each option.

[**Source:** *Production/Operations Management by William J.Stevenson, Irwin/McGraw-Hill*]

WEGMANS FOOD MARKETS

Wegmans Food Markets, Inc., is one of the premier grocery chains in the United States. Headquartered in Rochester, NY, Wegmans operates over 70 stores. The company employs over 23,000 people and has annual sales of over Rs. 2.0 billion.

Wegmans has a strong reputation for offering its customers high product quality and excellent service. Through a combination of market research, trial and error, and listening to its customers, Wegmans has evolved into a very successful organization. In fact, Wegmans is so good at what it does that grocery chains all over the country send representatives to Wegmans for a firsthand look at operations.

SUPERSTORES

Many of the company's stores are giant 100,000-square-foot superstores, double or triple the size of average supermarkets. A superstore typically employs from 500 to 600 people.

Individual stores differ somewhat in terms of actual size and some special features. Aside from the features normally found in supermarkets, they generally have a large bakery Section (each store bakes its own bread, rolls, cakes, pies, and pastries), and extra large produce sections. They also offer film processing a complete pharmacy, a card shop and video rentals. In- store floral shops range in size up to 800 square feet of space, and offer a wide variety of fresh- cut flowers, flower arrangements, varies and plants. In-store card shops covers over 1000 square feet of floor of floor space. The bulk foods department allows customers to select what quantities they desire from a vast array of foodstuffs and some nonfood items.

Each store is a little different. stores some stores' special features are a dry cleaning department, a wokery, and a salad bar. Some feature a Market Cafe that has different food stations, each devoted to preparing and serving a certain type of food. For example, one station has pizza and other Italian specialties, and another oriental food. There are also being a sandwich bar, a salad bar and a dessert station. Customers often wander among stations as they decide what to order.

In several affluent locations, customers can stop in on their way home from work and choose from a selection of freshly prepared dinner entrees. Some stores have a coffee shop section with tables and chairs where shoppers can enjoy regular or speciality coffees and a variety of tempting pastries.

PRODUCE DEPARTMENT

The company prides itself on fresh produce. Produce is replenished as often as 12 times a day. The larger stores have to produce sections four to five times the size of a produce section of an average supermarket. Wegmans offers locally grown produce a season. Wegmans uses a 'farm to market' system whereby some local growers deliver their produce directly to individual stores, bypassing the main warehouse. That reduces the company's inventory holding costs and gets the produce into the stores as quickly as possible. Growers may use specially designed containers that go right onto the store floor instead of large bins. This avoids the bruising that often occurs when fruits and vegetables are transferred from bins to display shelves and the need to devote labour to transfer the produce to shelves.

MEAT DEPARTMENT

In addition to large display cases of fresh and frozen meat products, many stores have a full-service butcher shop that offers a variety of fresh meat products and where butchers are available to provide customised cuts of meat for customers.

ORDERING

Each department handles its own ordering. Although sales records are available from records of items scanned at the checkouts, they are not used directly for replenishing stock. Other factors, such as pricing, special promotions, local circumstances, must all be taken into account. However, for seasonal periods, such as holidays, managers often check scanner records to learn what past demand was during a comparable period.

The superstores typically receive one truckload of goods daily from the main warehouse. During peak periods, a store may receive two truckloads from the main warehouse. The short lead-time significantly reduces the length of time an item might be out of stock unless the main warehouse is also out of stock.

The company exercises strict control over suppliers, insisting on product quality and on-timedeliveries.

EMPLOYEES

The company recognises the value of good employees. It typically invests an average of Rs.7000 training training each new employee. In addition to learning about stores operations, new employees learn the importance of good customer service and how to provide it. The employees are helpful, cheerfully answering customer questions or handling complaints. Employees are motivated through a combination of compensation, profit sharing, and benefits.

QUALITY

Quality and Customer satisfaction are utmost in the minds of Wegmans management and its employees. Private label food items as well as name brands are regularly evaluated in test kitchens, along with the potential new products. Managers are responsible for checking and maintaining products and service quality in their departments. Moreover, employees are encouraged to report problems to their managers.

If a customer is dissatisfied with an item and returns it, or even a portion of the item, the customer is offered a choice of a replacement or a refund. If the item is a Wegman's brand food item, it is then sent to the test kitchen to determine the cause of the problem. If the cause can be determined, corrective action is taken.

Questions

1. How do customers judge the quality of a supermarket?

2. Indicate how and why each of these factors is important to the successful operation of a supermarket:

(a) Customer satisfaction.

(b) Forecasting.

(c) Capacity planning.

(d) Location

(e) Inventory management.

(f) Layout of the store.

(g) Scheduling.

[**Source:** *Production/Operations Management by William J.Stevenson, Irwin/McGraw-Hill*]

UNIT : 2	PRODUCT & PROCESS DESIGN & AUTOMATION

2.1 INTRODUCTION TO PRODUCTION AND OPERATION MANAGEMENT

Production/operations management is the process, which combines and transforms various resources used in the production/operations subsystem of the organization into value-added product/services in a controlled manner as per the policies of the organization. Therefore, it is that part of an organization concerned with transforming a range of inputs into the required (products/services) with the requisite quality level.

The set of interrelated management activities, which are involved in manufacturing certain products, is called **production management**. If the same concept is extended to services management, then the corresponding set of management activities is called as **operations management**.

2.1.1 The Product/ Process Continuum

Various organization can be placed on a continuum, whose extreme limits are product orientation (where the emphasis is on what the customer buys) and process orientation (wherethe emphasis is on how it is provided). The two extreme presents the 'Pure' manufacturing and "pure' service' industries. In fig 1, the automobile manufacturers are shown at the product orientation extreme and consultancies and undertake lie on the process orientation extremeof the continuum.

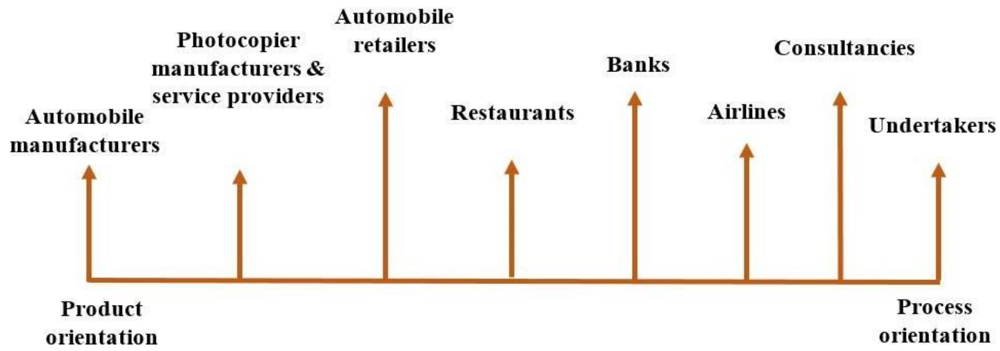


Fig. 1 Organizations on a Product/Process Continuum

2.1.2 Concept of Production

Production function is that part of an organization concerned with transforming a range of inputs into the required outputs (products) having the requisite quality level.

Production is defined as "the step-by-step conversion of one form of material into another form through a chemical or mechanical process to create or enhance the utility of the product to the user." Thus, production is a value-addition process. At each stage of processing, therewill be value addition.

Edwood Buffa defines production as 'a process by which goods and services are created'. Someexamples of production are manufacturing custom-made products like boilers with a specific capacity, constructing flats, some structural fabrication works for selected customers etc., andmanufacturing standardized products like car, bus, motor cycle, radio, television, etc.

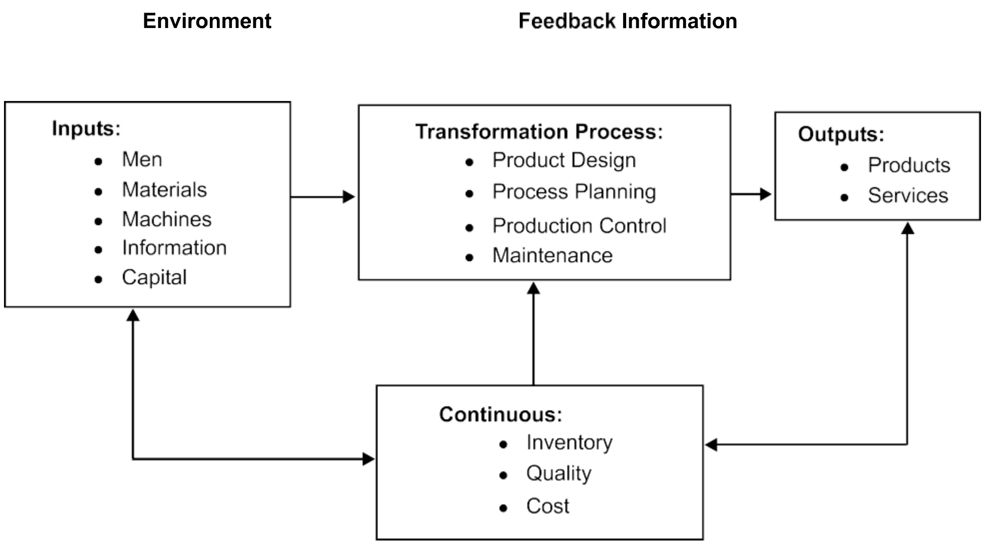


Fig. 2 Schematic production system

2.1.3 Production System

The production system of an organization is that part, which produces products of an organization. It is that activity whereby resources, flowing within a defined system, are combined and transformed in a controlled manner to add value in accordance with the policies communicated by management. A simplified production system is shown above in fig 2.

The production system has the following characteristics:

1. Production is an organized activity, so every production system has an objective.
2. The system transforms the various inputs into useful outputs.
3. It does not operate in isolation from the other organization system.
4. There exists feedback about the activities, which is essential to control and improve system performance.

2.2 PROCESS DESIGN

Process design is a macroscopic decision-making of an overall process route for converting raw material into finished goods. These decisions encompass the selection of a process, choice of technology, process flow analysis and layout of the facilities. Hence, the important decisions in process design are to analyse the workflow for converting raw material into the finished product and to select the workstation for each included in the workflow.

2.2.1 Classification of Production System:

Production systems can be classified as Project, Job Shop, Batch, Mass and ContinuousProduction systems.

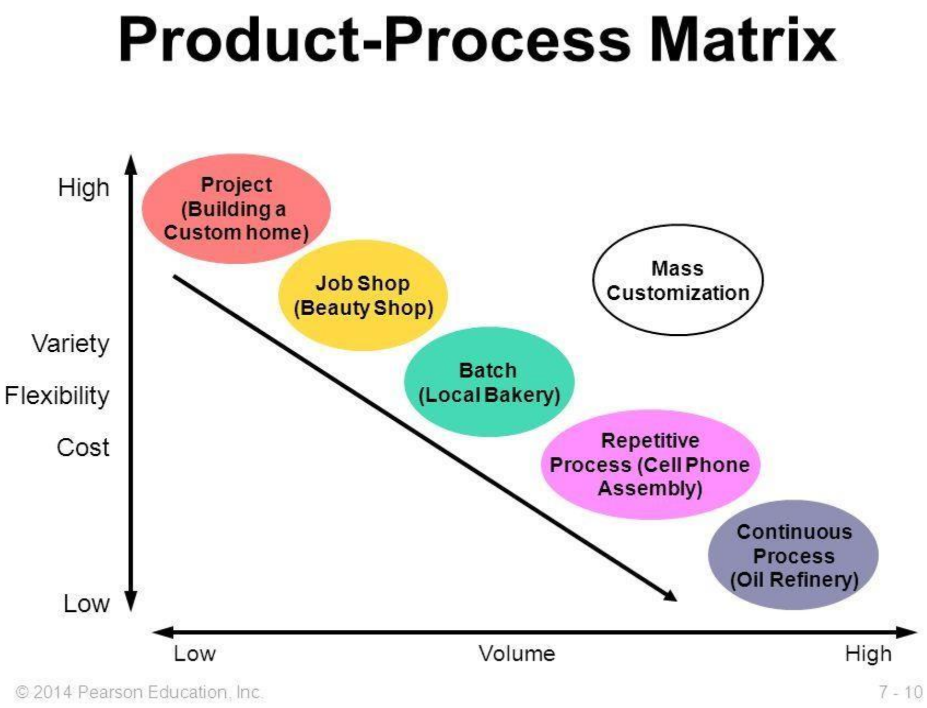


Fig. 3 Types of Processes

2.2.1.1 Project

Projects take a long time to complete, involve a large investment of funds and resources, and produce one item at a time for consumer order. Examples include construction projects,shipbuildinew productduct development, and aircraft manufacturing etc.

Characteristics

1. Project is very unique.
2. Demand volume very low.
3. Varied equipment used.
4. Specialized workers and experts required.
5. Long-term project.

Advantages

1. Custom work with the latest technology

Disadvantages

1. Nonrepetitive
2. Small customer base
3. Expensive

2.2.1.2 Job Shop

Job shop production is characterized by the manufacturing of one or few quantities of products designed and produced as per the specification of customers within prefixed time and cost. The distinguishing feature of this is low volume and high variety of products.

A job shop comprises general-purpose machines arranged into different departments. Each job demands unique technological requirements and demands processing on machines in a certain sequence. For example, in a restaurant, every customer gives a different order of dishes, which are prepared by different cooks using different utensils, ovens etc., and different recipes.

Characteristics

The Job-shop production system is followed when there is:

1. High variety of products and low volume.
2. Use of general- purpose machines and facilities.
3. Highly skilled operators who can take up each job as a challenge because of uniqueness.
4. Large inventory of materials, tools, parts.
5. Detailed planning is essential for sequencing the requirements of each product,capacities for each work center and order priorities.

Advantages

The following are the advantages of job shop production:

1. Because of general-purpose machines and facilities, various products can beproduced.
2. Operators will become more skilled and competent, as each job gives them learningopportunities.
3. Full potential of operators can be utilized.
4. Opportunity exists for creative methods and innovative ideas.

Limitations

The following are the limitations of job shop production:

1. Higher cost due to frequent set-up changes.
2. Higher level of inventory at all levels and hence higher inventory cost.
3. Production planning is complicated.
4. Larger space requirements.

2.2.1.3 Batch Production

Batch production is defined by American Production and Inventory Control Society(APICS) “as a form of manufacturing in which the job passes through the functional departments in lots or batches and each lot may have a different routing.” It is characterizedby the manufacture of limited number of products produced at regular intervals and stocked awaiting sales. For example, in a bakery, a batch of salted biscuits may be made in the oven, a batch of chocolate, a batch of bread and so on. The equipment used is the same in all the cases with the same processing steps but cleaning and adjustments of the equipment may be required after each production run.

Characteristics

Batch production system is used under the following circumstances:

1. When there are shorter production runs.
2. When plant and machinery are flexible.
3. When plant and machinery set up is used for the production of the item in a batch and change of set up is required for processing the next batch.
4. When manufacturing lead time and cost are lower as compared to job order production.

Advantages

The following are the advantages of batch production:

1. Better utilization of plant and machinery.
2. Promotes functional specialization.
3. Cost per unit is lower as compared to job order production.
4. Lower investment in plant and machinery.
5. Flexibility to accommodate and process number of products.
6. Job satisfaction exists for operators.

- **Limitations**

Following are the limitations of batch production:

1. Material handling is complex because of irregular and longer flows.
2. Production planning and control is complex.
3. Work in process inventory is higher compared to continuous production.
4. Higher set up costs due to frequent changes in set up.

2.2.1.4 Mass Production

The manufacture of discrete parts or assemblies using a continuous process are called mass production. This production system is justified by very large volume of production. The machines are arranged in a line or product layout. Product and process standardization existsand all outputs follow the same path. For example, automobiles, electronic items, white goods, these processes require specialised machines, and semi-skilled workers and result in low cost per unit.

Characteristics

Mass production is used under the following circumstances:

1. Standardization of product and process sequence.
2. Dedicated special-purpose machines having higher production

capacities and outputrates.

3. Large volume of products.
4. Shorter cycle time of production.
5. Lower in process inventory.
6. Perfectly balanced production lines.
7. Flow of materials, components and parts is continuous and without any backtracking.
8. Production planning and control is easy.
9. Material handling can be completely automatic.

Advantages

Following are the advantages of mass production:

1. Higher rate of production with reduced cycle time.
2. Higher capacity utilization due to line balancing.
3. Less skilled operators are required.
4. Low process inventory.
5. Manufacturing cost per unit is low.

Limitations

Following are the limitations of mass production:

1. Breakdown of one machine will stop an entire production line.
2. Line layout needs major change with the changes in the product design.
3. High investment in production facilities.
4. The cycle time is determined by the slowest operation.

2.2.1.5 Continuous Production

Production facilities are arranged as per the sequence of production operations from the first operation to the finished product. The items are made to flow through the sequence of operations through material handling devices such as conveyors, transfer devices, etc. The products produced by such a process are highly standardized with almost no variety. They are measured continuously (tones per day, meter length per day, etc.) rather than in discrete units. For example, urea, sugar, textiles, etc., are based onthe continuous process and are therefore known as process industries.

Characteristics

Continuous production is used under the following circumstances:

1. Dedicated plant and equipment with zero flexibility.
2. Material handling is fully automated.
3. Process follows a predetermined sequence of operations.
4. Component materials cannot be readily identified with the final product.
5. Planning and scheduling are routine action.

Advantages

The following are the advantages of continuous production:

1. Standardization of product and process sequence.
2. Higher rate of production with reduced cycle time.
3. Higher capacity utilization due to line balancing.
4. Manpower is not required for material handling as it is entirely automatic.
5. Person with limited skills can be used on the production line.
6. Unit cost is lower due to the high volume of production.

Limitations

The following are the limitations of continuous production:

1. Flexibility to accommodate and process number of products does not exist.
2. Very high investment for setting flow lines.
3. Product differentiation is limited.

2.3 PRODUCT DESIGN

The design has a tremendous impact on the quality of a product or service. Poor design may not meet customer needs or may be so difficult to make that quality suffers. Product design defines the product's appearance, sets performance standards, specifies which materials are tobe used, and determines dimensions and tolerance. Fig 4 outlines the design process from ideageneration to product launch.

2.3.1 Idea generation

Ideas for new products or improvements to existing products can be generated from many sources, including a company's own R&D department, customer complaints or suggestions, suppliers, factory workers and new technological developments. Perceptual maps, benchmarking and reverse engineering can help companies learn from their competitors. **Perceptual maps** compare customer perceptions of a company's products with competitor's products. **Benchmarking** refers to finding the best-in-class product or process, measuring the performance of your product or process against it, and making recommendations for improvement based on the results. The benchmarked company may be in an entirely differentline of business.

Reverse engineering is the process of carefully dismantling an existing product (of a competitor) step by step in order to understand the unique underlying concepts. It helps in designing the new products, which are better than those of the competitors. In the filed of consumer electronics, Sony corp. is on the forefront in designing new innovative items such as Walkman, handy Cam, digital cameras etc. Many other companies have to follow the reverse engineering approach in order to break Sony's monopoly of new products in the shortest possible time.

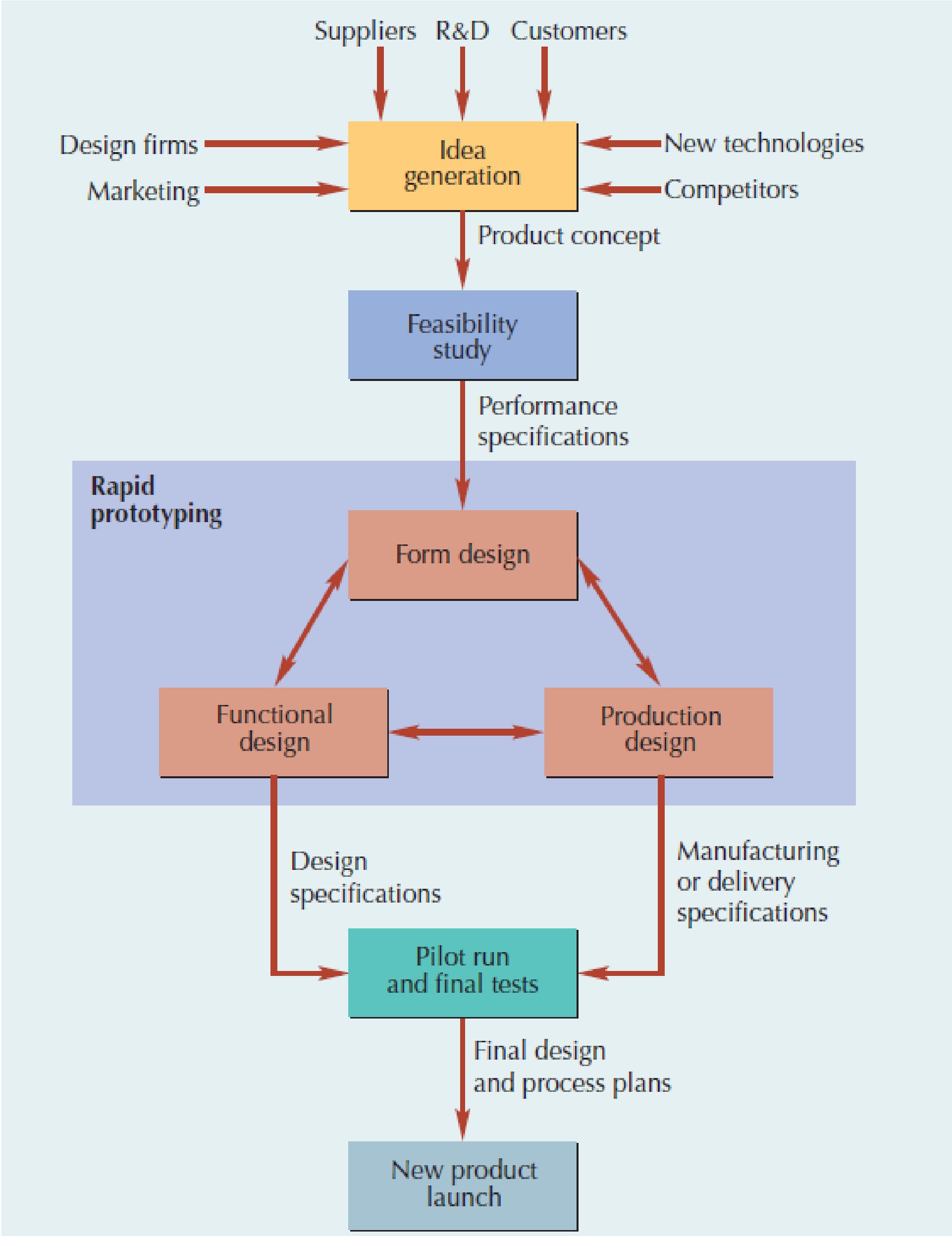


Fig 4 The Design Process of Product

2.3.2 Feasibility Study

The promising concepts undergo a feasibility study that includes several types of analyses, beginning with a market analysis. Most companies have staff of market researchers who can design and evaluate customer surveys, interviews, focus groups, or market tests. The **market analysis** assesses whether there's enough demand for the proposed product to invest in developing it further.

Then there's an **economic analysis** that looks at estimates of production and development costs and compares them to estimated sales volume. A price range for the product compatible with the market segment and an image of the new product is discussed. Quantitative techniques such as cost/benefit analysis, decision theory, net present value, or internal rate of return are commonly used to evaluate the project's profit potential. Finally, technical and strategic analyses answer such questions as: Does the new product require new technology? Is the risk or capital investment excessive? Does the company have sufficient labour and management skills to support the required technology? Is sufficient capacity available for production? The next step in the process is rapid prototyping.

2.3.3 Rapid Prototyping and Concurrent Design

Rapid prototyping creates preliminary design models that are quickly tested and either discarded (as fast failures) or further refined. The models can be physical or electronic, rough facsimiles or full-scale working models. The iterative process involves form and functional design and production design. It is important that these design decisions be performed concurrently at the rapid prototype stage. Concurrent design is the product design approach in which the design team includes personnel from the marketing department (to specify the customer requirements), engineering department (to look at the feasibility of the design), production department (to suggest if production capability exists for the design), material department (to give inputs about material availability according to design specification) and finance department(to suggest financial feasibility of the design) in addition to the design department.

2.3.3.1 Concurrent Design

Concurrent design saves a lot of time and effort, unlike the sequential approach in which feedback between departments, rejection of the suggested designs and wastage of a lot of time and effort. There are three types of concurrent designs: form, functional, and production design.

- **Form design** refers to the physical appearance of a product—its shape, colour, size, and style. Aesthetics such as image, market appeal, and personal identification are also part of form design. In many cases, the functional design must be adjusted to make the product look or feel right.
- **Functional design** is concerned with how the product performs. It seeks to meet the performance specifications of fitness for use by the customer. Three performance characteristics considered during this design phase are reliability, maintainability, and usability.
  - **Reliability** is the probability that a given part or product will perform its intended function for a specified length of time under normal conditions of use. You may be familiar with reliability information from product warranties. Ex: a TV will work without repair for about seven years.
  - **Maintainability** (also called serviceability) refers to the ease and/or cost of maintaining or repairing a product or service.
  - **Usability** makes a product or service easy to use and a good fit for its targeted customer. It is a combination of factors that affect the user's experience with a product, including ease of learning, ease of use, and ease of remembering how to use, frequency and severity of errors, and user satisfaction with the experience.
- **Production design** is concerned with how the product will be made. Designs that are difficult to make often result in poor-quality products. Engineers tend to overdesign products, with too many features, options, and parts. A lack of knowledge of manufacturing capabilities can result in make impossible designs or require skills and resources not currently available. Many times, production personnel find themselves redesigning products on the factory floor. Late changes in design are both costly and disruptive. An adjustment in one part may necessitate an adjustment in the preliminary design phase. Recommended approaches to production design include simplification, standardization, modular design and design for manufacture.
  - **Design simplification** attempts to reduce the number of parts, subassemblies, and options in a product. It also means avoiding tools, separate fasteners, and adjustments.
  - **Standardization** refers to less variety in the design of products, i.e., new products are designed such that there is no major variation from the existing products. For example, all computers and typewriters have the same arrangement of keys in the keyboard because it has become standard consumers are used to, although many other more efficient designs of keyboard keys are available, no company is willing to take the risk of deviating from standard. Lack of standardization creates problems such as the NTSC and PAL standards

in TV and VCRs. In computers, different operating systems, such as windows, Linux etc. have resulted in major compatibility issues. On the other hand, standardization has benefits such as lower design cost due to use of existing components/parts and easy availability of components for replacement if any defects arise.

- **Modular design** is another type of standardization which means designing a product in parts or modules. The modules are sub-assemblies of different components and parts. For example, in personal computers there are separate modules (small boxes inside which there are various integrated components) for the motherboard, the hard disk, the power supply, the CD drive etc. whenever a defect occurs, an entire module can be replaced by a new one. However, it may be slightly more expensive than searching for the defective component in a non-modular design and replacing it. It is easier to find the defect because the investigation is limited only to a particular module. This approach reduces the effort and time required to design the product. The inventory management of modulesis simple compared to that of many different components in a non-modular design.
- **Design for manufacture (DFM)** is the process of designing a product to be produced easily and economically. The term was coined in an effort to emphasise the importance of incorporating production design early in the design process. When successful, DFM not only improves the quality of product design but also reduces both the time and cost of product design and manufacture. Specific DFM software can recommend materials and processes appropriate for a design and provide manufacturing cost estimates throughout the design process. More generally, DFM guidelines promote good design practice, such as:

1. Minimize the number of parts and subassemblies.
2. Avoid tools, separate fasteners, and adjustments.
3. Use standard parts when possible and repeatable, well-understood processes.
4. Design parts for many uses, and modules that can be combined in differentways.
5. Design for ease of assembly, minimal handling, and proper presentation.
6. Allow for efficient and adequate testing and replacement of parts.

Some of the organization also going for applying **manufacturability** concepts before designing a new product. Manufacturability implies designing a product in such a way that its manufacturing/ assembling can be done easily. While designing a new product, the manufacturing capabilities (such as existing machines, skills of workers etc.) of the organization have to be kept in mind. If the required capabilities do not exist, the management can consider enhancing the production capabilities by investing more.

2.3.4 Final Design and Process Plans

In the preliminary design stage, prototypes are built and tested. After several iterations, a pilot run of the process is conducted. Adjustments are made as needed before the final design is agreed on. In this way, the design specifications for the new product have considered how the product is to be produced, and the manufacturing or delivery specifications more closely reflect the intent of the design. This should mean fewer revisions in the design as the product is manufactured and the service is provided. The final design consists of detailed drawings and specifications for the new product or service.

The accompanying process plans are workable manufacturing instructions, including necessary equipment and tooling, component sourcing recommendations, job descriptions and procedures for workers, and computer programs for automated machines.

The use of technology aids good design. Part of the impetus for the deluge of new products is the advancement of technology available for designing products. It begins with computer-aided design (CAD) and includes related technologies such as computer-aided engineering (CAE), computer-aided manufacturing (CAM), and collaborative product design (CPD).

2.3.4.1 Computer-aided design (CAD)

CAD is software which helps the designer to make the three-dimensional design of a product on the computer and visualize the design from various angles. In the earlier times, when CAD softwares were not available, design engineers had to make designs from various angles (say front, back, top, and bottom views of the product) on paper charts by using rulers and other equipment, which was tedious and time-consuming. The designs made on CAD can be seen at different workstation through intranets simultaneously. Also, these can be transmitted to a distant location (for experts' comments, etc.) using the internet. New ideas can be suggested and tested immediately, allowing more alternatives to be evaluated.

2.3.4.2 Computer-Aided Engineering (CAE)

CAD-generated products can also be tested more quickly. Engineering analysis, performed with a CAD system, is called computer-aided engineering (CAE). CAE retrieves the description and geometry of a part from a CAD database and subjects it to testing and analysis on the computer screen without physically building a prototype. Advances in virtual reality and motion-capturing technology allow designers and users to experience the design without building a physical prototype.

2.3.4.3 Computer-Aided Manufacturing (CAM)

The ultimate design-to-manufacture connection is a computer-aided design/computer-aided manufacturing (CAD/CAM) system. CAM is the acronym for computer-aided manufacturing. CAD/CAM involves automatically converting CAD design data into processing instructions for computer-controlled equipment and the subsequent manufacture of the part as it was designed. This integration of design and manufacture can save enormous amounts of time, ensure that parts and products are produced precisely as intended, and facilitate revisions in design or customised production.

2.4 AUTOMATION

Automation is a technology that applies mechanical, electronic, and computer-based systems to operate and control production. This technology includes automatic machine tools to process parts, automatic assembly machines, industrial robots, automatic material handling and storage systems, automatic inspection systems for quality control, feedback control and computer process control, and computer systems for planning, data collectionand decision-making to support manufacturing activities.

2.4.1 Types of Automation

Automated production systems can be classified into three basic types:

1. Fixed automation,
2. Programmable automation, and
3. Flexible automation

2.4.1.1 Fixed Automation

It is a system in which the equipment configuration fixes the sequence of processing (or assembly) operations. The operations in the sequence are usually simple. The integration and coordination of many such operations into one piece of equipment makes the system complex.

The typical features of fixed automation are:

(a) High initial investment for custom–Engineered equipment;
(b) High production rates; and
(c) Relatively inflexible in accommodating product changes.

The economic justification for fixed automation is found in products with very high demand rates and volumes. The high initial cost of the equipment can be spread over a very large number of units, thus making the unit cost attractive compared to alternative methods of production. Examples of fixed automation include mechanized assembly and machiningtransfer lines.

2.4.1.2 Programmable Automation

In this the production equipment is designed with the capability to change the sequence of operations to accommodate different product configurations. The operation sequence is controlled by a program, a set of instructions coded so the system can read and interpret them. New programs can be prepared and entered into the equipment to produce new products. Some of the features that characterize programmable automation are:

(a) High investment in general-purpose equipment;
(b) Low production rates relative to fixed automation;
(c) Flexibility to deal with changes in product configuration; and
(d) Most suitable for batch production.

Programmable production systems are used in low and medium-volume production. The parts or products are typically made in batches. To produce each new batch ofa different product, the system must be reprogrammed with machine instructions corresponding to the new product. The physical setup of the machine must also be changed over, tools must be loaded, fixtures must be attached to the machine table also be changed machine settings must be entered. This changeover procedure takes time. Consequently, the typical cycle for the given product includes a period during which the setup and reprogramming take place, followed by a period in which the batch is produced. Examples of programmed automation include numerically controlled machine tools and industrial robots.

2.4.1.3 Flexible Automation

It is an extension of programmable automation. A flexible automated system is capable of producing a variety of products (or parts) with virtually no time lost for changeovers from one product to the next. Production time is maintained while reprogramming the system and altering the physical setup (tooling, fixtures, and machine setting). Consequently, the system can produce various combinations and schedules of products instead of requiring that they be made in separate batches. The features of flexible automation can be summarized as follows:

(a) High investment for a custom-engineered system.
(b) Continuous production of variable mixtures of products.
(c) Medium production rates.
(d) Flexibility to deal with product design variations.

The essential features that distinguish flexible automation from programmable automation are:

(1) the capacity to change part programs with no lost production time; and (2) the capability to changeover the physical setup, again with no lost production time. These features allow the automated production

system to continue production without downtime between batches, which is characteristic of programmable automation. Changing the part programs is generally accomplished by preparing the programs offline on a computer system and electronically transmitting the programs to the automated production system. Therefore, the time required to do the programming for the next job does not interrupt production on the current job. Advances in computer systems technology are largely responsible for this programming capability in flexible automation. Changing the physical setup between parts is accomplished by making the changeover off-line and then moving it into place simultaneously as the next part comes into position for processing. Using pallet fixtures that hold the parts and transfer them into position at the workplace is one way of implementing this approach. For these approaches to be successful, the variety of parts that can be made on a flexible automated production system is usually more limited than a system controlled by programmable automation. The relative positions of the three types of automation for different production volumes and product varieties are depicted in Fig.5.

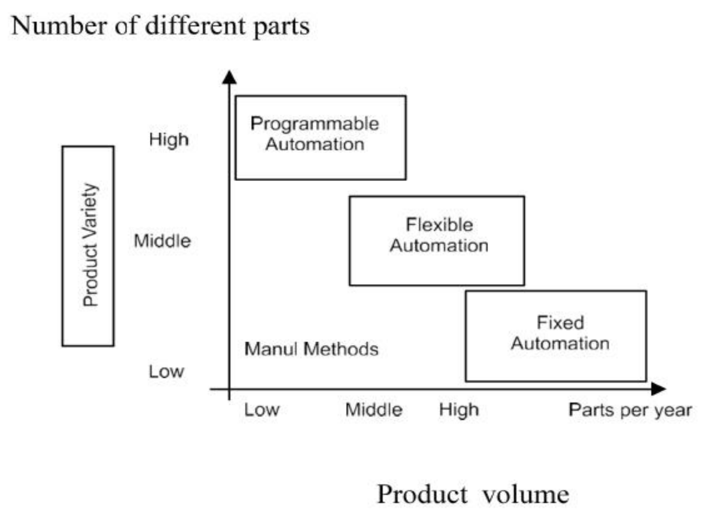


Fig 5 Types of production automation

2.4.2 Advantages of Automation

Following are some of the advantages of automation:

1. Automation is the key to a shorter workweek. Automation will allow the average number of working hours per week to continue to decline, thereby allowing greater leisure hours and higher quality of life.
2. Automation brings safer working conditions for the worker. Since there is less direct physical participation by the worker in the production process, there is less chance of personal injury to the worker.

3. Automated production results in lower prices and better products. It has been estimated thatthe cost to machine one unit of a product by conventional general-purpose machine tools requiring human operators may be 100 times the cost of manufacturing the same unit using automated mass-production techniques. The electronics industry offers many examples of improvements in manufacturing technology that has significantly reduced costs while increasing product value (*e.g*., colour TV sets, stereo equipment, calculators, and computers).

4. The growth of the automation industry will provide employment opportunities. This has been especially true in the computer industry, as the companies in this industry have grown(IBM, Digital Equipment Corp., Honeywell, etc.), new jobs have been created. These new jobs include not only workers directly employed by these companies, but also computer programmers, systems engineers, and others needed to use and operate the computers.

5. Automation is the only means of increasing the standard of living. Only through productivity increases brought about by new automated methods of production, it is possible to advance the standard of living. Granting wage increases without a commensurate increase in productivity will result in inflation. To afford a better society, it is a must to increase productivity.

2.4.3 Disadvantages of Automation

Following are some of the disadvantages of automation:

1. Automation will result in a machine's subjugation of the human being. Automation tends to transfer the skill required to perform work from human operators to machines. In so doing, it reduces the need for skilled labour. The manual work left by automation requires lower skill levels and tends to involve rather menial tasks (*e.g*., loading and unloading work part, changing tools, removing chips, etc.). In this sense, automation tends to downgrade factory work.

2. There will be a reduction in the labour force, with resulting unemployment. It is logical to argue that the immediate effect of automation will be to reduce the need for human labour, thusdisplacing workers.

3. Automation will reduce purchasing power. As machines replace workers and these workersjoin the unemployment ranks, they will not receive the wages necessary to buy the products brought by automation. Markets will become saturated with products that people cannot affordto purchase. Inventories will grow. Production will stop. Unemployment will reach epidemic proportions and the result will be a massive economic depression.

Summary:

- Products and service organizations are similar to each other in many ways. Manufacturing organizations not only produce goods but also provide after-sales service, warranty service etc. similarly, service organization produce products, e.g., insurance companies talk of designing new insurance schemes. Both manufacturing and service organizations involve a transformation process in their production process, which converts various inputs into desired outputs, i.e., goods and services.
- Production and operation management is the management of the transformation process.
- New products and services enhance a company's image, invigorate employees, and helpa firm to grow and prosper. The design process begins with ideas formulated into a product concept. Once a product concept passes a feasibility study, performance specs are given to designers who develop and test prototype designs. For selected prototypes, design and manufacturing specs are taken through a pilot run where the design is finalized, and the planning for product launch begins.
- Time-to-market can be accelerated using design teams, concurrent design, design for manufacture concepts, and CAD/CAM systems.
- The type of production process selected depends primarily on demand volume and degree of product standardization. Projects are produced one at a time to customer order. Batch production is used to process a variety of low-volume jobs. Mass production produces large volumes of a standard product for a mass market. Continuous production is used for very-high-volume commodity products.
- Automation of facilities results in lot of advantages such as increase in productivity, no risk of worker strike etc., but there are disadvantages also, such as the loss of creativityon part of workers.

Keywords:

- Automation means replacing human labor with machines.
- Benchmarking, finding the best-in-class product or process, measuring one's performance against it, and making recommendations for improvements based on the results.
- Batch production the low-volume production of customized products.
- Continuous production the production of a very-high-volume commodity product withhighly automated equipment.
- Concurrent engineering is the product design approach in which the design team includes personnel from various departments such as marketing, engineering, production, finance and materials in addition to the design department.
- Computer-aided design (CAD) is a software system that uses

computer graphics to assist in creating, modifying, and analysing a design.

- Computer-aided manufacturing (CAM) the ultimate design-to-manufacture connection.
- Computer-aided engineering (CAE) engineering analysis performed at a computer terminal with information from a CAD database.
- Job shop process can handle a larger variety of products than the batch process. The products may be so different from each other that their processing requirements may bevaried processes, on different machines, indifferent sequences and with different processing times.
- Maintainability the ease with which a product is maintained or repaired.
- Mass production the high-volume production of a standard product for a mass market.
- Modular design combining standardized building blocks, or modules, in a variety ofways to create unique finished products.
- Perceptual map visual method for comparing customer perceptions of differentproducts or services.
- Project the one-of-a-kind production of a product to customer order that requires a longtime to complete
- Rapid prototyping quickly testing and revising a preliminary design model.
- Reliability the probability that a given part or product will perform its intended functionfor a specified period of time under normal conditions of use.
- Reverse engineering carefully dismantling and inspecting a competitor's product tolook for design features that can be incorporated into your own product.

CHECK YOUR PROGRESS :

❖ **Long Question**

1. What are the advantages and disadvantages of automation?
2. Describe the basic types of process design. What are the advantages anddisadvantages of each? When should each be used?
3. What is job shop production? What are its characteristics, advantages and limitations?
4. What is batch production? What are its characteristics, advantages and limitations?
5. What is continuous production? What are its characteristics, advantages andlimitations?
6. What is automation? Explain the types of automation.
7. Explain the product design concept with diagram.

Short Questions

1. How is the job shop different from the batch production process?
2. Explain the terms reverse engineering and standardization.
3. Mention any four advantages of job shop production.
4. Explain the following terms: Manufacturability, Standardization and Rapidprototyping.
5. What is concurrent design? Explain the types of concurrent design.
6. Explain three performance characteristics considered during the phase of Functionaldesign.
7. Explain the terms CAD and CAM
8. What is production system?

❖ **MCQ:**

1. is the process by which raw materials and other inputs are converted intofinished goods.
    a. Inventory
    b. Logistics
    c. Production
    d. Supply chain
2. Which of the following are the different type of process structure?
    a. Job Shop
    b. Project
    c. Batch process
    d. All of the above
3. Which of the following is not the advantage of continuous flow process?
    a. Highly effective
    b. High variety of product
    c. Ease of control
    d. Large capacity
4. Which of the following is not the advantage of job shop?
    a. Extremely flexible
    b. Can handle different batch size
    c. The work in process inventory is small
    d. Breakdown of one machine doesn't halt the entire process.
5. Which of the following policies is advisable in case of low product variety and largevolumes?
    a. Skilled labour, special purpose machines
    b. Low skilled labour, general purpose machine
    c. Low Skilled Labour, Special Purpose Machines
    d. Any of the above

6. Which kind of labour force is required in case of Jobbing Production?
   a. Highly Skilled
   b. Semi-skilled
   c. Unskilled
   d. D. Any of the above
7. Which of the following is not the characteristic of Project Production?
   a. Continuous flow of material
   b. Highly mechanised material handling
   c. Virtually zero manufacturing cycle time
   d. All of the above
8. CAD stands for _____.
   a. Critically analyzed drawing
   b. Computer aided design
   c. Computer assisted design
   d. Computer analyzed design
9. Automation system is also called as__________
   a. Process automation
   b. Automation technique
   c. Manual process
   d. All of the above
10. Which of the following statement is true regarding the automation process?
    a. It is a process that automatically controls process like pulp factories
    b. It is a process that controls process like pulp factories using robots
    c. It is a process that controls process like pulp factories using humans None of the above

UNIT : 3 CAPACITY DESIGN & LAYOUT DESIGN

PART 1 – DESIGN CAPACITY

3.1 INTRODUCTION

The creation of capacity means committing financial and other resources to it mostly on substantial basis. It is an investment decision. It brings out the operational strategy of an organization. In services of organizations, it means creation of more space, furniture, and other accessories and equipment. Planning for capacity is in response to the future growth and expansion plans, market trends, sales forecasting, multiple scenario analysis and our policy towards risk capacity planning decisions has to decide a centralized capacity at one geographical location or decentralized decision of plants at several locations, some other considerations also affect capacity decisions. How to tide over a temporary deficient in capacityby operating additional shifts givingover timee or holiday work? How best we should satisfy the market demand either the demand to be fully met or can we allow some lost sales? All these factors are a part of capacity planning.

What is Capacity? A dictionary meaning of Capacity is the ability to hold, receive, store, or accommodate. The capacity is also defined as the maximum output of a system in a given period of time under ideal conditions. Thus, the annual capacity of Bajaj is seven lacs scooters currently. It means the production is limited to this productive capacity over a period of time, here a year. The capacity, however, is subject to the intensiveness of the use of the facilities. Imagine a transformation process having many sub-processes, each of these interlinked. Here capacity isdetermined by the capacity of that sub-process which produces the least. If we want to upgrade the capacity, we can do so by balancing the equipment to create a better balance amongst the processes. The concept of capacity is thus invariably connected with the weakest link in the chain. This means that even when the capacity is fully utilized in terms of definition of capacity, there may be individual processes that mayremain underutilized

3.2 CAPACITY MANAGEMENT

Management of capacity basically involves capacity planning, the balance between various issues against economic advantages and disadvantages and its proper utilization_, before discussing the planning and management of capacity let understand the process of measurement of capacity.

3.2.1 Process of Measurement of Capacity

To estimate capacity, one should first select a yardstick to measure it. The first major task in capacity measurement is to define the unit of output. In some cases, the choice is obvious, for example. RIL set up a capacity to manufacture 250, 000MT of polypropylene and 160,000MTof polyethene at Hazira plant. This measures the output of end products.

Capacity Planning Framework: A capacity planning exercise is initiated in response to several scenarios that an organization facesfrom time to time. However, two of these are more common. First is the changing market condition leading to an increase in demand of the products and services that a firm offers? Due to increased demand, the capacity becomes inadequate and calls for a detailed computation of the new requirement. Moreover, since capacity additions are done over longer intervals, an estimate of the future capacity planning exercise is the strategic decision taken with respect to introduction of new productsand new markets. In this situation also, there is a need to revisit the capacity issue.

Estimating Total Requirement: -Estimation of capacity requirements begins with inputs from a forecasting exercise if the intent of the capacity planning exercise is to respond to imminent and future growth projections in the market. There are several techniques available for forecasting, which an organization can use to estimate the end product, or the service offered. Capacity planning exercises typically make use of medium term and long term demand projection methods. These exercises use past data collected at the end user level and systematically aggregated in the hierarchy before being analyzed and projected into the future. Once the projections for the end product sales are forecast, then detailed capacity computations can be done at individual facilities in the plant. On the other hand, the estimation of capacity requirements can also be in response to some targeted capacity build up in the factory. For example, ABB's medium voltage circuit breakers manufacturing facility at The capacity requirements are computed to meet the revised target in this casecapacity requirements are computed to meet the revised target.

Estimating Labor and Machine Requirements: The computation of the labor requirements depends on two major factors, the amount of standard labor hours required per unit of the product and the efficiency of the labor. Let the

Projected demand per unit time during the planning horizon =D Standard labor hours required per unit of product=S_L Efficiency of labor=E_L

D x S_L ……….Equation 1

Then the capacity requirements (labor)= E_L

Although the above computation appears simple, in reality, estimating S_L and E_L has certain operational difficulties. The standard labor hours are supposed to be established by a standard setting routine in every organization. This will call for studying each and every process, estimating normal allowances and incorporating them. Further, as the process is put into practice, some assumptions are required about the efficiency of the workers. The efficiency is likely to be somewhat low during the initial stages. However, as the employees experience learning curve effects, the efficiency of the process improves, thereby calling for a revision of these standard labour hours. Despite this, revisions are not done as frequently as the process warrants. This is because the employees' earning potential is inextricably linked to standard hours and efficiency assumptions. By keeping the standards loose and efficiencies low, it is possible for some workers to earn productivity bonus even for normal work. Due to these reas s, ina vast majority of industrial organizations, S_L and E_L have an industrial relations angle as well. In recent years, however, the notion of productivity and how employees are rewarded for good performance in productivity are not linked to these issues.

Operations managers must be aware of these limitations while making a judicious choice of these parameters.

One can use a similar expression for computing the machine requirements by using the subscript "M" in the place of "L".

D x S_M Equation 2

Capacity requirement (Machine) = E_M

Example: A manufacturer of medium voltage circuit breakers is planning for a capacity build-up of 8 cubicles and 13 circuit breakers per day. A year is made of 305 working days. The fabrication division is responsible for manufacturing metal sheet components that are welded to host the circuit breakers inside the cubicle. The components are painted after welding. While the fabrication uses a CNC Turret press, painting is a manual job. The standard time required at the CNC turret press for fabricating a cubicle is 150 minutes and the time for the breaker housing is 36 minutes. A cubicle requires 43 square meters of area to be painted and breaker housing requires 2.60 square metres of painting. The standard time required to paint one square to paint one square metre of area is 18 minutes. The machines work at 80 percent efficiency and the manual labour works at 90 percent efficiency. Using the above data, computer the labour hour and machine hour requirements.

Solution: Capacity planning is done for the planning horizon. In our example, the basic data for the problem pertains to the planning horizon. The table below summarises the data for further computations.

Since the demand during the planning horizon is the basis for computing the capacity requirement, we compute the demand using thedata. Since eight cubicles are to be manufactured per day, in a year therequired capacity is to fabricate 2440 (8 x 305 = 2440) cubicles. The table below shows the computation.

Planning horizon	1 Year
Number of working days in a year	305

	Cubicles	**Breaker housing**
Number per day	8	13
Demand per annum	2440	3965

The standard time for fabricating one unit of cubicle and breaker housing is available. Also known is the efficiency of the machine. Using equation 2, we can therefore compute the machinehours required. The table below has the computations.

Machine hourcalculations				
Efficiency of CNC TurretPress	80%			
		Cubicles	**Breaker housing**	**Total**
Machine hours required per unit		2.50	0.60	
Machine hours required per annum		7,625.00	2,973.75	10,598.75

One can use equation 1 to compute the labour hours required in a similar manner. The table below shows the details of the computation.

Labor hour calculations				
Efficiency of theworkers	90 %			
Standard man hours for painting 1sq.m	0.30			
		Cubicles	**Breakerhousing**	**Total**
Square meters of area to be painted per unit		43.00	2.60	
Total area to be painted during one year (sq.m)		104,920.00	10,309.00	115,229.00
Labour hours required Per annum		34,973.33	3,436.33	38,409.67

Computing Capacity Availability: Once the capacity required is computed, one can estimate how much is already available in the system. By performing this computation and comparing it with the requirements, one can identify the gaps or excess capacity available for each resource in question. The comparison of the available with the requirement serves several important purposes in a capacity planning exercise. Some of these worth mentioning are:-

The comparison provides a basis to understand comparison provides a basis to understand the consequence of the capacity expansion initiative to the operations manager.

It helps to separate the resources into those with adequate capacity and insufficient capacity and help focus on the latter category for problem solving.

It provides impetus for process plan changes andimprovements for uncovering waste and thereby discovering more capacity at some of the bottlenecks.

Finally, it helps the manager to draw out capital budgeting and investment requirements of the capacity expansion initiative.

The availability of capacity in a system is a function of two parameters. One is the system availability and the second is the resource availability. System availability is a function of the number of working days and the number of hours per day. The number of hours in a day depends on operating policies pertaining to the number of shifts and overtime practices. Resource availability is a function of maintenance schedules and breakdown behavior of the resource (in the case of machines) and absenteeism (in the case of labour). Based on these, the capacityavailable in the system can be computed. The relevant computational details are as follows:

System availability	
Number of working days in the planning horizon	N_d
Number of working hours per day	h
System availability (hours)	N_d xh
Resource availability'	
Number of machines available	N_m
Machine: Time lost in breakdowns and maintenance	b%
Number of workers available	N_L
Number of workers available	a%

Capacity available in the system

Machine : N_d x h x N_m x (1-b/100)

Labour : N_d x h x N_L x (1-a/100)

Example: Consider the fabrications shop. Referred in this previous example. Suppose the factory works on a two-shift basis with six workers in the paint shop. There is only one CNC turret press currently available. Suppose preliminary data shows that the equipment at the shop has a downtime of 12 percent and the absenteeism rate of the employees is5 percent, assess the impact of the capacity expansion initiative in the plant.

Solution: The capacity requirements have already been computed in the previous example. They are as follows: -

Labour hours required at the paint shop:38,409.67
Machine hours required at CNC Turret press facility: 10,598.75
Now let us compute the available capacity using equation 4.1.3. Tablerelevant computations are in the table below:

Number of days in the planning horizon	305
Number of working hours per day	16
System availability (hours)	4880

Number of turret presses available	1
Percent of time lost in breakdown & maintenance	12%
Capacity of CNC turret press available (hours)	**4,294.40**

Number of workers in the paint shop	6
Percent of time lost in absenteeism	5%
Total labour hours available	**27,816.00**

Comparison of Availability and Requirement: The table below shows the comparison between the requirement and availability for the CNC Turret press and the labour in the paint shop. Since only 72 percent of the total requirement is available in the paint shop, cubicles and breaker housing can be fabricated only to that extent (as shown in the table). Clearly, there is insufficient capacity in both of these cases.

	Capacity Scenario (Hours)			
	Requirement	**Availability**	**Excess (Deficits)**	**Availability (% of reqt.)**
Labour in paintshop	38,409.67	27,816.00	(10,593.67)	72%
CNC Turret press	10,598.75	4,294.40	(6,304.35)	41%

Present production capacity	**Paintshop**	**Fabrication**
Cubicles / day	5.79	3.24
Breaker Housings/day	9.41	5.27

The firm needs to explore methods for augmenting this capacity to meetthe revised capacity expansion initiative. One direct method is to compute the number of additional machines and labour required to meet the shortfall. Using the data already available, we can compute the number of additional hours that one can augment by adding one unit of labor on the machine. For example, one more worker will bring 4636 hours of work (305 days x 16 hours/day x 95 percent attendance). Using this information, the number of additional machines and workers can be computed as shown in the table below.

Number of hours of capacity added by one worker	4,636.00
Number of hours of capacity added by one CNC Turret Press	4,294.40
Additional workers required in the paint shop	2.29=3
Additional CNC Turret presses required	1.47=2

3.3 ECONOMIES AND DISECONOMIES OF SCALE AND LEARNING CURVE

3.3.1 Economies of scale:

Economies‖ refer to lower costs, hence economies of scale, would mean lowering of copses of production by way of producing in bulk. Stated in very simple terms, economies of scale refers to the efficienciesassociated with large scale operations ;it is a situation in which the long run average cost of producing a good or service decrease with increase in level of production. For example, it might cost Rs100 for one unit, Rs 180 for two units, Rs.240 for three and so on, so the average cost per unit decreases as the production volume increases. Economies of scale are extremely important in real-world production processes. Hence firms are often concerned about a minimum efficiency level of production, which is nothing but the amountof production that spreads setup costs sufficiently for the firms to undertake production profitably. This level is reached once the size of the market is large enough for firms to take advantages of all economies of scale. There are two types of economies of scale:

Internal economies (in which the cost per unit depends on size of the firm) External economies (in which the cost per unit depends on the size of industry, not firm).

1. Internal Economies: It includes the following:

i. **Specialization:** In large scale plants workers can be assigned repetitivejobs; an entire job can be broken down into components or processes and each such process can be assigned to a worker or a group of workers. This idea, also termed as division of labor, was propounded by Adam Smith, in his legendary pin factory example, and is nothing but specialization in a particular job. Such specializations would need lesser training; time taken to complete each assignment would be lesser; lesser time would be taken in switching from one operation to another; and lesser supervision would also be needed.

ii. **Greater efficiencies of machines:** In large scale production large machines would be needed; for a given amount of inputs these machines will render output in larger quantities. Besides, they would ensure more efficient use of available raw materials.

iii. **Managerial Economies:** Large production can ensure better managerial functions through better supervision and administration. Departmentalization becomes possible; planning and organizing become worthwhile.

iv. **Financial Economies:** Large firms going for large volumes of production may be able to raise capital from the market with much less difficulty than small firms. Cost of production may also decline for larger volume of output, because larger output enables a firm to obtain inputs at lower prices by quantitative discounts etc.

v. **Production in stages:** A large plant may house all the processes of production, and this saves time and cost in moving components from one location to the other for final assembling. Modernization of production processes is possible only in a large scale.

2. **External Economies:** It Includes the following:

i. **Technological advancement:** A large growing industry would encourage investment in research and would result in the development of better technology of production, as the industry expands, technological innovations get a definite boost, as has been the case with cars, computers and TV etc.

ii. **Easier access to cheaper raw materials:** Suppliers would have large markets to cater to and therefore, the availability of raw materials would beeasier. Expanded demand for raw material encourages increased supplies. Buying in bulk will also give the firms more discounts and better commercial terms.

iii. **Financial institutions in proximity:** As the industry needs finances to grow and financial institutions look for avenues for investment? This mutuality of interest encourages their mutual growth and coexistence, No wonder you find a boomin the financial sector in India afteglobalisationon.

iv. **The pool of skilled workers:** Large industries provide opportunities for employment; hence just like technology, material and fin,ance human resources too would acquire needed skills

3.3.2 Dis-economies of Scale:

Diseconomies of scale are disadvantages that arise due to the expansion of production scale and lead to a rise in cost of production. Like economies, diseconomies may be internal or external. Internal diseconomies are those which are exclusive and internal to the firm—they arise within the firm. External diseconomies arise outside the firms, mainly in the input market as:

i. **Internal Diseconomies:** As everything else, economies of scale have a limit too. This limit is reached when the advantages of division of labour managerial staff have been fully exploited; excess capacity of plant, warehouses transport and communication systems etc., is fully used; and economy in advertisement cost tapers off.

ii. **Managerial inefficiencies:** Diseconomies begin to appear first at the management level. Managerial inefficacies arise, among other things, from the scale of the expansion itself. With fast expansion of production scale, personal contacts and communications between (i) Owner and manager and (ii) managers and labour) get rapidly reduced. Close control and supervision is replaced by remote control management. With the increase in managerial personnel, decision-making becomes complex, and delays become inevitable

iii. **Labor inefficiencies:** Another source of internal diseconomy is the overcrowding of labour leading to loss of control over labor productivity. The increase in number of workers, on the other hand, encourages labor union activities which means the loss of output per unit of time and hence rise in cost of production.

iv. **External Diseconomies:** External diseconomies are the disadvantages that originate outside the firm, in the input market and due to natural constraints, especially in agriculture and extractive industries. With the expansion of the firm, particularly when all the firms in the industry are expanding; the discounts and concessions that are available in bulk purchase in inputs and confessional finance come to an end. More than that, increasing demand for inputs puts pressure on the input markets and input prices begin to rise ,causing a rise in the cost of production. On the production side, the law of diminishing returns to scale comes in force due to excessive use of fixed factors, more so in agriculture and extractive industries.

3.3.3 Learning Curves

Do you remember your first attempt at learning new skill?Be it setting your hand on the computer mouse, or playing any musical instrument. You would agree that you learn by doing and gradually gain experience at any activity which previously took a lot of time (and perhaps cost) when you were beginner. Learning by doing means that as we do something, we learn what works, and what does not, and over time we become more proficient, at it. In economics learning, by doing refers to the process by which producers learn from experience; in fact, production techniques available to real world and firms are constantly changing because of learning by doing and technological change.

In many businesses the effect by learning by doing is incorporated into their pricing structures. Average costs may decline with cumulative production, because of and other learning effects. Experience with a particular set of suppliers, production process, facility, workforce, distribution channels and managerial teams can result in improvement in technical efficiency. The concept of the learning curve represents the extent to which an average cost of production falls in response to an increase in output. The learning curve was adopted from the historical observation that individuals who perform repetitive tasks exhibit an improvement in performance; as the task is repeated a number of times. The equation of learning curve can be expressed as:

bthC=AQ

Where C is the cost of inputs and Q unit of output produced and A is the cost of the first unit of output obtained. Now following the logic that increase in cumulative output leads to decrease in cost, ―b‖ has a negative value. The logarithmic form of the equation is given as:

In C= In A+ b in Q

In this logarithmic form, b is the slope of learning curve.

Sources of lower costs include greater familiarity of workers and managers with the production process, reduction in overheads, division of labour process improvement, etc. The only recurring costs are likely affected by learning, while non-recurring costs, like the cost of acquiring equipments, are not affected by learning.

3.4 CAPACITIES STRATEGIES

Capacity strategies can be discussed under two major heads:
Short-term response
Long -term response

3.4.1 Short-term Strategies

In short-term periods of up to one year, fundamental capacity is fixed. Major facilities are seldom opened or closed on a regular monthly or yearly basis. Many short-term adjustments for increasing or decreasing capacity are possible, however. Which adjustment to make depend on whether the conversion process is labour or capital intensive and whether the product is one that can be stored in inventory

Capital intensive processes rely heavily on physical facilities, plant, and equipment. Short term capacity can be modified by operating these facilities more or less intensively than normal. The cost of setting up, changing over and maintaining facilities, procuring raw materials and managing inventory, and scheduling can all be modified by such capacity changes. In labour-intensive processes, theshort-termm capacity can be changed by laying off or hiring people or having employees work overtime or be idle. These alternatives are expensive, though since hiring costs, severancepay, or premium wages may have to be paid, the scarce human skills may be lost permanently.

3.4.2 Long-term Responses

Capacity expansion strategies- capacity expansion adds capacity, within the industry, to further the objectives of the firm to improve the competitive position of the organization. It focuses on the organisation's growthtion by enabling it to increase the flow of its products in the industry. Capacity expansion is a very significant decision; the strategic issue is how to add capacity while avoiding industry overcapacity. Overbuilding of capacity has plagued many industries e.g. paper, aluminum and many chemical businesses. The accountants‘ or financial procedure for deciding on capacity expansion is straightforward. However, two types of expectations are crucial:

Those about future demand, Those about competitors behavior

With known future demand, organizations will compete to get the capacity on stream to supply that demand, and perhaps preempt such action from others.

Horizontal and vertical integration: Horizontal and vertical integration add capacity, within the industry, to further the objectives of the firm to improve the competitive position of the organization.

Horizontal Integration: Horizontal integration is a company's growth at the same stage of value chain. Horizontal integration consists of procuring (related companies, products or processes) the company could start a related business within the firm, which would be an example ofinternal concentric diversification.

Vertical Integration: Vertical integration is the combination of economic processes within the confines of a single organization. It reflects the decision of the firm to utilize internal transaction rather than a market transaction to accomplish its economic purpose. It is expressed by the acquisition of a company either further down the supplychain, or further up the supply chain, or both.

Backward Integration: In case of backward integration, the volumes of purchases of the organization must be large enough to support an in-house supplying unit, If the volume of through puts is sufficient to set up capacities with economies of scale, organization will reap benefits in production, sales purchasing and other areas.

Takeover or Acquisitions: Takeover or acquisition is a popular strategic alternative to accelerate growth. Major companies which have been taken over post-liberalization period include Shaw Wallace, Ashok Leyland, Dunlop, etc. The acquisition can either be for value creation or value capture.

3.5 DECISION TREES

Decision Trees are most commonly used in capacity planning. They are excellent tools for helping choose between several courses of action. They provide an effectivestructure within which you can lay out options and investigate the possible outcomes of choosing those options. They also provide a balanced picture of the risks and rewards associated with each possible course of action.

The capacity planning exercise requires methods by which alternative options are evaluated. Two metrics are helpful to perform the evaluation. In the cost-based methods, each alternative can be evaluated from the perspective of costand benefits accruing out of the alternative. A firm, for example, may be considering three options: not to do anything about capacity, add a new machine or go for sub- contracting. Another firm may have three options of varying technological and operational capabilities for capacity addition, resulting in different capital costs, operating costs and useful life of the resource. In each of the above examples, one can evaluate the alternatives from the perspective of costs and benefits.

3.5.1 Waiting Line Models

Consider the capacity planning in the case of the computerized passenger reservation facility of Indian Railways. In simple terms, the question boils down to deciding the number of booking counters to be made available to the public. It is obvious that if there are fewer booking counters to be made available to the public. It is obvious that if there are fewer booking counters, the queue is likely to build and customers may end up spending more time in the system before they get their tickets booked. We have similar experiences in a banking system or BSNL's bill payment counters. Capacity decisions in service systems are often made on the basis of the impact on the customers.

Waiting line models use queuing theory fundamentals such as queue length, waiting for time and utilization of resources, to analyze the impact of alternative capacity choices on important operational measures in operating systems. Therefore, the capacity planning problem could be analyzed using queuing system and the alternative scenarios that can be analyzed that can be analyzed using the waiting line models developed.

3.5.2 Basic Structure of a Queuing System

The following figure depicts the basic structure of a queuing system. The demand for the products/ services offered by the operating system originates from a calling population or source. In the case of a restaurant, the calling population (source) of demand could be the citizens in the vicinity of the restaurant. The demand manifests in the form of arrivals at the system. In the case of service systems it could be actual customers arriving to get the service. In the case of a manufacturing system, it could be work orders at a shop or customer orders at a division. The third element is the waiting line, which characterizes the provisions for the arrivals to wait for their turn. There are servers in the system for service delivery and finally, the served customers exit the system. We shall understand each element in detail and enumerate alternative representations that exist in real life in each of these. Figure 4.3 provides the elements of waiting for line models in a nutshell and enumerates the alternatives pertaining to each element.

3.5.3 Calling Population:

The calling population in an operating system places a demand and uses the capacity deployed. In several cases the calling populating is infinite for all practical purposes. For instance, the calling population for a petrol bunk in the city of Delhi could be the entire set of vehicles running on the roads of Delhi. Similarly, for a bank in a metropolitan city such as Chennai, the calling population could be the individual and institutional members of the society in the city. These typically amount to an infinite number as far as the operating system is concerned. However, in some cases, the calling population could be finite. Consider the maintenance department in a large manufacturing plant. If there are 300 machine tools in the plant, they form the calling population for the maintenance department in the manufacturing plant.Every machine breakdown corresponds to arrival at the maintenance shop. In this situation, the calling population is finite. The important difference between an infinite source and a finite one is the manner in which arrival rates are estimated. Clearly, every arrival from a calling population decreases the probability of arrival of the remaining machines at the maintenance shop.

❖ **CHECK YOUR PROGRESS**

1. How will you measure the capacity of the plant?
2. What are economies of scale?
3. What are the diseconomies of Scale?
4. Discuss the various strategies for the measurement of capacity.
5. What are decision trees, and what is their importance?

PART 2 – LAYOUT DESIGN

3.6 INTRODUCTION

Plant layour is a floor plan of the physical facilities which bare used in production Layour planning is referred to the generation of several possible plans for the spatial arrangement of physical facilities and selecting the one that minimises the distance between departments. The following are the main objectives of plant layout:

- Minimum investment in equipment
- Minimum overall production time
- Utilize existing space effectively
- Provide for employment convenience, safety and comfort
- Maintain flexibility of arrangement and operations
- Minimized material handling costs
- Facilitate the manufacturing process
- Facilitate the organizational structure

Imagine yourself visiting a multi-specialty hospital for a master health check up. What if the radiology department was located in the second floor, the general physicians were sitting in the ground floor at the rear side, ECG and tread-mill test facilities were in the fourth floor and so on. Finally, imagine that you need to walk out of the main complex and go 50 meters away to another building to have your breakfast after giving your fasting food samples and return to the main complex to continue the process. Such instances are uncommon. How many times have you felt that you were made to walk too much in a hospital when you went for a health check up or went to a financial institution asking for a loan sanction or to a government office to pay some utility bill and make some enquiries? What is the core problem in these examples? In simple terms, these examples suggest that with a better arrangement of resources, it is possible to provide better service to customers. That is where layout planning in manufacturing and service organization is important.

3.7 LAYOUT PLANNING

Layout planning in manufacturing and service organizations deals with the physical arrangement of various resources that are available in the system with the objective to improve the performance of the operating system, thereby better customer service. Typically, in a manufacturing organization, there may be over 200 machine tools of various kinds to be located in a machine shop. Similarly, in the case of a service organization such as hospital or hotel, there are various resources to be physically located. We can identify the best possible locations for various resources in organizations through good layout planning exercises. Layoutplanning provides a set of tools and techniques that help an operation manager to decide where to locate the resources and also assess the impact of the alternative choices that he/she may have for locating the resources.

A good layout design will ensure that a vast majority of jobs in a manufacturing system may have to travel shorter distances before completing their processing requirements. Similarly, in the case of service organizations, customers may need to walk shorter distances and spend less time in the systems of the processes come down. On the other hand, a bad layout design will result in longer distances tobe covered before completing the process. This creates several problems in organizations, and several key performance measures suffer. The most significant and visible effect is the time taken to complete the process. Longer distances would mean more time to complete the process and more material handling in the case of manufacturing organization, leading to higher material handling costs. Eventually, in both service and manufacturing systems, this leads to poor quality.

Implications of Layout Planning: Addressing the layout planning problems it begins with a good understanding of the key factors that influence the layout design. The nature of issues to be tackled and the manner in which these issues could be addressed vary from one type of organization to another. Let us consider a high variety manufacturer such as Bharat Heavy Electrical Limited (BHEL) and that of high volume manufacturer such as Maruti Udyog Limited (MUL); it is reasonable to expect that the basis on which the resources are to be located will differ in these two cases. A high-volume manufacturer like MUL will have dominant flow pattern, and this information will be useful for the layout planner. On the other hand, in the case of low volume manufacturers like BHEL there will not be the dominant flow of material in the shop. The demand placed on different resources will vary widely in this case from time to time.

In more general case, the relationship between ‗volume- variety-flow' provides crucial inputs to a layout problem. Variety and volume are inversely related in any operating system. Thus, when variety is low, the volume of production is high. The typical examples are processing industry firms such as petrochemical manufactures and mass manufacturers such as automobile components manufacturers. In these cases, the flow is highly streamlined. Raw materials move progressively through the system from one end of the process until to reach the final assembly, testing and packing, similar effect existsin service systems also. In case of fast-food joint with just few offerings, the process could be highly streamlined. Customers may enter the eatery, place , order and pay at the cash counter, move to the delivery counter, pick up their order, and move to the dining area. Finally, they may move to disposal area to leave their used plates before exiting the system. At the other extreme is a project shop. In a project shop the volume is typically one. Examples include building of large-scale power projects, nuclear facilities, and a multi- level flyover system for a large metropolitan city and so on. Resources requirements in these projects are vast and varied, uneven in demand and stretched over long periods. Therefore, layout planning is a very different problem.

Between these two extremes we have operating systems that vary volume-variety dimension and therefore, have varying flow implications. As variety increases the volume drops, leading to batch manufacturing firms. Further increase in variety leads to reduction in volume as we find incase of job shops and customized product and service providers. In general, as the flow becomes more cumbersome, the type of layout may significantly influence the ability of operation manager to effectively plan and control operations on shop floor.

3.8 LAYOUT TYPES

It is clear from the above discussion that alternate types of layouts are required for the above systems. Over the years, operation management researchers and practitioners have evolved certain types of layouts. These are described below:

1. Process Layout: A process or functional layout is an arrangement of resources on the basis of process characteristics of the resources available. Consider a machine shop consisting of lathes (L), grinders (G), milling machines (M) and drilling machines (D). A sample process layout for this shop is shown in figure 6.1. In the example, components belonging to product A first visit a lathe, then they visit a drilling machine, a milling machine and finally a grinding machine .The sequence of visits is functional of the process plan and is available in route card. The major implication of this design is that each component manufactured in the shop needs to visit the machines in order of their processing. In reality, when the number of components manufactured is large, there will be enormous crisscrossing in the shop, as components need to visit machines in multiple combinations. This increases material handling and poses challenges for production control.

Each department in a process layout is typically organized into functional groups. Thus, all lathes will be organized into a lathe department. Similarly, there will be drilling department milling department and so on. In the fabrication area a similar arrangement would be a welding department, fitting department, and shearing department and so on. All manufacturing support areas are also arranged on a functional basis. Examples include the maintenance department, quality control department procurement store and production control department.

2. Product Layout: A product layout is an alternative design for the arrangement of resources. In this case, the order in which the resources are placed exactly follows the visitation sequence dictated by a product. In the product layout shown in figure 6.1 the required set of resources for every product is made available in dedicated fashion. Due to this, it is possible to arrange the resources in the order of machining requirements and ensure smooth component flow in the shop. Since each product will have its own set of resources, material handling is simpler and it is possible to invest in fixed-path material handling systems to speed up material transfer between successive work stations. Moreover, the production volumes also are higher. The production control issues are much simpler in a product type layout as compared to the process layout.

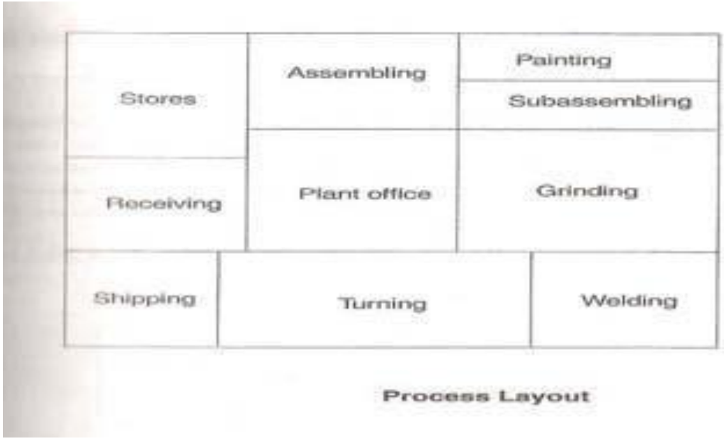


Figure 3.1: A Sample Process Layout

Very often, the final assembly in several manufacturing plants follow a product layout. The assembly workstations are designed so that at each workstation, a part of the job is completed. The feeder stations are linked to assembly workstations to ensure material availability. As the products move through the assembly, the process is completed. Testing, final inspection and even packing could be part of this layout so that at the end of the line, it is ready for dispatch to the market. The notion of product and process layouts applies not only to manufacturing settings but also to service settings.

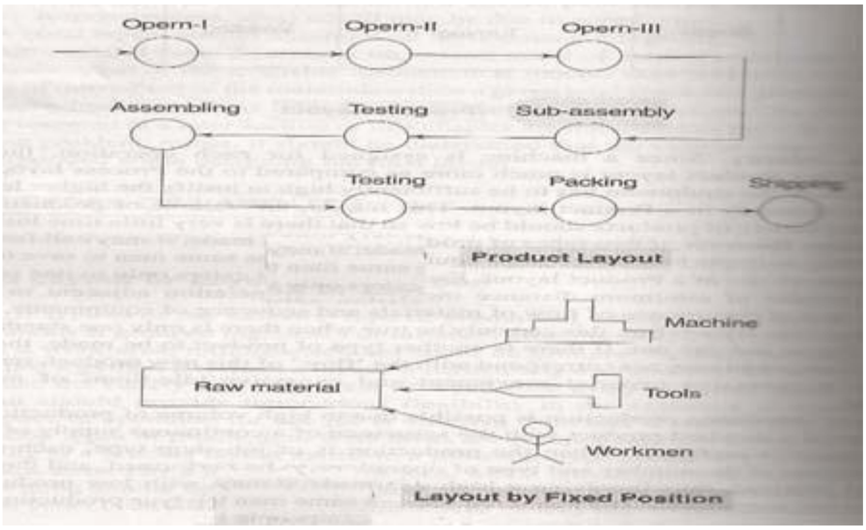


Figure 3.2: A Sample Product Layout

3. Group Technology Layout: Product layouts are feasible only in case of mass production systems. When the production volume is less, it may be difficult to justify the dedication of resources to individual products. Therefore, organisations have been using process layouts for such situations. However, since process layouts create more problems in production planning and control due to the complex routing of various components on the shop floor, operation managers were looking for alternatives to the process layout. On the other hand, there has been an increasing trend towards more variety. The industrial fans and blowers division of ABB Ltd, a multinational company operating in India manufactures about 725 models, Titan Industries increased the jumpers of watch models from 850 in 1993 to 1200 in 1996, an average of more than 100 new models yearly. Group Technology (GT) layout provides an alternative method for configuring resources in organizations that have mid-value, mid variety product portfolios. Group Technology is a philosophy that seeks to exploit commonality in manufacturing and uses this as the basis for grouping components and resources. The implications of GT are often known as cellular manufacturing. In cellular manufacturing, the available components are grouped into part families. An approximate measure for manufacturing similarity is used to identify part families. Corresponding to each part family, machine groups are identified and the layout isformed accordingly.

The benefits of GT are many. Once the part families and the machine groups are identified, the layout ensures that each cell has only a certain number of components to be processed. In essence, it is akin to breaking a monolith structure into smaller, more manageable and independent units of production. The components seldom travel outside their respective cell for processing. Therefore, material handling becomes easier, and traceability improves.Moreover, employees can relate better to their workplace and make concerned concerningimprovements. The new structure also helps to implement several other operations management practices such as small group improvement, Kaizen and JIT manufacturing practices.

4. Fixed Position Layout: There are several situations in which the product manufactured is very bulky, difficult to move, and often made in quantities of one or few pieces. In such situations, the layout design ought to be very different. Typical examples include building very large machines tools and equipments, ships, and aircraft building. Since the equipments are very large and bulky, they dictate several choices with respect to layout. The specific orientation of the equipment will dictate the placement of specific resources required for the process. Layout planning in such cases is often a question of a good workplace organization Some examples include the nuclear engineering division of Bharat Heavy Electrical Division at Tiruchirapalli, and the final assembly panel of the advanced helicopter division.

Reasons for Location Changes: In addition to the need forgreater capacity, there are other reasons for changing or adding locations.

1. Changes in resources may occur. The cost or availability of labour, raw materials, and supporting resources (such as subcontractors) may change.
2. The geography of demand may shift. As product markets change, it may be desirable to change facility locations to provide better service to customers.
3. Companies may merge, making facilities redundant.
4. New products may be introduced, changing the availability of resources and markets.
5. Political and economic conditions may change.

3.9 DESIGN OF PRODUCTS AND PROCESS LAYOUTS

Design of Product layout: Layout design for products can be classified into the following two methods

- Manual methods
- Computerized methods

Manual Methods: Under this category there are some conventional methods like travel chart and Systematic Layout Planning (SLP). We will discuss Systematic Layout process:

Systematic Layout Design Method (SLP) This is an organized approach to layout planning. This approach has been developed by Muther. It is clear that once the appropriate information is gathered, a flow analysis can be combined with an activity analysis to develop the relationship diagram. This space-relationship diagram is constructed by combining space considerations with the relationship diagram. Based on space relationship diagram, modifying considerations and practical limitations, a number of alternative layouts are designed and evaluated.

Computerized methods: Under these methods the layout design procedures can be classified into constructive type algorithms and improvement type algorithms.

Constructive type algorithms are:

- Automated Layout Design Program (ALDEP)
- Computerized Relationship Layout Planning (CORELAP)

Improvement type algorithms are:

- Computerized Relative allocation of Facilities Technique (CRAFT)

We shall discuss only the Computerized Relative Allocation of

Facilities Technique (CRAFT). Armour and Buffa originally developed this algorithm. Craft is more widely used than other computerized methods. It starts with an initial layout and improves the layout by interchanging the department‘s pairwise so that transportation costs areminimized.

CRAFT requirements

- Initial layout
- Flow data
- Cost per unit distance
- Total number of departments
- Fixed departments , their number and location
- Area of departments.

CRAFT Procedures: The steps of CRAFT algorithm are summarisedbelow

Step 1:

- Number of Department
- Number of interchangeable departments
- Initial layout
- Cost matrix
- Flow matrix
- Area of departments

Step 2: Compare cetroids of departments in the present layout.

Step 3: Form a distance matrix using the controls

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

Step 5: Find all the possible pair wise interchanges of departments based on common border of equal area criterion

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

Step 7: Interchange the selected pair of departments. Call this new layout

LAYOUT DESIGN FOR SERVICES

The principles of designing layouts for manufacturing settings do apply to service setting also. However, other aspects of the service system will influence its layout design. Therefore, the layout designer should factorin these also during the design process. Two important factors that influence the layout design problem of in a service organization are degree of customer contact and line of visibility.

Customer contact refers to the physical presence of thecustomer in the system. For example, customers‘ presence in a restaurant is confined to the dining area. The kitchen, back office and stores are areas that are outside the zones of physical presence of the customers. Similarly, in the case of a bank, the front office, facilities such as cash and payment counters and locker facilities have a customer contact, whereas the record keeping rooms, network infrastructure facilities, strong rooms and other such facilities are outside scope of customer access. By degree of customer contact, we mean the percentage of time the customer spends to get service. The notion of customer contact significantly influence service delivery and layout design .If the firms aim to high degree of service, then customer convenience is of paramount importance, and the firms may have to forego the efficiency aspect of design. Appropriate ambience comfort of using and extent of travel and the search required to get the service well done are key objective of design. On the other hand, if the design is with low customer contact, efficiency in utilizing the space as well as other resources could be pursued without seriously jeopardizing service efficiency.

One of the fallouts and operational implications of the degree of customer contacts is the line of visibility available to the customer. As the degree of customer contact increase, the line of visibility also gets pushed back into the system. Therefore, more and more aspects of business processes are exposed to customers, paving the way for multiple opportunities for jeopardizing service quality. Layout decisions are critical in such situations.

3.10 JOB DESIGN

The Hawthorne Studies conducted from 1924 onwards, showed that productivity is not only influenced by asset of methods and procedures that specify a set of tasks but also by employees' feelings about their jobs. This is actually one of the major determinants of productivity. For many years, Job Design has also been involved with the physical environment of the job. This often means specifying the allowable levels of noise, dirt, temperature, and the layout of facilities. Job Design also takes into account all factors which affect the work and organizes the content of the tasks

.Job Design refers to how a set of tasks or an entire job is organized within the social and psychological environment of the organization. Job Design helps to determine:

What tasks are done? How the tasks are done?

How many tasks are done?

In what order the tasks are done?

Humans have certain physiological, psychological andsociological characteristics. In performing work, human functions at three different levels:

- They receive information through the sense organs,
- Process the information received and the information stored in the memory for decision making
- Take action based on these decisions. The decision may be automatic based on learned responses, as with highly repetitive jobs, or involve extensive reasoning and the results may be complex.

These characteristics define their capabilities and limitationsin the work situation. There is variation in these characteristics among individuals. In addition, there are socio-psychological and socio-technical factors that determine behaviour. Such factors include not only how a job is done, but the employee feels about the job. It considers how easily or quickly a person may perform a job and how she or he will react emotionally to that job and the environment in which it is performed.

Job Design, as it is seen today, has expanded to include social and psychological environments by considering what is called socio-psychological factors related to a job and socio-technical considerations- the social and technical make-up of the individual

Socio-technical Factors: Based on different levels of human functioning the socio-technical theory believes that machines and humans at one level have the general structure of a closed-loop automated system. However, machines and humans are alike in certain important respects. Both have sensors, stored information, comparators, decision makers, effectors and feedback loops. The difference between the two is that unlike machines—which are specialized in the kind of range of tasks they can perform—humans have a tremendous range of capabilities and limitations which are imposed by their physiological and sociological characteristics. Machinesperform tasks as faithful servants reacting mainly to physical factors. Humans, however, react to their psychological and sociological environments as well as to the physical environment.

The socio-technical theory believes that humans operate on socio-technical systems. In their job environment, they optimise both social and technological considerations. Every socio- technical system is defined by the social aspects, reflected by the environment that consists of culture and its values and by a set of generally accepted practices. The environment provides certain roles for organizations, groups and people. At the same time, technology imposes constraints that limit the possible arrangements of processes and jobs, impacting job satisfaction and social system needs. According to socio-technical principles, Job Design is the application of the concept of their joint optimization between technology and the values of the social systems.

Socio-psychological factors: Humans have certain physiological, psychological and sociological characteristics that define their capacities and limitations in the work situation. They can be related to empirical evidence that suggests that workers prefer tasks of a substantial degree of wholeness, in which the individual has control over the materials and the process involved and which integrates the employee into the fabric of organization.

Keeping these observations and empirical evidence in mind, jobs should be designed such that there are an optimal variety of tasks within each job. The optimal level allows the employee to rest from the high level of attentionor effort while working on another task or, conversely, to stretch after a period of routine activity. There is research that suggests employees derive satisfaction from using a number of skill levels. Some points must beconsidered for Job Design:

- The jobs should be challenging for each skill category
- the group or individual undertaking the job must be able to exercise some control over their work.
- Area of discretion and decision-making should be available to them.
- Ideally, employees should have some responsibility for settingtheir own standards of quantity and quality.
- There should be clarity in the sets of tasks. Wherever possible, a group or individual employee should have responsibility for a set of tasks that are clearly defined, visible and meaningful.
- As people have sociological needs, they require feedback. Workers should know when they have achieved their targets and how they are doing relative to others.

Performance and Job Design: Achieving good Job Design involves administrative practices that determine what the employee does, for how long, where and when,, and gives the employees choices wherever possible. In Job Design, you may choose to examine the various tasks of a particular job or design of a group of jobs. Job Design principles can address problems such as:

- Work overload
- Work under load
- Repetitiveness
- Limited control over work

- Isolation
- Shift work
- Delay in filling vacant positions
- Excessive working hours
- Limited understanding of the whole job process.

However, one has to look beyond these limitations. Job Design is more rewarding if we understand the psychological and sociological of employees. In determining whether a job is designed for high performance, we must look at four basic spans of the job control, accountability, influence and support. The span of control is reflected in each employee wanting to know the answer to four basic questions:

- What resources do I control to accomplish my task,?
- What means will be used to evaluate my performance?
- Whom do I need to interact with and influence to achieve my goals?
- How much support can I expect when I reach out to others for help?

3.11 WORK MEASUREMENT

It determines the degree and quantity of labour in performing tasks. It is the actual quantifying of performance dimensions. Managers are used to measuring work in terms of "hours of work done". In many cases, this provides very inaccurate data on performance. With performance measurements which depend on establishing standards, we can determine how well a process is proceeding to forecast the end conditions. The fundamental purpose of work measurement is to set time standards for work. Standards are needed for several reasons: One is the need to measure performance, which requires a comparison of accomplishment against a standard. Performance data is needed so that one can avoid surprises when one has to make decisions.

All scheduling requires estimates of how much time it takes to do the work. Standards are necessary to schedule work and allocate capacity. Standards are used in industry as a basis for payments to workers where output based incentive plans employed. This requires an objective basis for motivating the workforce and measuring worker's performance. Costing and monitoring of work presume the existence of standards. In contracting, this is particularly important for new contracts. Questions such as "Can we do it"? And "How best can we do it"? Can only be answered using standards. Most important, standards provide benchmarks for improvement. Using universal standard data, it is possible to compare your work standards with those of similar jobs in other organizations.

There are many techniques used to measure work. However, they can be classified into those that rely either on direct observation of the work or indirect observation of the work. Some techniques, such as motion-time systems or standard data, can provide standard times from simulation, etc. However, the dataon which such techniques are basedis based on earlier observations of actual work.

Work Measurement Techniques: There are six basic ways of establishing a time (work) standard:

- Ignoring formal work measurement
- Using the historical data approach'
- Using the direct time study approach
- Using the predetermined time study approach
- Using the work sampling approach
- Combining approaches 2 through 5

Ignoring Formal Work Measurement: For many jobs in many organizations, especially in the labour-intense service sector, formal labour standards are not set at all. The issue of a fair day's work for a fair day's pay is ignored. Even though there is no explicit basis for criticism, workers may be blamed for poor performance and inefficiency. Often, because management has not established a work (time) standard, some informal standard is established by default. Since this informal standard generally compares unfavourably with those set by other techniques, we do not recommend ignoring formal work measurement.

Historical Data Approach: This method assumes that past performance is normal performance. In the absence of otherformal techniques, some managers use part performance as their main guide in setting standards. What are the advantages of these methods? It is quick, simple, inexpensive, and probablybetter than ignoring formal work measurement altogether. The major disadvantage, as you can reason, is that past performancemight not be what an average worker can reasonably be expected to perform under average working conditions.

Direct Time Study: Often called a time study, a stopwatch study, or clocking the job, this technique is certainly the most widely used method for establishing work standards in manufacturing. Perhaps you have observed a job being studied by an industrial engineer, clipboard and stopwatch in hand. How does direct time study work? Basically, there are six steps in the procedure:

Select the job to be timed: The direct time study approach depends upon direct observation and is therefore limited to jobs that already exist. The job selected should be standardized, in terms of equipment and materials, and the worker should be representative of all workers doing the job.

Select a job cycle: Identify the elements and tasks that constitute a complete cycle. Decide how many cycles you want to time with a stopwatch?

Time the job for all cycles and rate the worker: Workersbehave in varying ways when their performances are being recorded; common reactions are resentments, nervousness, and slowing the work pace. To minimize these effects, repeated study across several workers, and standing by one worker while studying a job somewhere nearby, perhaps in another department, can be helpful. You can assign the worker a rating, as a percentage of the "normal" or average worker. Industrial engineers frequently use a rating factor when timing jobs. Inessence, the engineer judges the worker as 85 percent normal, 90 percent normal, or some other rating depending on his or her perception of "normal." Obviously, ratings of this kind depend on subjective judgments. Compute the normal time basedon the average cycle time and the worker rating. Determine the fraction of time available, making allowances for personal needs; delays, and fatigue, Set the performance standard (standard time) based on the normal time and the allowances.

To be more precise about the calculations of this procedure

$$\text{Average cycle time} = \frac{\text{Sum of cycle times recorded.}}{\text{Number of cycles observed}}$$

Normal time = Average cycle time x Worker rating

Allowance fraction = Fraction of time for personal needs, fatigue, and unavoidable delays

Available fraction of time = 1- Allowance faction

$$\text{Standard time} = \frac{\text{Normal time}}{\text{Available fraction of time}}$$

Predetermined Time Study: The predetermined time study is helpful for setting standards for jobs that are not currently being performed but are being planned. A predetermined time study can also be applied to existing jobs as an alternative to a direct time study. The bases of this technique are the stopwatch time study and time study from films. Historical data have been accumulated on thousands of people making such basic motions as reaching, grasping, stepping, lifting, and standing. These motions have been broken down into elements, each element timed, the times averaged to yield predetermined time standards, and the standards published in table form. The procedure for setting a predetermined time standard is as follows:

- Observe the job or think it through if it is not yet being performed: Itis best to observe under "typical" conditions: typical machine, materials, and worker.
- Itemize the job element: Do not be concerned about timing them; thoroughly document all the motions performed by the worker.
- From a table of predetermined time standards, record the standard for each motion units: Motion units are expressed in some basic scale (a The rblig scale is often used) that corresponds to time units.
- Find the sum of the standards for all motions.
- Estimate an allowance for personal time, delays, and fatigue to the sum of standards. This total sum is the predetermined timestandard for the job.

The primary advantage of predetermined time studies is that they are not skewed by the typical performance of workers who are nervous because they are being timed: the timing has already taken place - away from the workplace in a logical, systematic manner. The basic disadvantage of this technique is that some job elements may not be recorded, or maybe recorded improperly. Furthermore, if job elements can't be properly categorized and located in a table, a direct time study approach must be made instead of the predetermined time study.

Work sampling: Work sampling does not involve a stopwatch measurement, as do many other techniques; instead, it is based on simple random sampling techniques derived from statistical sampling theory. The sampling aims to estimate what proportion of a worker's time is devoted to work activities. It proceeds along the following steps:

- Decide what activities are defined as "working." "Not working" comprises all activities not specifically defined as "working."
- Observe the worker at selected intervals, recording whether a person is working or not.
- Calculate the portion P of time a worker is working as :

Number of observations during
which working occurred P = ... Total number of observations
This calculation can then be used as a performance standard.

Work sampling can also be used to set standards; the procedure is similar to the one used in direct time studies. Work sampling is particularly adaptive to service to service sector jobs such as those in libraries, banking, health, banking, health care, insurance companies, and government. The accuracy of this technique depends keenly upon sample size.

Disadvantages of work sampling are that the analyst may not be completely objective or may study only a few workers, and that "working" is a broad concept not easily defined with precision. There are, however, some obvious, advantages to work sampling: It is simple, easily adapted to the service sector and indirect labour jobs, and an economical way to measure performance. In short, work sampling is a useful work measurement technique if it is used with discretion.

Combining Work Measurement: Techniques which work measurement technique should you use? In practice, they are used in combination, as cross-checks. One common practice is observing a job, writing all the job elements in detail, and setting a predetermined time standard. Then you can check the history of performance on this orsimilar jobs to verify that the predetermined standard is reasonable. To provide a further check, a direct time study can be made of the job by element and total. No one work measurement technique is totally reliable. Because of the high skill level required in setting the standard, a cross-check is desirable whenever possible.
Each span can be adjusted to get the setting right.

❖ Check Your Progress

1. Why is layout planning important?
2. Discuss the various types of layout.
3. Give explain of product and process layout.
4. What is job design?
5. Define work measurement Discus the various types used and workmeasurement.

UNIT: 4 FACILITY LOCATION PLANNING

4.1 CONCEPT AND INTRODUCTION

The issue of the location of an industrial enterprise for an entrepreneur is generally faced by everyone who wishes to start a manufacturing firm. These decisions are also taken when anyone wishes to shift their plant to another location or, expand their operations to another location. The problem of location leads to several economic and engineering implications and therefore it is vital that before taking a decision of starting a new plant or shifting an existing plant to some other place, the promoters should take into consideration various relevant factors that affect profitability and cost structure of the organization. This is because a wrong decision can have a substantial effect on the operational viability of the industrial unit.

4.2 IMPORTANT ASPECTS OF LOCALIZATION OF INDUSTRIAL UNIT

A thorough study of all relevant factors is necessary before reaching a final decision because errors in decision-making in the area of plant location often lead to long-term problems which are very difficult to overcome. The selection of an appropriate location enables the enterprise to operate smoothly, efficiently and with minimum cost. Some of the points which describe the importance of selecting an appropriate plant location are as under:

- ✓ Selection of a plant location is said to have an impact on the cost structure up to 10% of the total cost. The location of the plant has a direct influence on the cost of production as well as on the distribution of the product. Hence a wrong selection of location can increase the cost of production by 10%.
- ✓ An inappropriate decision leads to wastage in the efforts and talents of the entrepreneur with subsequent uncertainty in profits. An

industry unit employs a lot of people with talent which will go to waste if the end product does not meet the requirements of the market.

- ✓ It is said that once the location is selected, it cannot be changed easily in the near future or rather it is difficult to reverse the plant location decision because it will lead to loss of losses. Hence, an entrepreneur is compelled to remain in that location with high costs for a substantial period of time.
- ✓ Plant location selection leads to a direct effect on the success or failure of an enterprise. If the selection is not up to the mark then all the money invested in form of land and building, plant and machinery, furniture and fixtures et cetera will go waste and the entrepreneur will have to suffer great losses.
- ✓ In order to run an industrial enterprise, the entrepreneur has to collect raw materials, machinery is, equipments, labour and other inputs from society. Collection of all these factors of production requires an entrepreneur to incur transportation costs. Hence location should be selected so that the transportation cost is minimised in the long run.
- ✓ It is very apt that the location selected near the source of raw materials when the raw material in the process start losing weight and the ultimate product is not as heavy as the raw material. This would reduce the transportation cost to a great extent, and hence it lowers the cost of production as well.
- ✓ On the other hand, nearness to the market is also an important factor for an entrepreneur not only to reduce transport costs but also to save on storage costs as the products can be supplied quickly when the demand emerges.

Thus, while selecting a location, the entrepreneur must consider technical, commercial and financial aspects and select a suitable site that may provide a maximum advantage. In spite of its importance, many entrepreneurs ignore the problem of the proper location of their units.

4.3 STAGES OF SELECTION OF LOCATION OF UNIT

In order to select the best location which matches all the feasibility requirements, an entrepreneur is expected to follow the below-mentioned steps:

A. Selection of the Region

Boundaries of the state affect the selection of region. The entire world is considered one market, but it is divided into different nations. The state boundaries are determined by natural factors like seashores, mountains, deserts, etc., and other artificial factors. The boundaries of the nation are determined by state agreement and other political factors. So, first thing is to decide in which nation the entrepreneur wants to establish his/her factory. Once the nation is determined, the next thing that comes is the state in which they are planning. Like in India, we have 28 states and 8 UTs. Each of these states is divided into various district. Hence, an entrepreneur needs to narrow the search down to a particular district and then to a particular site. Each region or state, or district offers certain merits and demerits. The following factors are required to be considered by the businessmen when they plan to select a region for establishing the firm:

- The availability of raw materials
- Market proximity
- Availability of power and fuel
- Transportation
- Climate suitability
- Government policy
- Topography of the region
- Terrain, etc.

B. Selection of Locality

In this stage, an entrepreneur needs to determine the locality in which he/she is trying to establish the factory or unit. An entrepreneur is available with the following three broad choices for selecting the location:

1. Urban Areas

Urban areas are more developed areas, with significant populationscomparatively with a high standard of living in people.

Merits:

- Good transport facility and communication. Again, they are available in abundance, easily and quickly.
- Lots of financial institutions are there which can help an entrepreneur to finance his venture.
- Facility of insurance, godowns, warehouses, etc, are available to store the finished products and inputs.
- Adequate supply of skilled and unskilled labours.
- Availability of ancillary and supportive industries
- Large market due to large population
- Various training centres, and social infrastructure in form of educational institutes, hospitals, and recreational facilities are available which is a good motivator.

Demerits:

- Higher prices of land and also the shortage of land as well.
- Prices of labour and other inputs are also high comparativelywhich

increases the overall cost of production.

- Competition level is high
- There is the existence of local taxes and other duties. They are also expected to be higher comparatively.
- Problems of disposal of garbage or waste are also a burning issue in urban areas.

2. Rural Areas

Rural areas are less developed comparatively, with a small population and a lower standard of living in the societal structure.

Merits:

- Prices of land are lower comparatively and are also available adequately as compared to urban areas. The company can expand their operations efficiently and quickly.
- The labour and other inputs prices are also comparatively low in rural areas as they have lower standards of living. Labour will have more stability as they will not leave their job easily because of the lack of options in rural areas.
- Local taxes and other charges are pretty low.
- Putting up a plan in rural areas will create less environmental damage and hence few problems from the side of the government.
- Government also gives lots of benefits to industries that set up their plant in backward areas. They offer a subsidy, tax rebate, and easy loans to units in rural areas.

Demerits:

- Less developed infrastructure leads to problems in transportation, communication, banking, warehousing, etc.
- For major financial and banking transactions, one has to depend on the nearest urban areas.
- Lack of training facilities, recreational facilities, etc., leads to a little boring life for workers.
- Due to less population, the local market will be small and transport costs from the factory to urban areas will increase.
- Local facilities like water, fire and emergency, healthcare, etc, is also less developed.

3. Sub-Urban Areas

Urban and Rural areas are the extreme ends for selecting plant locations, while sub-urban areas are in the middle. They are the combination of both with varying proportion. Suburban areas are a little far away from the city but still offer advantages that are available in urban areas it also tries to remove the limitations of rural areas. With the passage of time, these areas might get converted into urban areas, but till then, it can offer lots of advantages to an entrepreneur.

Following are the factors which are to be considered when we select alocality for setting up a plant:

- ✓ Availability of labour and also the adequacy
- ✓ Civil amenities for workers in adequate quantity
- ✓ Existence of supportive industries
- ✓ Research centres and finance facility
- ✓ Availability of power, water and waste disposal
- ✓ Local taxes and rates
- ✓ Banking and communication
- ✓ Political stability of the locality
- ✓ Educational environment.

C. Selection of Exact Site

The third and last stage for selecting a plant location is of selecting exact site. Once we determine the locality in which we plan to set up the plant, the last thing is to decide the exact site for the plant location. For instance, we one decides to set up the plant in Rajkot city (Urban Area), then where exactly in Rajkot city, viz., GIDC Metoda, GIDC Kuvadva, Shaper-Veraval, etc?

In order to select the same site, the following factors need to be studied andconsidered by an entrepreneur:

- Soil type, size of plant and topography of the area
- Provision for disposal of waste and scrap
- Prices of land and cost of construction
- Potential to expand the factory premises
- Availability of amenities in the local area
- Statutory conditions of the area
- Attitude of local people
- Assistance from the district and state and many more…

4.4 FACTORS AFFECTING INDUSTRIAL LOCATION

There are several factors which are common among all industries which need to be given proper thought before setting up an enterprise. Some of these factors can be crucial, while others could be arranged easily while locating an industrial enterprise. While selecting the location, due importance should be given to factors that impact the cost of production, distribution expenses and profitability substantially. The following are a few important factors which an entrepreneur should consider while locating the enterprise:

1. Availability of raw materials

For any industrial unit, the ideal location will be the one where the raw material costs are the minimum and they are also available in adequate quantity and in specified quality, which suits the requirements of the target market. This is also necessary because in adequate supply maintains the regular flow of production, which is also important to minimize the cost of production. The industrial unit can afford to locate the factory near the source of supply of raw materials when the raw material is localized and it has the tendency of losing weight during production. This will reduce the transportation cost when the finished goods are transported from production area to market.

Alternatively, if the product is ubiquitous and does not lose weight during the production process it is advisable to locate the plant near the market so as to supply goods whenever demanded.

2. Supply of labour

   availability of adequate labour supply is significant to ensure that the production runs smoothly. Thus, it is one of the most important factor affecting the location of an industrial enterprise. Industrial enterprise should locate their plant at a place where the right type of labour is available in adequate quantity at reasonable wage rate. But in recent years, this factor has lost its significance because of the following reasons:

- labour is now a completely mobile factor, and it can be easily brought to various places thus, they have lost certain significance.
- Industrial units are required to pay minimum wages to all labourers wherever they are locating their unit. Hence it makes no difference whether you hire labourers from any part of the country as the wage rate would remain common.
- Due to the revolution in industrial technology and more and more firms starting to become more capital intensive, the importance of labour has reduced, and it will not attract any industry to locate a plant near the source of supply of labour.
- Skill levels can also be brought even from distant places by giving them higher wage rates and hence it is not a barrier to locate a plant near the source of supply of labour

3. Proximity to market

   proximity to the market is yet another important factor affecting the location of industrial enterprises. The industrial unit, which wants to take maximum benefit of quick delivery of goods and services and thereby cater to the largest market share, generally prefers to locate the plant near the target market. This will also help them in providing additional after-sale services which may not be possible if the plant is located far away. Industries producing perishable and fragile items are attracted to locate their plant near the market, which minimizes the costs and other expenses.

4. Communication and Transport

   transportation is a very key industrial input as it is required for true purposes, namely, to bring raw material to the plant location and then to bring produced products to the markets. Thus, an industrial enterprise should consider adequate transport facility is available in the form of roads, rails, water or air transport at reasonable rates and in adequate quantity, before locating their plant. Apart from transportation, communication is also one of the important factors affecting the location of industrial enterprises. Communication is the heart of a business firm which is required to process lots of information for decision-making in a business. The business houses should be able to get every type of business information, for instance, the performance of the economy, the position of the labour market, adequacy of raw materials, demand for products in the market, purchasing power of the target market, et cetera. If the communication facility is not available in the required proportion, the industries will be reluctant to start their plant in those areas.

5. Power and Fuel the supply of energy sources with the power or fuel in an uninterrupted and adequate manner is a major factor affecting the location of an industrial enterprise. Industries which use coal as a major energy source should locate their plant near the source of coal because it will help them get continuous supply and also reduces the transportation cost to a great extent. In case if the firm is using any other power source such as oil, gas, wind energy, et cetera, they can locate the factory where these energy sources are easily obtainable.

6. Climatic conditions
   climatic conditions are one of the optional factors which may affect a certain type of industry while for other industries, it may not be as important. There are some industries which need a special type of climate to run their operations effectively. For example, cotton industries require a humid climate and, therefore it is located in areas where the humidity is high. Of course, with scientific development and new inventions, this factor has lost its significance as few artificial simulations can be created which can help the product survive in any location of the world.

7. Availability of other industrial units
   many entrepreneurs would try to locate their industries at places where there are already a few industries existing because it provides them with few benefits which have been developed there and which may not be there in a remote area. A few of these facilities, which are developed at important concentrated industrial centres are mentioned below:

- transport facilities are developed in those areas because of already existing units and they are available readily
- few supportive industries are existing there which can be of help
- there is a scope for a few specialized firms which offer repairs and

maintenance facilities

- banking and insurance facilities are already there along with skilled and unskilled labour.

8. Government policy

   In the majority of the economies of the world, Government also plays crucial role in deciding location of an enterprise. Particularly, in India, government follows the policy of balanced regional growth where every area should get equal opportunity to develop itselfdevelop itself with other areas. This is also very important from the point of view of defence and social problems like slums (houses unfit for human habitation), disparity of income and wealth, and optimum use of resources. In order to implement this policy, the government offers several incentives to locate their industrial units in backward regions on non-industry regions. If it offers tax concessions or loan facilities or factory sheds at cheaper rates. Sometimes government announces certain dis-incentives to industries located at a certain place. Thus, government policy plays an essential role in locating an industrial enterprise.

9. Personal factors

   Many entrepreneurs have their personal preferences and prejudices when it comes to locating an industrial enterprise. In this case, the rational decisions and economic considerations would not matter much as their emotions are attached to a particular place. For instance, an entrepreneur could set up a plant in his home town because he is emotionally connected with that place. Popular example was of Henry Ford when he started car manufacturing in Detroit, because it was his home town. Of course, in today's world, an entrepreneur needs to think harder as these decisions can be detrimental to a firm's survival in the long run.

10. Strategic considerations

    Lastly, an entrepreneur also needs to take into account a few strategic aspects such as law and order, political stability, the safety of workers in a particular area, local taxes and duties, historical factors, population demographics, habits of a particular locality, etc. Naturally, no entrepreneur will take a risk to start an industry at a place where these factors are not favourable.

❖ CHECK YOUR PROGRESS

Multiple Choice Questions (MCQs)

1. Is labour a mobile factor…?

a. Yes

b. No

c. Can't say

d. Subjective matter

2. Which of following has lost significance as a factor to determine location?

a. Raw materials
b. Power and fuel
c. Strategic considerations
d. Labour

3. Which of the following is characterised by high population and large market?

a. Urban Areas
b. Rural Areas
c. Sub-Urban Areas
d. Both (a) & (b)

4. Which of the following is characterised by low population and small market?

a. Urban Areas
b. Rural Areas
c. Sub-Urban Areas
d. Both (a) & (b)

5. Which of the factor does not give importance to rational decision making?

a. Political
b. Personal
c. Supply of labour
d. Nearness to market

Descriptive Questions

1. What is the facility location? Discuss why is it important for location industrialenterprise.
2. Discuss the significance of facility location/plant location
3. What is the facility location? Discuss the process/steps of locating a plant.
4. Explain various factors involved in deciding the location of an industrial enterprise
5. Where should a company locate their plant if the raw material has weight losingtendency and why? Also, discuss if it faces the reverse situation.
6. What are the strategic considerations for locating an industrial enterprise?

Short notes:

- Importance of supply of labour
- Personal factors v/s Economic considerations
- Selection of Locality
- Selection of an exact site
- Proximity to market v/s proximity to source of supply of raw materials.

UNIT : 5 PROJECT MANAGEMENT & SCHEDULING

As host for the 1992 summer Olympic games, the city of Barcelona was faced with an extremely complex logistical problem: scheduling more than 2,000 events in a 15-day period. The problem was not only very large but included a great many different types of constraints, some of them not ordinarily encountered in the scheduling of more familiar projects.

First were the precedence relationships—for example, qualifying rounds obviously had to take place before quarterfinals, semifinals, and finals. Then, there was the need to spread out the events, in both time and space. One concern was to avoid traffic jams that might result if two or more popular events were scheduled in nearby facilities at the same time. But even when different venues were involved, it was desirable to schedule the most attractive events at different times, to allow the largest possible audience for the greatest number of events. The requirements of live TV coverage of different events for different time zones also had to be considered. For instance, interest in soccer matches would be high in Europe, Africa, and South America, but not in North America. Finally, there were constraints on the available equipment (such as TV cameras) and personnel (for example, security).

This complex problem provided an interesting challenge for two professors at the Universitat Politecnica de Catalunya in Barcelona. It soon became evident that no single existing program was adequate for the task. They therefore developed a col- lection of interactive algorithms to supplement the more conventional project management software, along with a set of graphical aids to help compare different schedule characteristics. It was found useful first to create a calendar (assigning competitions to days), and then to refine the precise timetable of events on each day. This approach allowed rough schedules to be generated quickly. It also proved useful to work with time divisions both larger and smaller than an "event." The modelers discovered that each sport had its own rhythm and that it helped to think in terms of blocks of days that fit that rhythm. A particular sport, for example, might be best served by scheduling three consecutive days of preliminary competition, a day off, and then the finals.

- Equally helpful was the concept of a "unit"—a part of an event having intrinsic interest as a spectacle. Thus the end of the marathon, for example, was treated as a unit.

The objective function for the scheduling process incorporated several criteria, each of which was evaluated on a numerical scale. Among these were continuity (the number of days between the first and last activity for a particular event) and temporal profile (a measure of how well the schedule distributed the activities throughout the two-week period, com- pared to an ideal distribution).

The TV scheduling problem could be formulated as a binary integer programming model, but solving it would have required an impractical amount of computer time. Instead, a simpler greedy algorithm, designed for the situation, proved useful in developing timetables tailored to the needs of specific audiences.

A key feature of the resulting system, called SUCCESS92, is its speed and flexibility. In the event of weather problems, an alternative schedule can be quickly devised. SUCCESS92 has been received with great enthusiasm by the organizers of the games. (See Andreu and Corominas.)

5.1 INTRODUCTION

The task of managing major projects is an ancient and honourable art. In about 2600 B.C., the Egyptians built the Great Pyramid for King Khufu. The Greek historian Herodotus claimed that 400,000 men worked for 20 years to build this structure. Although these figures are now in doubt, there is no question about the enormity of the project. The Book of Genesis reports that the Tower of Babel was not completed because God made it impossible for the builders to communicate. This project is especially important, since it establishes a historical precedent for the ever-popular practice of citing divine intervention as a rationale for failure.

Modern projects ranging from building a suburban shopping center to putting a man on the moon are amazingly large, complex, and costly. Completing such projects on time and within the budget is not an easy task. In particular, we shall see that the complicated problems of scheduling such projects are often structured by the interdependence of activities. Typically, certain of the activities may only be initiated after others have been completed. In dealing with projects possibly involving thousands of such dependency relations, it is no wonder that managers seek effective methods of analysis. Some of the key questions to be answered in this chapter are

1. What is the expected project completion date?
2. What is the potential “variability” in this date?
3. What are the scheduled start and completion dates for each activity?
4. What activities are critical in that they must be completed exactly as sched- uled to meet the target for overall project completion?
5. How long can noncritical activities be delayed before a delay in the overall completion date is incurred?
6. How might resources be concentrated most effectively on activities to speed up project completion?
7. What controls can be exercised on the flows of expenditures for the various activities throughout the duration of the project so that the overall budget can be adhered to?
8. **PERT** and **CPM**, acronyms for Program Evaluation Review Technique and Critical Path Method, respectively, will provide answers to these questions. Each of these approaches to scheduling represents a project as a network, and hence the material in this chapter can be viewed as an extension of the deterministic networks discussed in Chapter.
9. When a project involves uncertain elements, the representation of the project requires a stochastic network, which introduces an additional level of complexity not present in Chapter 5.
10. PERT was developed in the late 1950s by the Navy Special Projects Office in cooperation with the management consulting firm of Booz, Allen, and Hamilton. The technique received substantial favorable publicity for its use in the engineering and development pro- gram of the Polaris missile, a complicatwithct that had 250 prime contractors and over 9,000 subcontractors. Since that time, it has been widely adopted in other branches of government and in industry and has been applied to such diverse projects as the construction of factories, buildings, and highways, research management, product development, the installation of new computer systems, and so on. Today, many firms and government agencies require all contractors to use PERT.
11. CPM was developed in 1957 by J. E. Kelly of Remington Rand and M. R. Walker of Du Pont. It differs from PERT primarily in the details of how time and cost are treated. Indeed, in actual implementation, the distinctions between PERT and CPM have become blurred as firms have integrated the best features of both systems into their efforts to manage projects effectively. The implementation of PERT and CPM immediately impacted scheduling projects because it allowed the practice of “manage- ment by exception.” Although there might be 10,000 activities during a project, perhaps only 150 of them would be “critical” and need to be watched closely. To put an American on the moon during the days of the Apollo project, North American Aviation used PERT to bring its part of the project in six weeks early. There were over 32,000 events and hundreds of thousands of activities, but only a few hundred needed constant monitoring.
12. In keeping with our philosophy throughout the text, we approach

the topic of project management on two levels. First, the essential techniques will be developed in an easily grasped illustrative example. Second, the use of the spreadsheet will be illustrated to indi- cate how one would handle the techniques in a large-scale, real-world application.

5.2 A TYPICAL PROJECT: THE GLOBAL OIL CREDIT CARD OPERATION

No one would claim that it is like building the Great Pyramid, but the impending move of the credit card operation to Des Moines, Iowa, from the home office in Dallas is an important project for Rebecca Goldstein and Global Oil. The board of directors of Global has set a firm deadline of 22 weeks for the move to be accomplished. Becky is a manager in the Operations Analysis Group. She is in charge of planning the move, seeing that everything comes off according to plan, and ensuring the deadline is met.

The move is difficult to coordinate because it involves many divisions within the company. Real estate must select one of three available office sites. Personnel has to determine which employees from Dallas will move, how many new employees to hire, and who will train them. The systems group and the treasurer's office must organize and implement the operating procedures and the financial arrangements for the new operation. The architects will have to design the interior space and oversee needed structural improvements. Each of the sites that Global is considering is an existing building with the appro- priate amount of open space. However, office partitions, computer facilities, furnishings, and so on, must all be provided.

A second complicating factor is that there is an interdependence of activities. In other words, some parts of the project can only be started once other parts are completed. Consider two obvious examples: Global can only construct the interior of an office aftIt can only hire new employees once it has been designed. Neither can it hire new employees until it has determined its personnel requirements.

THE ACTIVITY LIST

Becky knows that PERT and CPM are specifically designed for projects of this sort, and she wastes no time getting started. The first step in the process is to define the project's activities and establish the proper precedence relationships. This is an important first step since errors or omissions at this stage can lead to a disastrously inaccurate schedule. Table

14.1 shows the first activity list that Becky prepares for the move (the columns labeled "Time" and "Resources" are indications of things to come). This is the most important part of any PERT or CPM project and usually is done with several people involved, so that no important activities are missed. This must be a group effort not done in isolation.

Conceptually, Table 5.1 is straightforward. Each activity is placed on a separate line, and its immediate predecessors are recorded on the same line. The immediate predeces.

Table 5.1 First Activity List

ACTIVITY	DESCRIPTION	IMMEDIATEPREDECESSORS TIME RESOURCES
A	Select Office Site	—
B	Create Organization al and Financial Plan	—
C	Determine Personnel Requirements	B
D	Design Facility	A, C
E	Construct Interior	D
F	Select Personnel to Move	C
G	Hire New Employees	F
H	Move Records, Key Personnel, etc.	F
I	Make Financial Arrangements with Institutions in Des Moines	B
J	Train New Personnel	H, E, G

sors of activity are those activities that must be completed before the start of the activ-ity in question. For example, in Table 5.1 we see that Global cannot start activideterminemine personnel requirements, until activity B, create the organizational and financial plan, is completed. Similarly, activity G, hire new employees, cannot begin until activity F, select the Global personnel that will move from Texas to Iowa, is completed. This activity, F, cannot start until activity C, determining personnel requirements, is completed.

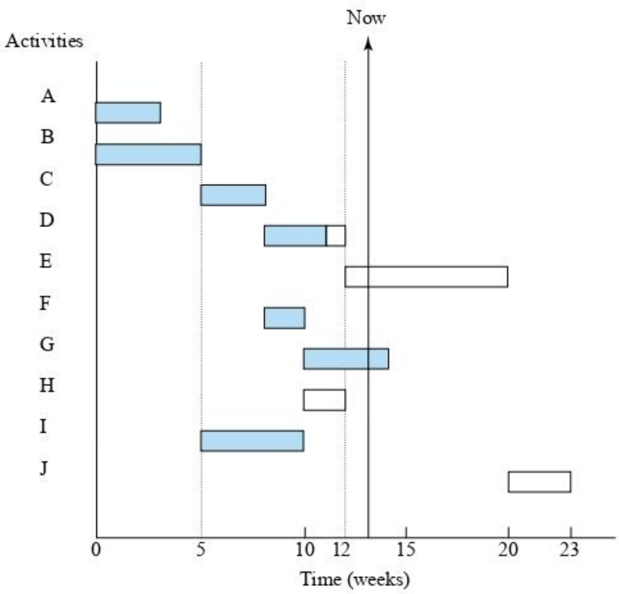
The activity list with immediate predecessors and the yet-to-be-obtained time esti- mates will provide the essential ingredients to answer the first five questions at the start of this chapter. We shall shortly see how PERT and CPM are used to produce these answers. In practice, however, another graphical approach, the Gantt chart, is commonly used to attack such problems. We thus make a slight detour to consider this precursor of the net- work approaches (PERT and CPM) before returning to the main thrust of the chapter.

The Gantt Chart

The Gantt chart was developed by Henry L. Gantt in 1918 and remains a popular tool in production and project schedule. Its simplicity and clear graphical display have estab- lished it as a useful device for simple scheduling problems. The Gantt chart for Becky's problem is shown in Figure 5.1. Each activity is listed on the vertical axis. The horizontal axis is time, and the anticipated, as well as actual duration of each activity, is represented by a bar of the appropriate length. The chart also indicates *the earliest possible starting* time for each activity. For example, activity C cannot start before time 5 since, according to Table 5.1, activity B must be completed before activity C can begin. As each activity (or part thereof) is completed, the appropriate bar is shaded. At any point in time, it is clear which activities are on schedule and which are not. The Gantt chart in Figure 5.1 shows that as of week 13 activities D, E, and H are behind schedule, while G has actually been completed (because it is all shaded) and is ahead of schedule.

This simple example shows how the Gantt chart is mainly used as a record-keeping device for following the progression in time of the subtasks of a project. As Figure 5.1 shows, we can see which individual tasks are on or behind schedule. It seems important to note at this point that in the Gantt chart context, the phrase "on schedule" means "it has been completed no later than the earliest possible completion time." Thus Figure 5.1

FIGURE5.1 A Gantt Chart



shows that D and H could have been completed, at the earliest, by week 12. Since they are not completed by week 13 they are, in this sense,behind schedulele. As we shall see, thisistoo simple a concept for whether an activity is on schedule. The appropriate point of view should be whether *the overall project* is being delayed in terms of a target completion date.Tneedsntt chart needs to revealf the important information needed to attack this question. For example, the Gantt chart fails to reveall which activities are *immediate predecessors* of other activities. In Figure 5.1, it may appear that F and I are immediate predecessors of G since G can start at 10 and F and I can each finish at 10. In fact, however, Table 5.1 tells us that only F is an immediate predecessor of G. A delay in I would *not* affect the potential starting time of G, or for that matter of any other activity. This type of "immediate predecessor" information themust be used to deduce the impact on completion time for the overall project. This latter type of infoTheir uselessness reflects the overall weakness of Gantt chartsof Gantt charts is reflected by their uselessness in mak ing such inferences. We shall now see that the network representation contains the immediate predecessor information that we need.

THE NETWORK DIAGRAM

In a PERT **network diagram,** each activity is represented by an arrow called a **branch** or an **arc**. The beginning and end of each activity is indicated by a circle that is called a **node**. The term **event** is also used in connection with the nodes. An event represents the completion of the activities that lead into a node. Referring to the activity list in Table 5.1, we see that "select office site" is termed activity A. When this **activity** is completed, the *event* "office site selected" occurs.

Constructing the Network Diagram Figure 5.2 shows a network diagram for activities A through C. We emphasize at the outset that the numbers assigned to the nodes are arbitrary. They are simply used to identify events and do not imply anything about precedence relationships. Indeed, we shall renumber the node that terminates activity C several times as we develop the network diagram for this project, but *correct precedence relationships will always be preserved*. In the network diagram each activity must start at the node in which its immediate predecessors ended. For example, in Figure 5.2, activity C starts at node ③ because its immediate predecessor, activity B, ended there. We see, how-ever, that complications arise as we attempt to add activity D to the network diagram. Both A and C are immediate predecessors to D, and since we want to show any activity such as D only once in our diagram, nodes ②and ④in Figure 5.2 must be combined, and D shoudl start from this new node. This is shown in Figure 5.3. Node ③ now represents the event that activities A and C have completed. Note that activity E, which has only D as an immediate predecessor, can be added with no difficulty. However, as we attempt to add activity F, a new problem arises. Since F has C as an immediate predecessor, it would

FIGURE 5.2 Network Diagram for Activities A through C

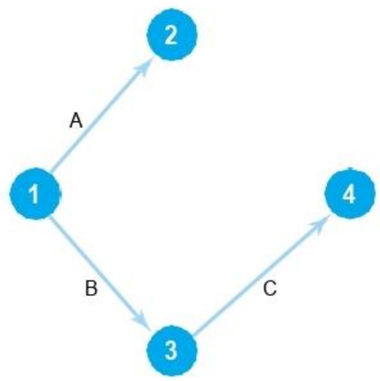
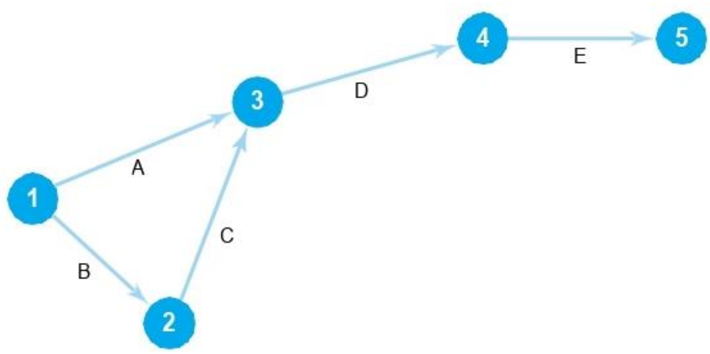


FIGURE 5.3 A Partial Network Diagram



emanate from node ③(of Figure 5.3). We see, however, that this would imply that F also has A as an immediate predecessor, which is incorrect.

The Use of Dummy Activities This diagramming dilemma is solved by introducing a **dummy activity**, which is represented by a dashed line in the network diagram in Figure This dummy activity is fictitious because it requires no time or resources. It merely provides a pedagogical device that enables us to draw a network representation that correctly maintains the appropriate precedence relationships. Thus, Figure 5.4 indicates that activity D can begin onlyr both activities A and C have been completed. Similarly, activity F can occur only after activity C is completed.

5.8 We can generalize the procedure of adding a dummy activity as follows. Suppose we wish to add an activity A to the network starting at node N. Still, not all of the activities that enter node N are immediate predecessors of the activity. Create a new node M with a dummy activity running from node M to node N. Take those activities that are currently entering node N and that are immediate predecessors of activity A and reroute them to enter node M. Now make activity A start at node M. (Dummy activities can be avoided altogether if, instead of associating activities with arcs (commonly known as activity on thearc [AOA]), we associate them with nodes. An example of this activity on the node (AON) approach is presented in the box that follows. Furthermore, all of the discussion in Section 5.8 uses the AON approach).

Figure 5.5 shows the network diagram for the first activity list as presented in Figure 14.4 We note that activities G and H both start at node ⑥ and terminate at node ⑦.Thsi does not present a problem in portraying the appropriate precedence relationships, since only activity J starts at node ⑦. This might, however, create a problem for certain software packages used to solve PERT and CPM problems. In some of these programs, each activityis identified by the number of its starting andending node. If such a program is to be used, the representation of G and H in Figure 5.5 would lead the computer to regard them as the same activity. This would be incorrect, since in fact activities G and H are not the same.

FIGURE 5.4 Introducing a Dummy Activity

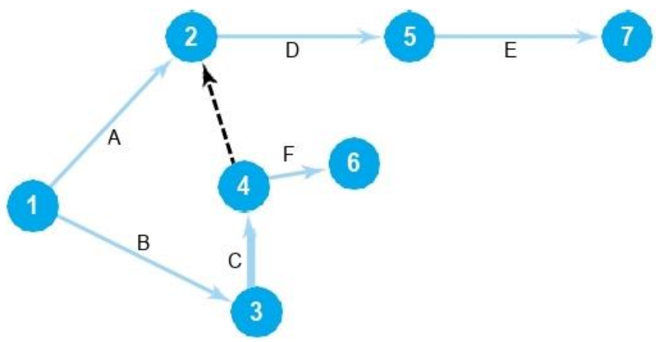
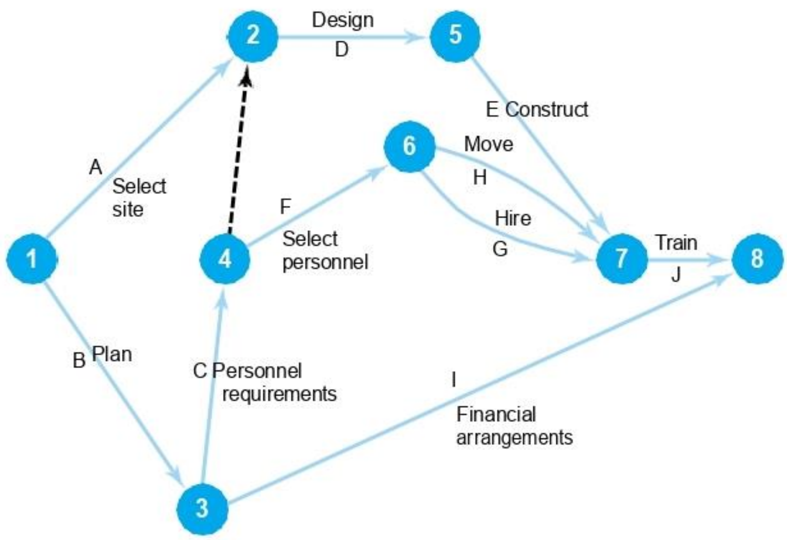


FIGURE 5.5 Network Diagram for the First Activity List for the Move to Des Moines



A dummy activity can be used to cure this condition. Figure 5.6 illustrates the procedure. Since the dummy activity requires no time, the correct time and precedent relationships are maintained. This new representation has been introduced into Figure 5.7. Many software packages do not require that these dummy activities be input. Thus, for our purposes, they serve mainly the pedagogical goal of correctly portraying the precedence relations (i.e., as used in Figure 5.4).

FIGURE 5.6 Introducing a Second Dummy Activity

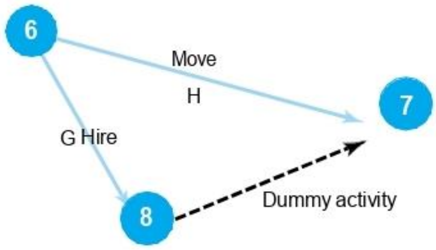
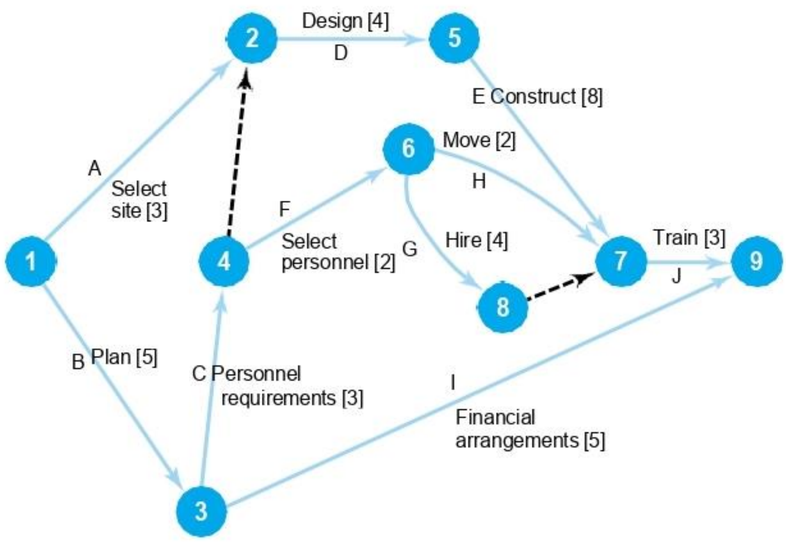
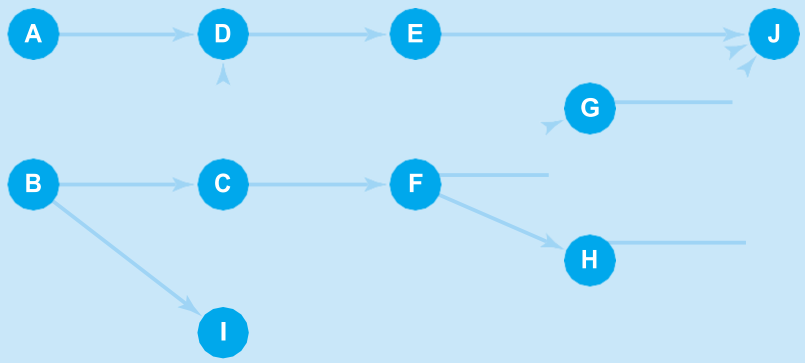


FIGURE 5.7 Network Diagram with Expected Activity Times



An Activity-on-Nodes Example

In the activity-on-nodes approach to representing a project as a network, the activities are associated with the nodes of the network while the arcs of the network display the precedence relationships. The Global Oil network in Figure 14.5 would be represented as shown below. For example, activity J has activities E, G, and H as immediate predecessors because there are arcs entering J from the nodes labeled E, G, and H. Note that there is no special difficulty in making A and C immediate predecessors of D, and C (but not A) an immediate predecessor of F.



5.3 THE CRITICAL PATH—MEETING THE BOARD'S DEADLINE

The activity list and an appropriate network diagram are useful devices for representing the precedence relationships among the activities in a project. Recall that the board has set a firm goal of 22 weeks for the overall project to be completed. Before Becky can tell if she can meet this goal, she will have to incorporate time estimates into the process.

The PERT-CPM procedure requires management to produce an estimate of the expected time it will take to complete each activity on the activity list. Let us assume that Becky has worked with the appropriate departments at Global to arrive at the expected time estimates (in weeks) shown in Table 5.2. (In Section 5.4 we shall discuss in more detail the way in which these time estimates were produced.) Figure 5.7 shows the net- work diagram with the expected activity times appended in brackets.

Table 5.2 First Activity List with Expected Activity Times in Weeks

ACTIVITY	DESCRIPTION	IMMEDIATE PREDECESSORS	EXPECTED ACTIVITY TIME	RESOURCES
A	Select Office Site	—	3	
B	Create Organizational and Financial Plan	—	5	
C	Determine Personnel Requirements	B	3	
D	Design Facility	A, C	4	
E	Construct Interior	D	8	
F	Select Personnel to Move	C	2	
G	Hire New Employees	F	4	
H	Move Records, Key Personnel, etc.	F	2	
I	Make Financial Arrangements with Institutions in Des Moines	B	5	
J	Train New Personnel	H, E, G	3	

THE CRITICAL PATH CALCULATION

From Table 5.2 you can see (by adding up the separate expected activity times) that the total working time required to complete all the individual activities would be 39 weeks. However, the total calendar time required to complete the entire project can clearly be less than 39 weeks, for many activities can be performed simultaneously. For example, Figure5.7 shows that activities A and B can be initiated at the same time. Activity A takes 3 weeks and B takes 5 weeks. If management arranges to begin both activities at the same time (at calendar time 0), both will be completed by calendar time = 5. To obtain a prediction of the minimum calendar time required for overall project duration, we must find what is referred to as a *critical path* in the network.

A **path** can be defined as a sequence of connected activities that leads from the starting node ① to the completion node ⑨ For example, the sequence of activities B–I, requiring10 weeks to complete, is a path. So is the sequence B-C-D-E-J, requiring 23 weeks to complete. You can identify several other paths in Figure 5.7. To complete the project, the activities *on all paths* must be completed. In this sense we might say that "all paths must be traversed." Thus, we have just seen that our project will take *at least* 23 weeks to complete, for the path B-C-D-E-J must be traversed. However, numerous other paths must also be traversed, and some of these may require even more time. Our task will be to analyze the total amount of calendar time required for all paths to be traversed. Thus, we wish to determine the *longest path* from start to finish. This path, called the **critical path**, will determine the overall proj- ect duration, because no other path will be longer. If activities on the longest path are delayed, then, since these activities must be completed, the entire project will be delayed. For this reason the activities on the critical path are called the **critical activities** of the proj- ect. It is this subset of activities that must be kept on schedule.

This is the opposite problem from the one in Chapter 5 (the shortest-route problem). Here, the longest route from beginning (start) to end (finish) is needed. We can either change this PERT problem to a shortest-route model and use the algorithm in Chapter 5 or change the algorithm to fit the problem. It is easier in this case to change the algorithm.

Earliest Start and Earliest Finish Times Another difference between the short- est-route problem and this longest route (critical path) is that the interest is not just in the longest path in the network, but in the earliest and latest times each activity can be started and not affect the current solution. Thus, what is needed is *sensitivity analysis* of each activ- ity and, therefore, finding the earliest and latest start times (and finish times) for each activ- ity. We now specify the steps employed in finding a critical path. Fundamental in this process will be the **earliest start time** for each activity. To illustrate this idea, consider activ- ity D, “design facility.” Now assume that the project starts at time zero and ask yourself: “What is the earliest time at which activity D can start?” Clearly, it cannot start until activ- ity A is complete. It thus cannot start before time = 3. However, it also cannot start before the dummy activity (that requires 0 time) is complete. Since the dummy cannot start until B and C are complete (a total of 8 weeks), we see that D cannot start until 8 weeks have passed. In this calculation, it is crucial to note that activities A and B both start at time 0. After 3 weeks A is complete, but B still requires another 2 weeks. After a total of 5 weeks, B is complete and C can start. After another 3 weeks, a total of 8 from the start, C is com- pleted. Thus, after 8 weeks, both A and C are complete and D can start. In other words,

earliest start time for activity D = 8 weeks

Another important concept is **earliest finish time** for each activity. If we let

ES = earliest start time for a given activity

EF = earliest finish time for a given activity

t = expected activity time for a given activity

then, for a given activity, the relation between earliest start time and earliest finish time is

EF = ES + *t*

For example, we have just shown that for activity D we have ES = 8. Thus, for activity D,

EF = ES + *t*

= 8 + 4 = 12

We now recall that each activity begins at a node. We know that a given activity leaving a node cannot be started until *all* activities leading into that node have been finished. This observation leads to the following rule.

Earliest Start Time Rule: The ES time for an activity leaving a particular node is the *largest* of the EF times for all activities entering the node.

Let us apply this rule to nodes ①, ②, ③, and ④ of Becky’s network, Figure5.7.The result is shown in Figure 5.8. We write in brackets the earliest start and earliest finish times for each activity next to the letter of the activity, as shown in Figure 5.8. Note that the ear- liest start time rule applied to activity D says that ES for activity D is equal to the larger value of the EF times for the two precedent activities C (via the dummy) and A. Thus, the ES for D is the larger of the two values [8, 3], which is 8.

Continuing to each node in a **forward pass** through the entire network, the values [ES, EF] are then computed for each activity. The result is shown in Figure 5.9. Note that the

FIGURE 5.8 **Earliest Start Time Rule**

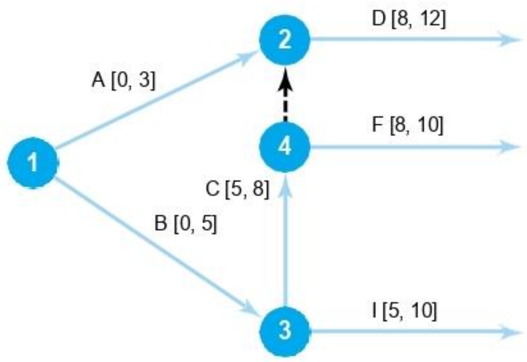
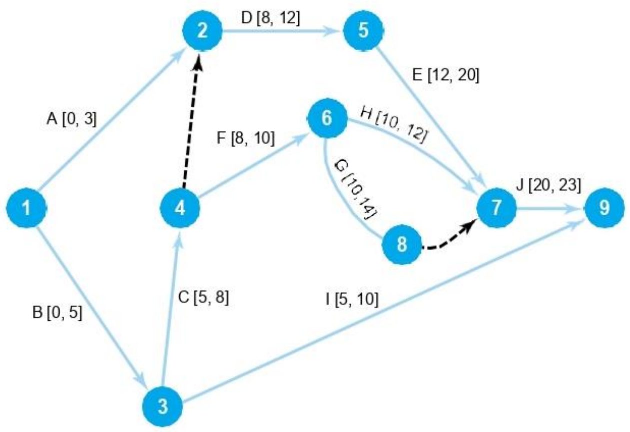


FIGURE 5.9 Global Oil Network with Earliest Start and Earliest Finish Times Shown



earliest finish time for J is 23 weeks. This means that the earliest completion time for the entire project is 23 weeks. This answers the first of the questions itemized in Section 5.1: "What is the expected project completion date?"

Latest Start and Latest Finish Times In order to identify possible start and com- pletion dates, the activities on the critical path, and how long noncritical activities may be delayed without affecting the overall completion date (answering the third, fourth, and fifth questions of Section 5.1), we now proceed with a **backward pass** calculation. The idea is that since we now have a target completion date (23 weeks from the start of the pro- ject), we can work backward from this date, determining the *latest* date each activity can finish without delaying the entire project. The backward pass begins at the completion node, node ⑨ We then trace back through the network computing what is termed a **latest start time** and **latest finish time** for each activity. In symbols,

LS = latest start time for a particular activity

LF = latest finish time for a particular activity

The relation between these quantities is

LS = LF – t

For activity J we define the latest finish time to be the same as its earliest finish time, which is 23. Hence, for activity,

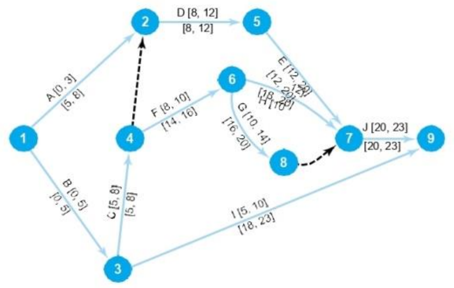
LS = LF – t = 23 – 3 = 20

Since the latest start time for activity J is 20, the latest activities E, H, and G can finish is 20. Thus, the latest E can start is 20 – 8 = 12, the latest H can start is 20 – 2 = 18, and the latest G can start is 20 – 4 = 16. To determine the latest finish time for activity F is a little more complicated. We apply the following general rule :

> *Latest Finish Time Rule*: The LF time for an activity entering a particular node is the *smallest* of the LS times for all activities leaving that node.

Thus, for activity F, which enters node ⑥, we apply the rule to see that LF = 16, because the latest start times for the activities leaving node ⑥ (activities H and G) are 18 and 16. The complete network with LS and LF entries is shown in Figure 5.10. These entries appear on the arc for each activity in brackets, directly under the ES and EF times.

FIGURE 5.10 Global Oil Network with LS and LF Times Shown Below Activities



Slack and the Critical Path Based on Figure 5.10, the next step of the algorithm is to identify another important value, the amount of slack, or free time, associated with each activity. **Slack** is the amount of time an activity can be delayed without affecting the completion date for the overall project. *Slack* is the same concept covered in LP and is the extra time that could be spent on that path without affecting the length of the critical path. An easy and important mathematical check is that every activity on the critical path should have the same slack, namely 0. For each activity, the slack value is computed as

slack = LS – ES = LF – EF

For example, the slack for activity G is given by

slack for G = LS for G – ES for G

= 16 – 10

= 6

and the same value is given by

LF for G – EF for G = 20 – 14 = 6

5.4 PERT

Let us now consider the second question raised in the introduction: “What is the potential variability in the expected project completion date?” So far, we have been acting as though the activity times and the derived values for ES, LS, EF, and LF were all deterministic. This may not be strictly correct, for in reality the activity times are often not known in advance with certainty. In view of this fact, PERT employs a special formula for estimating activity times. We shall now present the details, and in so doing it will be seen that the PERT approach can also be used to calculate the probability that the project will be completed by any particular time.

ESTIMATING THE EXPECTED ACTIVITY TIME

The PERT system of estimating activity times requires someone who understands the activity in question well enough to produce three estimates of the activity time:

1. **Optimistic time** (denoted by *a*): the minimum time. Everything has to go perfectly to achieve this time.
2. **Most probable time** (denoted by *m*): the most likely time. The time required under normal circumstances.
3. **Pessimistic time** (denoted by *b*): the maximum time. One version of Murphy’s Law is that if something can go wrong, it will. The pessimistic time is the time required when Murphy’s Law is in effect.

FIGURE 5.14 Spreadsheet Solution for the Redefined Project

G7 = =MIN(F8,F9,F12)

	A	B	C	D	E	F	G	H	I
1	Activity	Description	Time	EST	EFT	LST	LFT	Slack	Critical?
2	A	Select site	3	0	3	5	8	5	No
3	B	Create plan	5	0	5	0	5	0	Yes
4	C	Personnel Reqmts	3	5	8	5	8	0	Yes
5	D	Design Facility	4	8	12	8	12	0	Yes
6	E	Construct	8	12	20	12	20	0	Yes
7	F	Select Personnel	2	8	10	11	13	3	No
8	G	Hire New	4	10	14	13	17	3	No
9	H	Move Records	2	10	12	18	20	8	No
10	I	Make Financial	5	5	10	15	20	10	No
11	J	Train	3	14	17	17	20	3	No
12	K	Secure Training	3	10	13	14	17	4	No
13									
14		Minimum Project Length			20				

Cell	Formula	Copy To
D4	=MAX(E3)	—
D5	=MAX(E2,E4)	—
D6	=MAX(E5)	—
D7	=MAX(E4)	—
D8	=MAX(E4)	—
D9	=MAX(E7)	—
D10	=MAX(E3)	—
D11	=MAX(E8,E12)	—
D12	=MAX(E7)	—
E2	=D2+C2	E3:E12
F2	=G2—C2	F3:F12
G2	=MIN(F5)	—
G3	=MIN(F4,F10)	—
G4	=MIN(F5,F7)	—
G5	=MIN(F6)	—
G6	=E14	—
G7	=MIN(F8,F9,F12)	—
G8	=MIN(F11)	—
G9	=E14	—
G10	=E14	—
G11	=E14	—
G12	=MIN(F11)	—
H2	=F2—D2	H3:H12
I2	=IF(H2=0,“Yes”,“No”)	I3:I12
E14	=MAX(E2:E12)	—

Consider, for example, activity E, construct the interior. Becky and the general con- tractor carefully examine each phase of the construction project and arrive at the following estimates:

$a = 4$

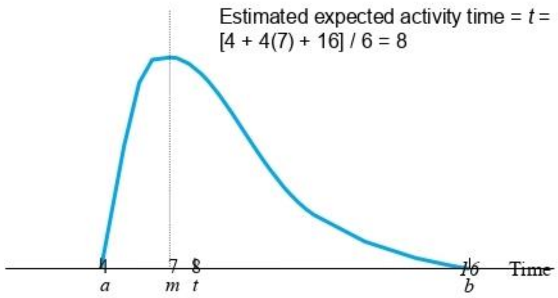
$m = 7$

$b = 16$

The relatively large value for b is caused by the possibility of a delay in the delivery of theair-conditioning unit for the computer. If this unit is delayed, the entire activity is delayed. Moreover, in this case, since E is on the critical path, a delay in this activity will delay over-all project completion.

In the original development of the PERT approach (during the late 1950s), the procedure for estimating the expected value of the activity times was motivated by the assump-

FIGURE 5.15 Unimodal Beta Distribution



tion that the activity time was a random variable with a particular probability distribution. This distribution (the **beta distribution**) has a minimum and maximum value, unlike the normal distribution, which has an infinite range of values. It also is capable of assuming a wide variety of shapes, again unlike the normal, which is always symmetrical about its most likely value. A typical beta distribution is shown in Figure 5.15. The expected value of a beta distribution is approximately (a + 4m + b)/6; thus the formula used to estimate the expected activity time is

$$\text{estimate of expected activity time} = \frac{a + 4m + b}{6}$$

Note that the estimate is a weighted average of the values of a, m, and b, where the weights
($^1\backslash 6$, $^4\backslash 6$, $^1\backslash 6$) sum to 1. This means that the estimate will always lie between a and b. Thus for activity E,

$$\text{Estimate of expected activity time } \frac{4+4(7)+16}{6} = 8$$

By working with the appropriate individuals in Global Oil, Becky used (5.1) to estimate each of the expected activity times that were presented in Table 5.2 and subsequently used in the critical path analysis.

Estimating the Standard Deviation of an Activity Time The standard devi- ation of an activity time is estimated by assuming that there are six standard deviations between the optimistic and pessimistic times:

$$\text{Estimate of the standard deviation of activity time} = \frac{b-a}{6}$$

Thus, for activity E,

$$\text{Estimate of standard deviation} = \frac{16-4}{6} = 2$$

Table 5.3 shows the three estimates (a, m, b), the expected activity times, the standard deviation of the activity times, and the *variance* of the activity times for the redefined activ-ity list. The variance is simply the square of the standard deviation. It is useful to record the variance of each activity since these values will be used in making statements about the probability of completing the overall project by a specific date.

In an application, it is of course possible to use any procedure that seems appropriate to estimate the expected value and standard deviation of the activity time. Indeed, in some circumstances data may be available and various statistical procedures can be used to estimate these parameters of the model.

Probability of Completing The Project On Time

The fact that activity times are random variables implies that the completion time for the project is also a random variable. That is, there is potential variability in the overall com

Table 5.3 Time Estimates

ACTIVITY	a	m	b	EXPECTEDVALUE $(a+4m+b)/6$	STD.DEV. $(b-a)/6$	VARIANCE $[(b-a)/6]^2$
A	1	3	5	3	$^{2}\backslash_{3}$	$^{4}\backslash_{9}$
B	3	4.5	9	5	1	1
C	2	3	4	3	$^{1}\backslash_{3}$	$^{1}\backslash_{9}$
D	2	4	6	4	$^{2}\backslash_{3}$	$^{4}\backslash_{9}$
E	4	7	16	8	2	4
F	1	1.5	5	2	$^{2}\backslash_{3}$	$^{4}\backslash_{9}$
G	2.5	3.5	7.5	4	$^{5}\backslash_{6}$	$^{25}\backslash_{36}$
H	1	2	3	2	$^{1}\backslash_{3}$	$^{1}\backslash_{9}$
I	4	5	6	5	$^{1}\backslash_{3}$	$^{1}\backslash_{9}$
J	1.5	3	4.5	3	$^{1}\backslash_{2}$	$^{1}\backslash_{4}$
K	1	3	5	3	$^{2}\backslash_{3}$	$^{4}\backslash_{9}$

pletion time. Even though the redefined project has an *expected* completion time of 20 weeks, there is no guarantee that it will actually be completed within 20 weeks. If *by chance* various activities take longer than their expected time, the project might not be completed within the desired 22-week schedule. In general, it would be useful to know the probability that the project will be completed within a specified time. In particular, Becky would like to know the probability that the move will be completed within 22 weeks.

The analysis proceeds as follows:

1. Let T equal the total time that will be taken by the activities on the critical path.
2. Find the probability that the value of T will turn out to be less than or equal to any specified value of interest. In particular, for Becky's project we would find Prob{T 22}. A good approximation for this probability is easily found if two assumptions hold.

a. *The activity times are independent randomvariables.* This is a valid assumption for most PERT networks and seems reasonable for Becky's problem. There is no rea- son to believe that the time to construct the interior should depend on the design time, and so on.

b. *The randomvariable* T *has an approximately normal distribution.* This assumption relies on the *central limit theorem,* which in broad terms states that the sum of independent random variables is approximately normally distributed.

Now recalling that our goal is to find Prob{*T* 22}, where *T* is the time along the crit- ical path, we will want to convert *T* to a standard normal random variable and use Table A.0 in Appendix A to find Prob{*T* 22}. The first step in this process is to find the standard deviation of *T*. To do this we need the variance of *T*. When the activity times are indepen-dent, we know that the variance of the total time along the critical path equals the sum of the variances of the activity times on the critical path. Thus, for Becky's problem

$$\text{var } T = \left(\begin{array}{c}\text{variance for}\\ \text{activity B}\end{array}\right) + \left(\begin{array}{c}\text{variance for}\\ \text{activity C}\end{array}\right) + \left(\begin{array}{c}\text{variance for}\\ \text{activity D}\end{array}\right) + \left(\begin{array}{c}\text{variance for}\\ \text{activity E}\end{array}\right)$$

Using the numerical values in Table 5.3 yields

$$\text{var } T = 1 + \frac{1}{9} + \frac{4}{9} + 4 = \frac{50}{9}$$

Finally,

$$\text{std. dev. } T = \text{C}(\text{var } T) = \sqrt{\frac{50}{9}} = 2.357$$

ow proceed to convert *T* to a standard normal random variable, *Z*, in the usual way

Z =. Recalling that 20 weeks is the mean (i.e., the expected completion time),

If we consult Table A.0 at the end of the text for the area under a normal curve from the left- hand tail to a point that is 0.8485 standard deviations above the mean, we find that the answer is about 0.80. Thus, there is about an 80% chance that the critical path will be completed in less than 22 weeks.

This analysis shows how to shed light on the second of the questions asked in the introduction. In particular, it shows how to find the probability that the *critical path* will be finished by *any* given time. It illustrates the importance of considering the variability in individual activity times when considering overall project completion times. The analysis for Becky's problem indicates that, using expected time as our "real-world forecast," the expected project duration will be 20 weeks and, if so, it will be completed 2 weeks ahead of the desired date. The analysis of uncertainty above sheds additional light on this estimate. It shows a significant probability (i.e., 0.2 = 1 – 0.8) that *the critical path* will not be com- pleted by the desired completion date. The implication is that there is *at least* a probability of

0.2 that the overall project may not be completed by the desired date. The modifier "at least" has been employed because of the following complicating factor: Because of ran- domness, some other path, estimated as being noncritical, may in reality take longer to complete than the purported critical path.

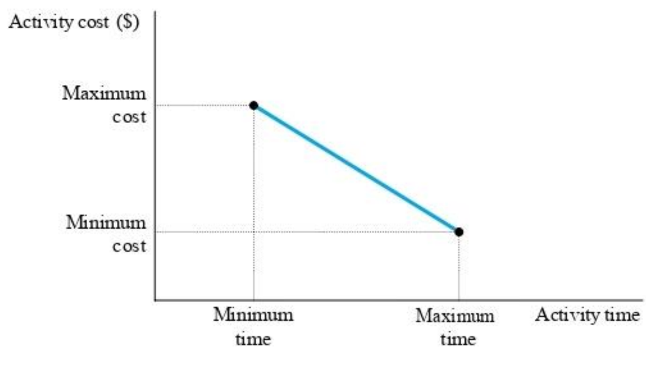
As an example of how this uncertainty can work in the business/educational world, San Diego State University and Georgia Tech contracted with some construction firms to build parking towers. The construction firms gave them two bids: one if PERT charts were used and a lower bid if PERT charts were *not* used. In the latter bids, the firms would not promise when the structures would be done so that if workers were needed on another pro- ject (which did have deadlines), they could be taken off the universities' projects for several days or weeks and used elsewhere. In exchange for this uncertainty, the educational institu- tions got cheaper construction rates for helping the contractors with their personnel balancing.

5.5 CPM AND TIME-COST TRADE-OFFS – CRASHING THE PROJECT

As we have just seen, PERT provides a useful approach to the analysis of scheduling prob- lems in the face of *uncertainty about activity times*. Such uncertainty will often occur in new or unique projects where there is little previous time and cost experience to draw upon. In other types of projects there may be considerable historical data with which one may make good estimates of time and resource requirements. In such cases it may be of interest to deal more explicitly with costs in the sense of analyzing possibilities to shift resources in order to reduce completion time. The concept that there is a trade-off between the time that it takes to complete an activity and the cost of the resources devoted to that activity is the basis of a model that was originally part of the CPM method.

The model assumes that cost is a linear function of time. Consider, for example, Figure 5.19. This figure illustrates that management has the opportunity to aim at an activity.

FIGURE 5.19 Time-Cost Trade-off Function



time anywhere between a minimum value and a maximum value. The choice of an activity time implies an activity cost as specified by the diagram.

Given the availability of such a time-cost trade-off function for each activity in the project, management has the opportunity to select each activity time (within limits) and incur the associated cost. Clearly, the choice of individual activity times affects the project completion time. The question becomes: "What activity times should be selected to yield the desired project completion time at minimum cost?" The CPM approach to answering this question will be presented in the context of the creation of a financial analysis package by the Operations Analysis Group at Global.

A FINANCIAL ANALYSIS PROJECT FOR RETAIL MARKETING

In addition to the move to Des Moines, Becky is responsible for a new financial analysis package that will be used in the retail marketing section of Global. The program is used in evaluating potential outlets (gas stations) in terms of location and other characteristics. The systems design is complete. The computer programming must still be done, and the package must be introduced to the retail marketing section.

Figure 5.20 shows the activity list and network diagram for this project. The time shown is termed the **normal time**. This corresponds to the maximum time shown in Figure 5.19. Recall that we are here assuming that activity times can be estimated with good accuracy, and hence "normal time" is a known quantity. From Figure 5.20 it is clearthat the longest path through the network is DAP-WAP-INT, and hence this is the critical path. The earliest completion time for the project is 194 hours.

Required Activity Data The CPM system is based on four pieces of input data for eachactivity :

1. **Normal time**: the maximum time for the activity.
2. **Normal cost**: the cost required to achieve the normal time.
3. **Crash time**: the minimum time for the activity.
4. **Crash cost**: the cost required to achieve the crash time.

FIGURE 5.20 Activity List and Network Diagram for the Financial Analysis Project

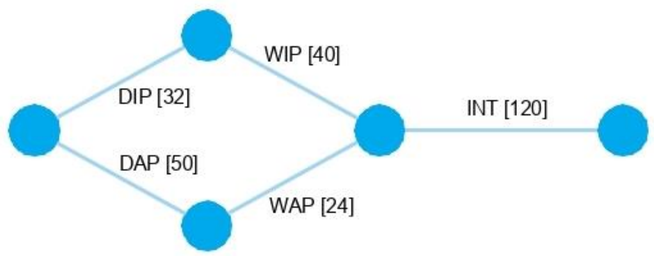


Table 5.4 Time-Cost Data for the Financial Analysis Project

ACTIVITY	(1) NORMAL TIME	(2) NORMAL COST ($)	(3) CRASH TIME	(4) CRASH COST ($)	(5) MAXIMUM CRASH HOURS	(6) COST PER CRASH HOUR ($)
DIP	32	640	20	800	12	13.33
WIP	40	480	30	720	10	24.00
DAP	50	1000	30	1200	20	10.00
WAP	24	288	15	360	9	8.00
INT	120	4800	70	5600	50	16.00
TOTAL		$7208				

These data for the financial analysis project are presented in the first four columns of Table 5.4. The fifth column shows the maximum crash hours, defined by

Max crash hours = normal time – crash time

Figure 5.21 shows how these data are used to create the time-cost trade-off function for activity DIP, design the information processor

Note that, according to Table 5.4, using all normal times leads to a total project cost of $7,208. Also note that the last column in Table 5.4 shows how much it costs per hour (as computed in Figure 5.21) to reduce each activity time to less than its normal time. In CPM jargon, the process of reducing an activity time is called **crashing.** For example, man- agement could choose to have DIP completed in 31 hours, rather than the normal 32 hours, for a marginal cost of $13.33. The normal time of 32 hours costs $640, and a time of31 hours would therefore cost 640 + 13.33 = $653.33.

CRASHING THE PROJECT

We have noted that, using only the normal time for each activity, the earliest completion time for this project is 194 hours (along the critical path DAP-WAP-INT). Management is now in a position to determine the minimum-cost method of reducing this time to speci- fied levels. To reduce the project time to 193, Becky would crash an activity on the critical path by 1 hour. Since it costs less per hour to crash WAP than either of the other two activ- ities on the critical path ($8 < $10 and $8 < $16), Becky would first crash WAP by 1 hour. This decision yields a project time of 193 hours, a critical path of DAP-WAP-INT, and a total project cost of $7,216 (= $7,208 + $8). If Becky wants to achieve a time of 192 hours, exactly the same analysis would apply, and she would crash WAP by another hour and incur a marginal cost of $8.

If Becky has crashed WAP by 2 hours to achieve a project time of 192 hours and still wants to crash the project by another hour (to achieve 191), the analysis becomes more

FIGURE 5.21 Time-Cost Trade-off Function for DIP

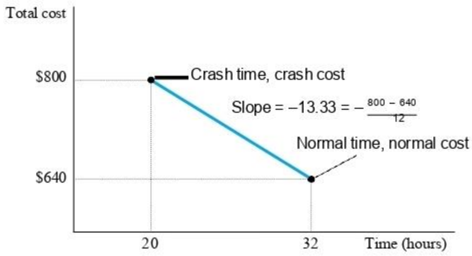
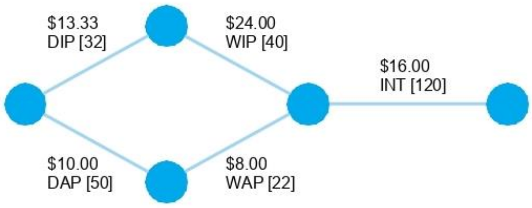


FIGURE 5.2 Marginal Costs of Crashing the Financial Analysis Projet



complicated. Figure 5.22 shows the situation. The dollar figure in the diagram is the marginal cost of crashing. Note that there are now two critical paths, DIP-WIP-INT and DAP- WAP-INT, and that both require 192 hours. Crashing one of the four activities (DIP, WIP, DAP, or WAP) by 1 hour would bring one path down to 191 hours, but would still leave the project time at 192, since there would still be a critical path of 192 hours. A time of 191 could be obtained only by crashing activities on both paths. If Becky crashed DIP and WAP by 1 hour each it would reduce both paths to 191 hours, and it would cost her $13.33 + $8.00 = $21.33. Alternatively, INT could be crashed by 1 hour for a cost of $16.00. Can you see that there are other alternatives to consider?

Although it is possible to do this sort of marginal cost analysis in any CPM network, it is clear that it would be difficult and tedious to carry it out in a complicated network. This consideration leads us to an LP formulation of the problem.

SUMMARY

This chapter dealt with the role of PERT and CPM in project management. The fundamen- tal concept is to represent a project as a network. Section 5.2 showed how to use an activ- ity list to construct a network diagram for a project, where the activity list identifies each activity in the project and its immediate predecessors. Section 5.3 showed how the net- work diagram and the expected activity times are used to determine the critical path, which is a longest path through the network. In the process, the terms *earliest start time*, *earliest finish time*, *latest start time*, *latest finish time*, and *slack* were defined.

Section 5.4 introduced the notion of variability in activity times. It dealt with two main topics: the PERT system of estimating times and the probability that all the activities on the critical path will be completed by a specified date. The PERT system of estimating time is based on the assumption that activity time has a beta distribution. It uses an opti- mistic, a most probable, and a pessimistic time estimate to derive the expected activity time and the standard deviation of the activitytime.

Management would like to know the probability that the project under consideration will be completed by a specific date. If one assumes that activity times are independent and that the sum of the activity times on the critical path has a normal distribution, it is a straightforward exercisetocalculate theprobability that thecritical pathwillbecompleted by a specified date. This is not the probability that the project will ultimately be completed by the specified date, for the effect of randomness could turn a supposedly noncritical path into a critical one. However, this does give an upper estimate for the probability that the overall project will be completed by a specific date.

Key Terms

PERT. An acronym for Program Evaluation Review Technique, a method for scheduling and controlling projects.

CPM. An acronym for Critical Path Method, a method for scheduling and controlling projects.

Activity List. A list of jobs in a project with their immediate predecessors, expected times, and resources required.

Immediate Predecessors. Those activi- ties that must be completed immedi- ately prior to the start of the activity in question.

Network Diagram. Graphical method of representing a project with nodes and arcs.

Branch. A line in a PERT network indi- cating an activity (in AOA) or prece- dence (in AON). Also called an *arc*.

Node. A circle in a PERT network indi- cating the completion of certain activi- ties and the initiation of others (in AOA) or the activity itself (in AON).

Event. The completion of all activities leading into a node in a PERT network using AOA.

Activity. A job that must be completed as part of a project.

Dummy Activity. An imaginary activity that requires no time and is used to maintain the appropriate precedence relationships in a PERT network dia- gram using AOA

Path. A sequence of activities leading from the starting node to the comple- tion node of a network.

Critical Path. A sequence of activities that determines the longest path through the network that yields the minimum time in which an entire pro- ject can be completed.

Critical Activities. The activities on the critical path.

Earliest Start Time. In a PERT network, the earliest moment at which an activ- ity can start.

Earliest Finish Time. In a PERT net- work, the earliest moment at which an activity can be completed.

Forward Pass. The process of moving along a network from beginning to end, computing the earliest start time and earliest finish time for each activ- ity.

Backward Pass. The process of moving backward along a network from end to beginning, computing the latest finish time and then the latest start time for each activity.

Latest Start Time. In a PERT network, the latest moment at which an activity can start without delaying completion of the overall project.

Latest Finish Time. The latest time at which an activity can be completed without delaying the completion of the overall project.

Slack. The time that an activity can be delayed beyond its earliest start time without delaying the completion of the overall project.

Optimistic Time. The time required to complete an activity if everything goes perfectly.

Most Probable Time. The time required to complete an activity under normal circumstances.

Pessimistic Time. The time required to complete an activity under the most unfavorable conditions.

Beta Distribution. A probability distri- bution used to model the activity times in PERT.

Normal Time. In CPM, the maximum time for completion of an activity, cor-responding to minimal resource usage.

Normal Cost. The cost required to achieve the normal time.

Crash Time. In CPM, the minimum possible time for completion of an activity, corresponding to maximal resource concentration.

Crash Cost. The cost required to achieve the crash time.

Crashing. A term in the CPM method describing the process of reducing the time required to complete an activity.

PERT/Cost. A system for determining the feasible patterns of cash flow dur-ing a project

❖ **Check Your Progress**

- **State wheatear the Statement are True or False**

1. In a PERT network diagram using AOA, each activity is represented by a circle called a node.
2. The term *event* is used to refer to nodes in a PERT network using AOA.
3. A dummy activity is required in a correct network representation of the following activitylist
4. The earliest finish time for an activity depends on the earliest finish time for the project.
5. The latest finish time for an activity depends on the earliest finish time for the project.
6. All activities on the critical path have their latest finish time equal to their earliest start time.
7. A strategic analysis of a PERT network concen- trates on the allocation of resources to reduce the time on the critical path.

8. The probability of completing the project by time *T* is equal to the probability of completing the critical path by time *T*.
9. The standard deviation of an activity time is esti- mated as (*b* – *a*)/6, where *b* is the pessimistic and *a* is the optimistic time.
10. The CPM approach to time-cost trade-offs assumes that cost is a linear function of time.
11. The LP formulation of the network-crashing problem minimizes the total cost of crashing subject to an upper bound on project duration.
12. In the PERT/Cost model the earliest starting time total cost schedule always is less than or equal to the latest starting time total cost schedule.
13. Time variabilities leading to a longer-than- expected total time for the critical path will always extend the project completion date.
14. If a noncritical activity is delayed more than its slack time, all other factors remaining unchanged, then the project completion date will be extended.
15. Gantt charts provide useful immediate predecessor information.

- **Multiple Choice**

1. All paths through the network, the critical path

a. Has the maximum expected time.
b. Has the minimum expected time.
c. Has the maximum actual time
d. Has the minimum actual time

2. The earliest start time (ES) for an activity leaving node C (in the AOA approach)

a. Is the Max of the earliest finish times for all activities entering node C
b. Equals the earliest finish times for the same activity minus its expected activity time
c. Depends on all paths leading from the start through node C
d. All of the above

3. The latest finish time (LF) for an activity entering node H (in the AOA approach)

a. Equals the Max of the latest start times for all activities leaving node H
b. Depends on the latest finish time for the project
c. Equals the latest start time minus the activity time for the same activity
d. None of the above

4. The slack for activity G

a. Equals LF for G – LS for G
b. Equals EF for G – ES for G
c. Equals LS for G – ES for G
d. None of the above

5. Estimating expected activity times in a PERT network

a. Makes use of three estimates
b. Puts the greatest weight on the most likely time estimate
c. Is motivated by the beta distribution
d. All of the above

6. The calculation of the probability that the critical path will be completed by time *T*

a. Assumes that activity times are statistically independent
b. Assumes that total time of the critical path has approximately a beta distribution
c. Requires knowledge of the standard deviation for all activities in the network
d. All of the above

6. In the CPM time-cost trade-off function

a. The cost at normal time is 0
b. Within the range of feasible times, the activity cost increases linearly as time increases
c. Cost decreases linearly as time increases
d. None of the above

7. The marginal cost of crashing a network could change when

a. The activity being crashed reaches its crash time
b. The activity being crashed reaches a point where another path is also critical
c. Both a and b
d. None of the above

8. Fundamental ideas in the LP network crashing models are

a. Activity time equals normal time + crash time
b. Earliest start time for an activity leaving a node equals the Max of the earliest finish times for activities leaving that node
c. Earliest finish time equals latest finish time minus activity time
d. None of the above

9. The PERT/Cost model assumes that

a. Each activity achieves its optimistic time
b. The costs are uniformly distributed over the life of the activity
c. Activity times are statistically independent
d. None of the above

MBA

SEMESTER-2

PRODUCTION OPERATION

BLOCK: 2

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UNIT : 6 INVENTORY MANAGEMENT

6.1 OBJECTIVES

After completing this unit, you will be able to learn about:

- Define MRP.
- Identify the functions of MRP.
- Understand the meaning of JIT. Describe its Uses.
- Define Supply chain Management.
- Functions of Supply chain Management
- Aggregate product Planning

6.2 INTRODUCTION

Inventory management is a very important function that determines the health of the supply chain as well as the impacts of the financial health of the balance sheet. Every organization constantly strives to maintain optimum inventory to be able to meet its requirements and avoid over under inventoryory that can impact the financial figures.

Inventory is always dynamic. Inventory management requires constant and careful evaluation of external and internal factors and control through planning and review. Most of the organizations have a separate department or job function called inventory planners who continuously monitor, control and review inventory and interface with production, procurement and finance departments.

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6.3 DEFINING INVENTORY

Inventory is an idle stock of physical goods that contain an economic value, and are held in various forms by an organization in its custody awaiting packing, processing, transformation, use or sale in a future point of time.

Any organization which is into production, trading, sale and service of a product will necessarily hold stock of various physical resources to aid in future consumption and sale. While inventory is a necessary evil of any such business, it may be noted that organizations hold inventories for various reasons, which include speculative purposes, functional purposes, physical necessities etc.

The term inventory has been defined by several authors. The popular among them are:-"the term inventory includes materials-raw, in process, finished packaging, spares and others stocked in order to meet an unexpected demand or distribution in the future."

– ***B.D. Khare, Inventory Control, NPC, p.1.***

From the above definition, the following points stand out with reference to inventory:

- All organizations engaged in the production or sale of products hold inventory in one form oranother.

- Inventory can be in a complete state or incomplete state.
- Inventory is held to facilitate future consumption, sale or further processing/value addition.
- All inventoried resources have economic value and can be considered assets of the organization.

6.4 DIFFERENT TYPES OF INVENTORY

Inventory of materials occurs at various stages and departments of an organization. A manufacturing organization holds the inventory of raw materials and consumables required for production. It also holds an inventory of semi-finished goods at various stages in the plant with various departments. Finished goods inventory is held at the plant, FG Stores, distribution centers etc. Further, both raw materials and finished goods those that are in transit at various locations also form a part of the inventory depending upon who owns the inventory at the particular juncture. Finished goods inventory is held by the organization at various stocking points or with dealers and stockiest until it reaches the market and end customers.

Besides Raw materials and finished goods, organizations also hold inventories of spare parts to service the products. Defective products, defective parts and scrap also form a part of the inventory as long as these items are inventoried in the books of company and have economic value.

Types of Inventory by Function

INPUT	PROCESS	OUTPUT
Raw Materials	Work In Process	Finished Goods
Consumables required for processing. Eg : Fuel, Stationary, Bolts & Nuts etc. required in manufacturing	Semi Finished Production in various stages, lying with various departments like Production, WIP Stores, QC, Final Assembly, Paint Shop, Packing, Outbound Store etc.	Finished Goods at Distribution Centers throughout Supply Chain
Maintenance Items/Consumables	Production Waste and Scrap	Finished Goods in transit
Packing Materials	Rejections and Defectives	Finished Goods with Stockiest and Dealers
Local purchased Items required for production		Spare Parts Stocks & Bought Out items
		Defectives, Rejects and Sales Returns
		Repaired Stock and Parts
		Sales Promotion & Sample Stocks

6.5 NEED FOR INVENTORY MANAGEMENT

Packing Materials	Rejections and Defectives	Finished Goods with Stockiest and Dealers
Local purchased Items required for production		Spare Parts Stocks & Bought Out items
		Defectives, Rejects and Sales Returns
		Repaired Stock and Parts
		Sales Promotion & Sample Stocks

Most of the organizations have raw material inventory warehouses attached to the production facilities where raw materials, consumables and packing materials are stored and issue for production on JIT basis. The reasons for holding inventories can vary from case-to-case basis.

1. ***Meet variation in Production Demand:*** Production plan changes in response to the sales, estimates, orders and stocking patterns. Accordingly, the demand for raw material supply for production varies with the product plan in terms of specific SKU as well as batch quantities.

   Holding inventories at a nearby warehouse helps issue the required quantity and item to production just in time.

2. ***Cater to Cyclical and Seasonal Demand:*** Market demand and supplies are seasonal depending upon various factors like seasons; festivals etc. and past sales data help companies to anticipate a huge surge of demand in the market well in advance. Accordingly, they stock up raw materials and hold inventories to be able to increase production and rush supplies to the market to meet the increased demand.

3. ***Economies of Scale in Procurement:*** Buying raw materials in the larger lot and holding inventory is found to be cheaper for the company than buying frequent small lots. In such cases one buys in bulk and holds inventories at the plant warehouse.

4. ***Take advantage of Price Increase and Quantity Discounts:*** If there is a price increase expected few months down the line due to changes in demand and supply in the national or international market, impact of taxes and budgets etc., the company's tend to buy raw materials in advance and hold stocks as a hedge against increased costs.

   Companies resort to buying in bulk and holding raw material inventories to take advantage of the quantity discounts offered by the supplier. In such cases the savings on account of the discount enjoyed would be substantially higher that of inventory carrying cost.

5. ***Reduce Transit Cost and Transit Times:*** In case of raw materials being imported from a foreign country or from a faraway vendor within the country, one can save a lot in terms of transportation costs by buying in bulk and transporting as a container load or a full truckload. Part shipments can be costlier.

   In terms of transit time too, transit time for a full container shipment or a full truckload is direct and faster, unlike part shipment load where the freight forwarder waits for other loads to fill the container which can take several weeks.

   There could be a lot of factors resulting in shipping delays and transportation too, which can hamper the supply chain forcing companies to hold safe stock of raw material inventories.

6. *Long Lead and High demand items need to be held in Inventory:* Often raw material supplies from vendors have long lead running into several months. Coupled with this if the particular item is in high demand and short supply one can expect disruption of supplies. In such cases, it is safer to hold inventories and has control.

6.6 FINISHED GOODS INVENTORY

Production Strategy necessitates Inventory holding: The blueprint of the entire Production strategy is dependent upon the marketing strategy. Accordingly, organizations produce based on marketing orders. The production is planned based on Build to stock or Build Order strategies.

While the Build to Order strategy is manufactured against specific orders and does not warrant the holding of stocks other than in transit stocking, Build to Stock production gets inventoried at various central and forward locations to be able to cater to the market demands.

1. ***Market penetration:*** Marketing departments of companies frequently run branding and sales promotion campaigns to increase brand awareness and demand generation. An aggressive market penetration strategy depends upon the ready availability of inventory of all products at the nearest warehousing location so that products can be made available at short notice - in terms of the number of hours lead time, at all sales locations throughout the state and city. Any non-availability of stock at the sale point-of-sale counter will lead to a dip in market demand and sales. Hence holding inventories becomes a necessity.
2. ***Market Size, location and supply design:*** Supply chain design takes into account the location of the market, market size, demand pattern and the transit lead time required to reach stocks to the market and determine optimum inventory holding locations and network to be able to hold inventories at national, regional and local levels and

achieve two major objectives. The first objective would be to ensure correct product stock is available to service the market. Secondly, stocks are held in places where it is required and avoid unwanted stock build-up.

3. ***Transportation and Physical Barriers:*** Market location and the physical terrain of the market coupled with the local trucking and transportation network often demand inventory holding at nearest locations. Hilly regions for example may require longer lead time to service. All kinds of vehicles may not be available, and one may have to hire dedicated containerized vehicles of huge capacities. In such cases they will have to have an inventory holding plan for such markets.

   Far away market locations mean longer lead times and transportation delays. Inventory holding policy will consider these factors to work out the plan.

4. ***Local tax and other Govt. Rules:*** In many countries where GST is not implemented, regional state tax rules apply and vary from state to state. Accordingly, while one state may offer a tax rebate for a particular set of product category, another state may charge higher local taxes and lower interstate taxes. In such cases the demand for product from the neighboring state may increase than from the local state. Accordingly, inventory holding would have to be planned to cater to the market fluctuation.

   While in case of exports from the country of origin into another market situated in another country, one needs to take into account the rules regarding import and customs duties to decide optimum inventories to be held en route or at destination.

5. ***Production lead times:*** FG inventory holding becomes necessary in cases where the lead- time for production is long. Sudden market demand or opportunities in such cases require FG inventories to be built up and supplies to be affected.

6. ***Speculative gain:*** Companies always keep a watch on the economy, annual state budget, financial environment and international environment and can foresee and estimate situations, which can have an impact on their business and sales.

   In cases where they are able to estimate an increase in industry prices, taxes or other levies which will result in an overall price increase, they tend to buy and hold huge stocks of raw materials at current prices. They also hold up finished stock in warehouses in anticipation of a impending sale price increase. All such moves cause companies to hold inventories at various stages.

7. ***Avoid Certain Costs:*** Finally, organizations hold FG inventories to satisfy customer demand, to reduce sales management and ordering costs, stock out costs and reduce transportation costs and lead times.

Markets and Supply Chain Design: **Organizations carry out detailed analysis of the markets both at national as well as international / global levels and work out the Supply Chain strategy with the help of SCM strategists as to the ideal location for setting up production facilities, the network of and number of warehouses required to reach products to the markets within and outside the country as well as the mode of transportation, inventory holding plan, transit times and order management lead times etc., keeping in mind the most important parameter being, to achieve Customer Satisfaction and Demand Fulfillment.**

6.7 INDEPENDENT AND DEPENDENT DEMAND INVENTORIES

Inventory Management deals essentially with balancing the inventory levels. Inventory is categorized into two types based on the demand pattern, which creates the need for inventory. The two types of demand are Independent Demand and Dependent Demand for inventories.

Independent Demand

An inventory of an item is said to be falling into the category of independent demand when the demand for such an item is not dependent upon the demand for another item.

Finished goods Items, which are ordered by External Customers or manufactured for stock and sale, are called independent demand items.

Independent demands for inventories are based on confirmed Customer orders, forecasts, estimates and past historical data.

Dependent Demand

If the demand for inventory of an item is dependent upon another item, such demands are categorized as dependent demand.

Raw materials and component inventories are dependent upon the demand for Finished Goods and hence can be called as Dependent demand inventories.

Take the example of a Car. The car as finished goods are an held produced and held in inventory as independent demand item, while the raw materials and components used in the manufacture of the Finished Goods - Car derives its demand from the demand for the Car and hence is characterizedas dependent demand inventory.

This differentiation is necessary because the inventory management systems and process are different for both categories.

While Finished Goods inventories which is characterized by independent demand, are managed with sales order process and supply chain management processes and are based on sales forecasts, the dependent demand for raw materials and components to manufacture the finished goods is managed through MRP -Material Resources Planning or ERP – Enterprise Resource Planning using models such as Just In Time, Kanban and other concepts. MRP as well as ERP planning depends upon the sales forecast released for finished goods as the starting point for further action.

Managing Raw Material Inventories is far more complicated than managing Finished Goods Inventory. This involves analyzing and co-coordinating delivery capacity, lead times and delivery schedules of all raw material suppliers, coupled with the logistical processes and transit timelines involved in transportation and warehousing of raw materials before they are ready to be supplied to the production shop floor. Raw material management also involves periodic review of the inventory holding, inventory counting and audits, followed by detailed analysis of the reports leading to financial and management decisions.

6.8 INVENTORY COSTS

Inventory costs are basically categorized into three headings:

1. Ordering Cost
2. Carrying Cost
3. Shortage or stock out Cost & Cost of Replenishment

a. Cost of Loss, pilferage, shrinkage and obsolescence etc.

b. Cost of Logistics

c. Sales Discounts, Volume discounts and other related costs

1. *Ordering Cost:* Cost of procurement and inbound logistics costs form a part of Ordering Cost. Ordering Cost is dependent and varies based on two factors - The cost of ordering excess and the Cost of ordering too less.

Both these factors move in opposite directions to each other. Ordering excess quantity will result in the carrying cost of inventory. Whereas ordering less will result in an increase of replenishment cost and ordering costs.

These two above costs together are called Total Stocking Costs. If you plot the order quantity vs the TSC, you will see the graph declining gradually until a certain point after which with every increase in quantity the TSC will proportionately show an increase.

This functional analysis and cost implications form the basis of determining the Inventory Procurement decision by answering the two basic fundamental questions - How Much to Order and When to Order.

How much to order is determined by arriving at the Economic Order Quantity or EOQ.

2. Carrying Cost: Inventory storage and maintenance involves various types of costs namely:

d. Inventory Storage Cost

e. Cost of Capital

Inventory carrying involves Inventory storage and management either using in-house facilities or external warehouses owned and managed by third-party vendors. In both cases, inventory management and process involve extensive use of Building, Material Handling equipment, IT Software applications and Hardware equipment coupled managed by Operations and Management Staff resources.

a. *Inventory Storage Cost:* Inventory storage costs typically include the Cost of Building Rental and facility maintenance and related costs. Cost of Material Handling Equipment, IT Hardware and applications, including the cost of purchase, depreciation or rental or lease as the case may be. Further costs include operational costs, consumables, communication costs and utilities, besides the cost of human resources employed in operations as well as management.

b. *Cost of Capital:* Includes the costs of investments, interest on working capital, taxes on inventory paid, insurance costs and other costs associated with legal liabilities.

The inventory storage costs as well as the cost of capital is dependent upon and varies with the decision of the management to manage inventory in the house or through outsourced vendors and third-party service providers.

In current times, the trend is increasingly in favour of outsourcing inventory management to third-party service providers. For one thing, organizations find that managing inventory operations requires certain core competencies, which may not be in line with their business competencies. They would rather outsource to a supplier who has the required competency than build them in-house.

Secondly, in the case of large-scale warehouse operations, the scale of investments may be too huge in terms of the cost of building and material handling equipment etc. Besides, the project may span over a longer period of several years, thus blocking the capital of the company, which can be utilized in more important areas such as R & D, Expansion etc. than by staying invested in the project.

6.9 INVENTORY CLASSIFICATION-ABC CLASIFICATION, ADVANTAGES AND DISADVANTAGES

Depending upon the nature of the business, the inventory holding patterns may vary. While in some cases the inventory may be very high in value, in some other cases inventory may be very high in volume and number of SKU. Inventory may be help physically at the manufacturing locations or in a third-party warehouse location.

Inventory Controllers are engaged in managing Inventory. Inventory management involves several critical areas. The primary focus of inventory controllers is to maintain optimum inventory levels and determine order/replenishment schedules and quantities. They try to balance inventory all the time and maintain optimum levels to avoid excess inventory or lower inventory, which can cause damage to the business.

- **ABC Classification**

Inventory in any organization can run in thousands of part numbers or classifications and millions of part numbers in quantity. Therefore, inventory is required to be classified with some logic to be able to manage the same.

In most of the organizations, inventory is categorized according to ABC Classification Method, which is based on the parent principle. Here the inventory is classified based on the value of the units. The principle applied here is based on 80/20 principles. Accordingly, the classification can be as under:

- A Category Items Comprise 20% of SKU & Contribute to 80% of $spend.
- B Category Items Comprise 30% of SKU & Contribute to 15% of $spend.
- C Category Items Comprise 50% of SKU & Contribute to 5% of $ spend.

The above is only an illustration and the actual numbers as well as percentages can vary.

Example: Table of Inventory Listing by Dollar Usage Percentage.

Item	Annual Usage in No. Units	Unit Cost-$	Usage in Dollars	Percentage of Total DollarUsage
1	5,000	1.50	7,500	2.9%
2	1,500	8.00	12,000	4.7%
3	10,000	10.50	105,000	41.2%
4	6,000	2.00	12,000	4.7%
5	7,500	0.50	3,750	1.5%
6	6,000	13.60	81,000	32.0%
7	5,000	0.75	3,750	1.5%
8	4,500	1.25	5,625	2.2%
9	7,000	2.50	17,500	6.9%
10	3,000	2.00	6,000	2.4%
Total			**$254,725**	**100.0%**

Advantages of ABC Classification

This kind of categorization of inventory helps one manage the entire volume and assign relative priority to the right category. For Example A Class items are the high value items.

Hence one is able to monitor the inventory of this category closely to ensure the inventory level is maintained at optimum levels for any excess inventory can have a huge adverse impact in terms of overall value.

- ***A Category Items:*** Helps one identify these stocks as high-value items and ensure tight control in terms of process control, physical security as well as audit frequency.
  It helps the managers and inventory planners to maintain accurate records and draw management's attention to the issue on hand to facilitate instant decision-making.
- ***B Category Items:*** These can be given second priority with lesser frequency of review and less tightly controlled with adequate documentation, and audit controls in place.
- ***C Category Items:*** Can be managed with basic and simple records. Inventory quantities can be larger with very few periodic reviews.
  Example: Take the case of a Computer Manufacturing Plant; the various items of inventory can be broadly classified as under:

SKU Description	Classification of Inventory	Remarks
Processor Chips	A Class	Kept under High-Value Storage/Asset Tracking / Access Control required
Memory Chips	A Class	Kept under High-Value Storage/Asset Tracking / Access Control required
Hard Disk / Storage Media	A Class	Kept under High-Value Storage/Asset Tracking / Access Control required
Software License	A Class	Kept under High-Value Storage/Asset Tracking / Access Control required
Disk Drives	A Class	Normal Storage / Access Control Required
Cabinet / Case	B Class	Normal Procedures
Battery Pack	B Class	Normal Procedures
Monitor	A Class	Normal Storage / Access Control Required
Keyboard	B Class	Normal Procedures
Training Manuals	C Class	Minimal Procedures
Mouse	B Class	Normal Procedures
Stickers	C Class	Minimal Procedures
Screws & Nuts	C Class	Minimal Procedures
Power Cord	C Class	Minimal Procedures
Starter Assembly Pack-Instructions	C Class	Minimal Procedures

❖ **Disadvantages**

- Inventory Classification does not reflect the frequency of movement of SKU and hence can mislead controllers.

B & C Categories can often get neglected and pile in huge stocks or susceptible to loss, pilferage, slackness in record control etc.

6.10 FACTORS AFFECTING INVENTORY OPERATIONS

Inventory management entails the study of data on the movement of inventory, its demand pattern, supply cycles, sales cycles etc. Active management calls for continuous analysis and management of inventory items to target lean m inventory Management.

The inventory Management function is carried out by the inventory planners in the company in close coordination with procurement, supply chain logistics and finance, besides marketing departments. The efficiencies of inventory management are largely dependent upon the skills and knowledge of the inventory planners, the focus and involvement of management and the management policies coupled with the inventory management system.

However, inventory operations management is not under the control of the inventory management team but rests with the third-party service providers. In this section of the article, we aim to uncover a few of the critical areas and action points on the part of operations that can impact the inventory of the company.

1. ***Unskilled Labour and Staff:*** Inventory operations management is a process-oriented operation. Every task and action required to be carried out by the operatives will impact the inventory as well as the delivery lead times and other parameters. Therefore, knowledge of what one is required to do and the effect of the action should be known to the operatives who are on the shop floor. For Example: If an operative is given a put away task, he should know how and where he should put away the pallet, how to scan the pallet ID and confirm it back to the system. Besides he should also know the impact of not completing any of these actions or doing something wrong. The impact his action will have on the system as well as the physical inventory should be clear to the operative.

   Secondly, different inventory items would have to be handled differently. Operatives who are carrying out the task should know why and what is required to be done. They should also know the consequences of not following the process. A pallet might have to be scanned for the pallet id and put away on a floor location, while a carton might have to be opened and scanned for individual boxes inside and put away into a bin. The operatives should be trained on the entire process and understand why and what he is doing.

   The WMS systems are quite operational and task intensive. Where the warehouses are being managed on RF-based systems, the operatives should be able to manage the RF readers and understand how to access and complete transactions through the RF Guns.

   Often it is noticed that when the warehouse operations are being managed by a third-party service provider and the principal customer is not present at the location, the quality of staff and operatives is compromised, and people are not given adequate training before being allocated their responsibility. Such situations can lead to inventory discrepancies.

2. ***In adequate SOP, Training and emphasis on processes compliance:*** When an inventory management project kicks off at a third-party warehouse location, both the principal customer as well as the third-party service provider work on the project and setup basic processes, document them in Standard Operating Procedures and conduct training as a part of the project management methodology.

   However, over a period of time, the nature of business requirements changes, resulting in change in the operating processes. These do not get documented in terms of amendments and the SOPs become outdated. Thereafter one finds that the newcomers who are introduced on the shop floor are required to learn the processes by working along with others whereas no training or SOP document is provided to him for reference. With the result they often have half-baked knowledge of the processes and carry-on tasks not knowing why they are doing and what they are required to do.

   This situation is very dangerous for the health of the inventory, and it shows slackness in the attitude of the third-party service provider. Continuation of such a situation will lead to bad housekeeping, inventory mismatches, and discrepancies and also affect the service delivery. If left unchecked can lead to theft, pilferage and misuse of inventory.

   In any third party owned inventory operations warehouse, the principal client should ensure that periodic review and training is conducted for all staff. Inventory operations should be periodically reviewed, and inventory counts and audits carried out regularly.

6.11 INVENTORY TURNOVER AS INDICATOR OF HEALTH INVENTORY AND BUSINESS

Inventory management, as well as Supply chain operations, are often overlapping and hold the key to the success of sales operatthe ions. In all of businesses be in the automobile, manufacturing, pharma or retail industry, the status of inventory reflects the health of the business.

Inventory operations have two key elements namely Inventory System and Physical operations. Today inventory systems have replaced the bookkeeping and financial accounting that was being practised earlier. Current inventory systems not only do the bookkeeping but are linked to upstream as well as downstream activities including procurement, sales processing, and financial accounting.

In terms of measuring a sales performance in relation to Inventory, we often use the term Inventory Turnover. Inventory turnover simply refers to the number of times the inventory is sold or used in a period of one year. Inventory turnover is also termed as stock turn or stock turnover. Inventory Turnover is calculated by taking the Total Cost of Goods Sold, divided by the Average Inventory. Adding together opening inventory and closing inventory and dividing the figure by 2 which in turn gives Average Inventory.

Inventory turnover as a measure of the health of sales and business is used extensively in Retail, textile as well as FMCG segments. A higher inventory turnover does indicate a healthy trend of increased sales and indicates the need to maintain adequate inventory levels to avoid stockouts. Inadequate stocks can result in loss of business opportunities and is something that the management needs to keep watching closely. On the other hand, a lower inventory turnover shows that either the sales of the said inventory are slowing down or that the unused inventory is building up clogging the system somewhere. A slow inventory turn can help the inventory manager focus on finding non-moving, obsolete and slow-moving inventory items and thereby steps can be taken to deal with them appropriately.

Inventory turnover also reflects the holding cost that is incurred in managing inventory. Increased inventory turns to reduce the holding costs. The costs especially fixed costs like rent and cost of operations get distributed over higher inventory throughput and thereby the cost of inventory transactions reduces

Inventory turnover is also indicative of the health of inventory operations. When the inventory turnover is higher, the inventory operations efficiency will also be high to meet with the increased operational requirements thereby good housekeeping and increased responsiveness to market requirements.

Inventory turn in some cases, or some systems is also calculated based on the numbers sold rather than the average value of inventory. In such a system the Inventory turn is calculated by dividing the Number of Units Sold divided by the Average number of Units inventory held in a given period of time.

Over a number of years, each industry has developed methods to check inventory turnover and industry standards have been standardized. So, whenever a new business venture is set up, they are able to have the industry standard as benchmark to be achieved and use it as a guide to streamline operations.

6.12 INVENTORY PLANNING

When in the case of raw material inventory management function is essentially dealing with two major functions. The first function deals with inventory planning and the second being inventory tracking. As inventory planners, their main job consists in analyzing demand and deciding when to order and how much to order new inventories. The traditional inventory management approach consists of two models namely :

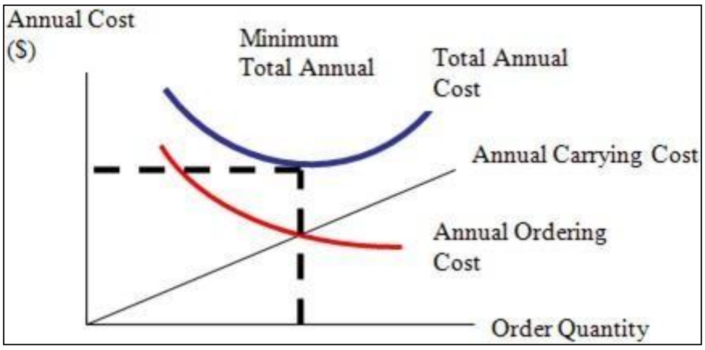
- EOQ - Economic Order Quantity
- Continuous Ordering
- Periodic Ordering

EOQ: Economic Order Quantity method determines the optimal order quantity that will minimize the total inventory cost. EOQ is a basic model and further models developed based on this model include the production Quantity Model and Quantity Discount Model.

Continuous Order Model: works on fixed order quantity basis where a trigger for fixed quantity replenishment is released whenever the inventory level reaches a predetermined safety level and triggers re-ordering.

Periodic System Model: This model works on the basis of placing orders after a fixed period of time.

EOQ Model



Example: Biotech.Co produces chemicals to sell to wholesalers. One of the raw materials it buys is sodium nitrate which is purchased at the rate of $22.50 per ton. Biotech's forecasts show an estimated requirement of 5,75,000 tons of sodium nitrate for the coming year. The annual total carrying cost for this material is 40% of the acquisition cost and the ordering cost is $595. What is the Most Economical Order Quantity?

D = Annual Demand C = Carrying Cost

S = Ordering Cost D = 5,75,000 tons

C =0.40(22.50) = $9.00/Ton/Year

S = $595/Order

= 27,573.135 tons per Order.

This model pre-supposes certain assumptions as:

- No safety Stocks available in inventory.
- No Shortages allowed in order delivery.
- Demand is at uniform rate and does not fluctuate
- Lead Time for order delivery is constant
- One order = One delivery no shortages allowed.

This model does not take into account other costs of inventory such as stock-out cost, acquisition cost etc. to calculate EOQ.

6.13 GOOD INVENTORY MANAGEMENT PRACTICES

Good inventory Management practices in the company help by adding value in terms of having control over and maintaining lean inventory. Inventory should not be too much or too less. Both situations are bad for the company. However often we see that inventory is not focused upon by the management and hence a lot of inefficiencies build up over a period of time without the knowledge of the management. It is only when we start a cost reduction drive that the inventory goof-ups and skeletons come out of the cupboard and result in revamping the entire operations.

However, those companies, which have always focused on inventory as a principal function and recognized that the inventory affects their sales, as well as the books of accounts and profits, have managed to introduce and improve inventory management processes. Many business models work on the lean inventory principle or JIT inventory along with other models like VMI etc. Inventory management to a large extent is dependent upon the supply chain efficiency as well as operations.

Inventory management is a management cum operations function. It requires operational processes to be followed and maintained on the floor and in inventory management systems. Coupled with operations, it entails continuous study; analysis and decision-making to control and manage inventory levels.

We have covered below briefly a few of the points which when followed, can go a long way in ensuring that the inventory is lean and clean.

1. ***Review Inventory periodically and revise stocking patterns and norms:*** Inventory is dependent upon the demand as well as the supply chain delivery time. Often companies follow one stocking policy for all items. For example, all A, B & C categories may be stocking inventory of 15 days, which may not be the right thing that required. While some items may have a longer lead time thus affecting the inventory holding, the demand pattern and the hit frequency in terms of past data may show up differently for each of the inventory items. Therefore, one standard norm does not suit all and can lead to overstocking of inventory as well as efficiencies in the system.
2. ***Get into detailed inventory planning - One size does not fit all:*** Understand the inventory types and the specific characteristics of the items you are carrying. Then build the inventory stocking parameters taking into account the unique characteristics of the particular inventory.

From amongst your inventory list, you will find that all types of materials are not of the same value. Some might be very expensive and need to be carried in stock for a longer period, while another item might have a shorter lead time and may be fast moving. Quite a few items often have a shelf life and hence require separate norms and focus to manage such items.

Getting into a detailed understanding will help you identify the inventory-stocking norm required to manage these characteristics to ensure optimum efficiency. The solution quite often may not be to carry stocks; rather it may involve setting up the customer service standard for such items and specifying a delivery time depending upon the frequency of demand. Quite a few items often have a shelf life and hence require separate norms and focus tomanage such items.

3. ***Study demand patterns, movement patterns and cycles to build suitable inventory norms for different categories of inventory:*** Companies which are into retail segments and dealing with huge inventories in terms of a number of parts, as well as value, will necessarily need to ensure they practice review of the inventory list and cleanup operations on an ongoing basis.

   Popularly known as catalogue management, inventory norms review should be carried out based on detailed study of the sales data, demand pattern, sales cycles etc. Understanding of the business and sales cycles specific to the product category helps one manage inventories better. For example, in case of retail garments, with every season certain skus become redundant no matter how their demand was in the previous months. This helps identify those stocks which are required to be managed at a micro level and identify the high value and fast moving items that need to be always on the radar to avoid stock outs.

   It does not help for example to carry standard stocks of all items including low-value items as well as high-value items. If the low-value items are locally available and the lead-time is less, one can cut down on the inventory and change the buying pattern. , Similarly high-value items too can be managed by cutting down the delivery lead times and in turn reducing inventory.

   It helps to periodically study past data and extrapolate the same to identify slow-moving and obsolete items. The dead stocks should be flushed out and active catalogue items should be made available.

Why Inventory Management Is Important

Holding inventory ties up a lot of cash. That's why good inventory management is crucial for growing a company. Just like cash flow, it can make or break your business. Good inventory management saves you money in a few critical ways:

Avoid Spoilage

If you're selling a product that has an expiry date (like food or makeup), there's a very real chance it will go bad if you don't sell it in time. Solid inventory management helps you avoid unnecessary spoilage.

Avoid Dead Stock

Dead stock is stock that can no longer be sold, but not necessarily because it expired. It could have gone out of season, out of style, or otherwise become irrelevant. By managing your inventory better, you can avoid dead stock.

Save on Storage Costs

Warehousing is often a variable cost, meaning it fluctuates based on how much product you're storing. When you store too many products at once or end up with a product that's difficult to sell, your storage costs will go up.

Inventory Management Improves Cash Flow

Not only does good inventory management save you money, it also improves cash flow in other ways. Remember, inventory is the product that you've likely already paid for with cash (checks and electronic transfers count as cash too), and you're going to sell it for cash, but while it's sitting in your warehouse it is definitively not cash. Just try paying your landlord with 500 iPhone cases.

This is why it's important to factor inventory into your cash flow management. It affects both sales (by dictating how much you can sell), and expenses (by dictating what you have to buy). Both of these things factor heavily into how much cash you have on hand. Better inventory management leads to better cash flow management. When you have a solid inventory system, you'll know exactly how much product you have, and based on sales, you can project when you'll run out and make sure you replace it on time. Not only does this make sure you don't lose sales (critical for cash flow), but it also helps you plan ahead for buying more so you can ensure you have enough cash set aside.

6.14 INVENTORY MANAGEMENT TECHNIQUES

Inventory management is a highly customizable part of doing business. The optimal system is different for each company. However, every business should strive to remove human error from inventory management as much as possible. This means taking advantage of inventory management software. Regardless of the system you use, the following eight techniques will help you to improve your inventory management and cash flow.

Set Par Levels

Make inventory management easier by setting “par levels” for each of your products. Par levels are the minimum amount of product that must be on hand at all times. When your inventory stock dips below the predetermined levels, you know it’s time to order more. Ideally, you’ll typically order the minimum quantity that will get you back above par. Par levels will vary by product based on how quickly the item sells, and how long it takes to get back in stock. Although it requires some research and decision-making up front, setting par levels will systemize the process of ordering. Not only will it make it easier for you to make decisions quickly, but it will also allow your staff to make decisions on your behalf. Remember that conditions change over time. Check on par levels a few times throughout the year to confirm they still make sense. If something changes in the meantime, don’t be afraid to adjust your par levels up or down.

First-In First-Out (FIFO)

“First-in, first-out” is an important principle of inventory management. It means that your oldest stock (first-in) gets sold first (first-out), not your newest stock. This is particularly important for a perishable product so you don’t end up with unsellable spoilage. It’s also a good idea to practice FIFO for non-perishable products. If the same boxes are always sitting at the back, they’re more likely to get worn out. Plus, packaging design and features often change over time. You don’t want to end up with something obsolete that you can’t sell. In order to manage a FIFO system; you’ll need an organized warehouse. This typically means adding new products from the back or otherwise making sure old product stays at the front. If you’re working with a warehousing and fulfillment company they probably do this already, but it's a good idea to call them to confirm.

Manage Relationships

Part of successful inventory management is being able to adapt quickly. Whether you need to return a slow-selling item to make room for a new product, restock a fast seller very quickly, troubleshoot manufacturing issues, or temporarily expand your storage space, it’s important to have a good relationship with your suppliers. That way they’ll be more willing to work with you to solve problems. In particular, having a good relationship with your product suppliers goes a long way. Minimum order quantities are often negotiable. Don’t be afraid to ask for a lower minimum so you don’t have to carry as much inventory. A good relationship isn’t just about being friendly. It’s about good communication. Let your supplier know when you’re expecting an increase in sales so they can adjust production. Have them let you know when a product is running behind schedule so you can pause promotions or look for a temporary substitute.

Contingency Planning

A lot of issues can pop up related to inventory management. These types of problems can cripple unprepared businesses. For example:

- your sales spike unexpectedly, and you oversell your stock
- you run into a cash flow shortfall and can't pay for the product you desperately need
- your warehouse doesn’t have enough room to accommodate your seasonal spike in sales
- a miscalculation in inventory means you have less product than you thought
- a slow moving product takes up all your storage space
- your manufacturer runs out of your product and you have orders to fill
- your manufacturer discontinues your product without warning

Regular Auditing

Regular reconciliation is vital. In most cases, you’ll be relying on software and reports from your warehouse to know how much product you have stock. However, it’s important to make sure that the facts match up. There are several methods for doing this.

- **Physical Inventory:** A physical inventory is the practice is counting all your inventory at once. Many businesses do this at their year-end because it ties in with accounting and filing income tax. Although physical inventories are typically only done once a year, it can be incredibly disruptive to the business, and believe me, it’s tedious. If you do find a discrepancy, it can be difficult to pinpoint the issue when you’re looking back at an entire year.

Spot Checking: If you do a full physical inventory at the end of the year and you often run into problems, or you have a lot of products, you may want to start spot checking throughout the year. This simply means choosing a product, counting it, and comparing the number to what it's supposed to be. This isn’t done on a schedule and is supplemental to physical inventory. In particular, you may want to spot check problematic or fast-moving products.

- ***Cycle Counting:*** Instead of doing a full physical inventory, some businesses use cycle counting to audit their inventory. Rather than a full count at year-end, cycle counting spreads reconciliation throughout the year. Each day, week, or month a different product is checked on a rotating schedule. There are different methods of determining which items to count when, but, generally speaking, items of higher value will be counted more frequently.

Prioritize With ABC

Some products need more attention than others. Use an ABC analysis to prioritize your inventory management. Separate out products that require a lot of attention from those that don't. Do this by going through your product list and adding each product to one of three categories:

A High-value products with a low frequency of sales

B moderate-value products with a moderate frequency of sales C low-value products with a high-frequency of sales

Items in category A require regular attention because their financial impact is significant, but sales are unpredictable. Items in category C require less oversight because they have a smaller financial impact and they're constantly turning over. Items in category B fall somewhere in-between.

Accurate Forecasting

A huge part of good inventory management comes down to accurately predicting demand. Make no mistake; this is incredibly hard to do. There are so many variables involved and you'll never know for sure exactly what's coming—but you can get close. Here are a few things to look at when projecting your future sales:

- trends in the market
- last year's sales during the same week
- this year's growth rate
- guaranteed sales from contracts and subscriptions
- seasonality and the overall economy
- upcoming promotions
- planned ad spend

If there's something else that will help you create a more accurate forecast, be sure to include it.

Consider Dropshipping

Drop shipping is really the ideal scenario from an inventory management perspective. Instead of having to carry inventory and ship products yourself—whether internally or through third-party logistics—the manufacturer or wholesaler takes care of it for you. Basically, you completely remove inventory management from your business. Many wholesalers and manufacturers advertise drop shipping as a service, but even if your supplier doesn't, it may still be an option. Don't be afraid to ask. Although products often cost more this way than they do in bulk orders, you don't have to worry about expenses related to holding inventory, storage, and fulfilment.

Summary

Inventory management is a very important function that determines the health of the supply chain as well as the impacts the financial health of the balance sheet. Every organization constantly strives to maintain optimum inventory to be able to meet its requirements and avoid over or under inventory that can impact the financial figures. Inventory management requires constant and careful evaluation of

external and internal factors and control through planning and review. Good inventory Management practices in the company help by adding value in terms of having control over and maintaining lean inventory. Inventory should not be too much or too less. Both the situations are bad for the company. However often we see that inventory is not focused upon by the management and hence lot of inefficiencies build up over a period of time without the knowledge of the management. It is only when we start a cost reduction drive that the inventory goof ups and skeletons come out of the cupboard and results in revamping the entire operations. Inventory operations have two key elements namely Inventory System and Physical operations. Today inventory systems have replaced the book keeping and financial accounting that was being practiced earlier. Current inventory systems not only do the book keeping but are linked to upstream as well as down stream activities including procurement, sales processing, financial accounting.

Inventory management entails the study of data on the movement of inventory, its demand pattern, supply cycles, sales cycles etc. Active management calls for continuous analysis and management of inventory items to target lean m inventory Management.The inventory Management function is carried out by the inventory planners in the company in close coordination with procurement, supply chain logistics and finance, besides marketing departments.

❖ Check Your Progress

Short Type Questions

1. Define inventory.
2. What is finished goods inventory?
3. What do you mean by inventory costs?
4. Justify the concept of inventory turnover.
5. Explain the benefits of inventory turnover.
6. Explain the need for inventory management.

Essay Type Questions

1. Define inventory. Explain various types of inventory.
2. Describe the advantages and disadvantages of inventory management.
3. What do you mean by inventory turnover? Discuss different types of inventory costs.

Narrate the different types of inventory management techniques.

UNIT : 7 QUALITY MANAGEMENT, SOC & ACCEPTANCE SAMPLING

7.1 QUALITY

Different meaning could be attached to the word quality under different circumstances. Theword quality does not mean the quality of the manufactured product only. It may refer to the quality of the process (*i.e.*, men, material, and machines) and even that of management. Where the quality manufactured product is referred to as or defined as "Quality of the product as the degree in whichfulfilsills the requirement of the customer. It is not absolute but it ged orrealized by comparing it with some standards".

Quality begins with the design of a product in accordance with the customer specification further it involved the established measurement standards, the use of proper material, selection of a suitable manufacturing process etc., quality is a relative term and it is generallyused with reference to the end use of the product.

Successful companies understand the powerful impact customer-defined quality can have on their business. For this reason, many competitive firms continually increase their quality standards. The quality guru J. M. Juran defined quality as ‘Fitness for Purpose’. For assessing the quality of a product or service, the criterion of ‘fitness for purpose’ is highly subjective, which may vary from individual to individual.

In all subsequent stages, however, such as development, engineering, production, distribution after-sales service, quality is defined and measured in terms of ‘Conformance of specification’- as stated by another quality guru, Philip Crosby.

7.1.1 Dimensions of Quality

Quality should, first and foremost, be perceived from the customer’s point of view. This is because it is the customer who decides whether or not to buy a product or service according to his or her perception of quality (Fig.1). Performance is the most basic customer requirement for a product. A refrigerator which does not cool is a bad quality product. The customer also expects the product to be reliable, i.e., perform well without requiring repairs, adjustments etc. frequently. For example, an LCD projector purchased by an institute drips every half an hour due to heating. It has to be put off for an hour to allow it to cool down, andthen restarted for another half an hour of performance. Is this a reliable product? The obvious answer is a big No. Ease of service is another quality criterion for the customer. For example, Maruti Suzuki ltd has a big advantage over its competitors in India with respect to this factor. The service network of Maruti is very extensive, probably because it started its operation in India much earlier than any of its competitors. The durability of a product refers to its lifespan.Customers expect a quality product to last very long. This lifespan extends to a point in timewhere repairs become costlier than the replacement of the product with the new one.

The aesthetic sense in creating the outer appearance is the first impression of quality given to a customer. Usually, it is the outer appearance of a product which induces a customer to enquire further about it. With the intense competition today, the most important dimension of quality is customer service. In India, the domestic industry can overcome the threat of foreign MNCsby focus in on this aspect of quality. Manufacturingorganizations must focus on after sales service as an important opportunity for creating a difference in quality for competitive advantage.

Last but not the least, safety is an aspect of a quality product which cannot be neglected by a manufacturer. For example, electrical equipment must have proper earthing to preventelectric shock.

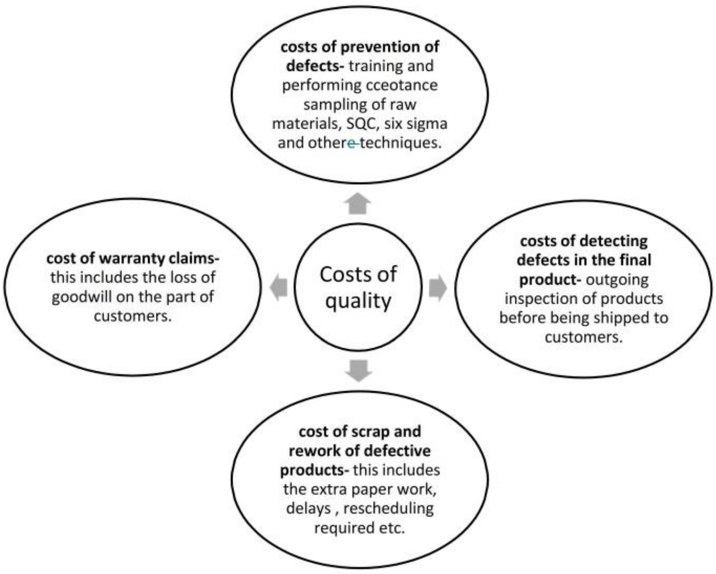


Fig 2 Costs of Quality

Fig 1 Dimensions of Quality

7.1.2 Costs of quality

Quality is free is the title of the famous book by quality guru Philip crospy. On the other hand, quality guru J.M. Juran is known for the concepts propounded by him regarding the costs of quality.

Fig 2 shows the four types of costs of quality. It should be emphasized here that there is an inverse relation between the cost of the prevention of defects and the other three types of costs. If the money spent on the prevention of defects is increased, usually the costs of detection of defects, scrap and rework and warranty claims tend to decrease. Companies such as Motorola, GE, Texas instruments etc. have saved billions of dollars by initially incurring a high cost for implementing quality philosophies like six sigma for the prevention of defects in their products.

7.1.3 Types of Quality control

Quality Control is not a function of any single department or person. It is the primary responsibility of any supervisor to turn out work of acceptable quality. Quality control canbe divided into three main sub-areas, those are:

1. Off-line quality control, 2. Statistical process control, and 3. Acceptance sampling plans.

1. **Off-line quality control:** Its procedure deal with measures to select and choose a controllable product and process parameters in such a way that the deviation between theproduct or process output and the standard will be minimized. Much of this task is accomplished through product and process design.

Example: Taguchi method, principles of experimental design etc.

2. **Statistical process control:** SPC involves comparing the output of a process or service with a standard and taking remedial actions in case of a discrepancy between the two. It also involves determining whether a process can produce a product that meets desired specifications or requirements. On-line SPC means that information is gathered about the product, process, or service while it is functional. The corrective action is taken in that operational phase. This is real-time basis.

Acceptance sampling plans: A plan that determines the number of items to sampleand the acceptance criteria of the lot, based on meeting certain stipulated conditions (suchas the risk of rejecting a good lot or accepting a bad lot) is known as an acceptance sampling plan.

7.1.4 Tools for Quality control

To make rational decisions using data obtained on the product, or process, or from the consumer, organizations use certain graphical tools. Graphical methods are easy tounderstand and provide comprehensive information; they are a viable tool for the analysis of product and process data. These tools affect quality improvement. The seven quality control tools are:

1. Pareto charts	2. Check sheets	3. Cause and effect diagram
4. Scatter diagrams	5. Histogram	6. Graphs or flow charts
7. Control Charts		

7.1.4.1 PARETO CHARTS

Pareto charts help prioritize by arranging them in decreasing order of importance. In an environment of limited, resources these diagrams help companies to decide on the order in which they should address problems. The Pareto analysis can be used to identify the problem in a number of forms.

Example: Fig. 3 shows a Pareto chart of reasons for poor quality. Poor design will bethe major reason, as indicated by 64%. Thus, this is the problem that the manufacturing unit should address first.

A — Poor Design B — Defective Parts C — Operator Error D— Wrong Dimensions E — Surface Abrasion F— Machine Calibrations G — Defective Material

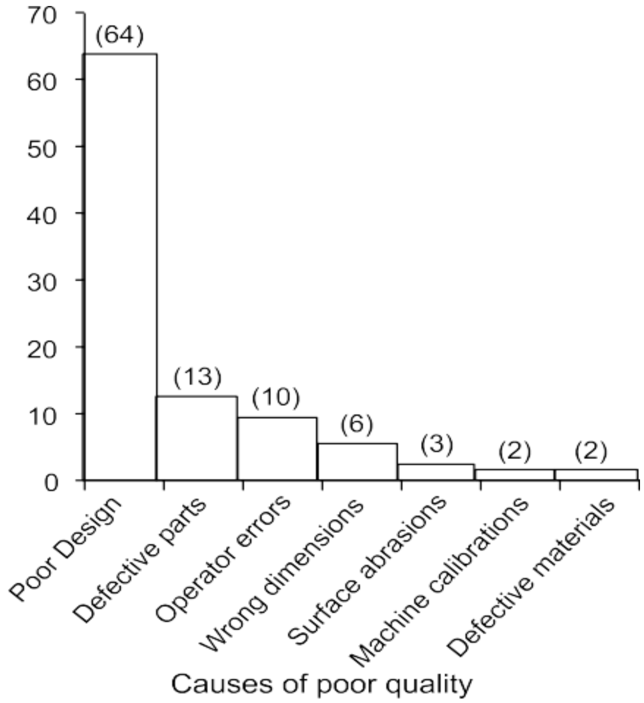
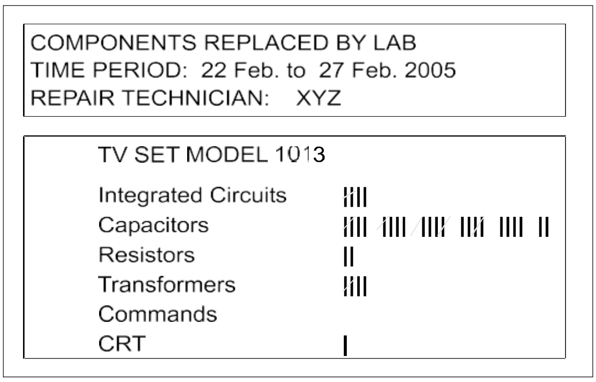


Fig. 3 Pareto chart

7.1.4.2 CHECK SHEETS

Check sheets facilitate systematic record keeping or data collection observations are recorded as they happen which reveals patterns or trends. Data collection through the use of a checklist is often the first step in the analysis of quality problems. A checklist is a form used to record the frequency of occurrence of certain product or service characteristics related to quality. The characteristics may be measurable on a continuous scale such as weight, diameter, time or length.

Example: The table is a check sheet for an organization’s computer-related problems.


COMPONENTS REPLACED BY LAB
TIME PERIOD: 22 Feb. to 27 Feb. 2005
REPAIR TECHNICIAN: XYZ

TV SET MODEL 1013

Integrated Circuits	||||
Capacitors	|||| |||| |||| |||| |||| ||
Resistors	||
Transformers	||||
Commands	
CRT	|

Fig. 4 Checklist

7.1.4.3 CAUSE AND EFFECT DIAGRAM

It is sometimes called a Fishbone diwas first developed by Kaorv Ishikawa in 1943 and is sometimes called the called as Ishikawa diagram. The diameter helps the management trace customer complaints directly to the operations involved. The main quality problem is referred to Fish-head; the major categories of potential cause structural bones and the likely specific causes to ribs. It explores possible causes of problems, with the intention being to discover the root causes. This diagram helps identify possible reasons for a process to go out of control as well as possible effects on the process.

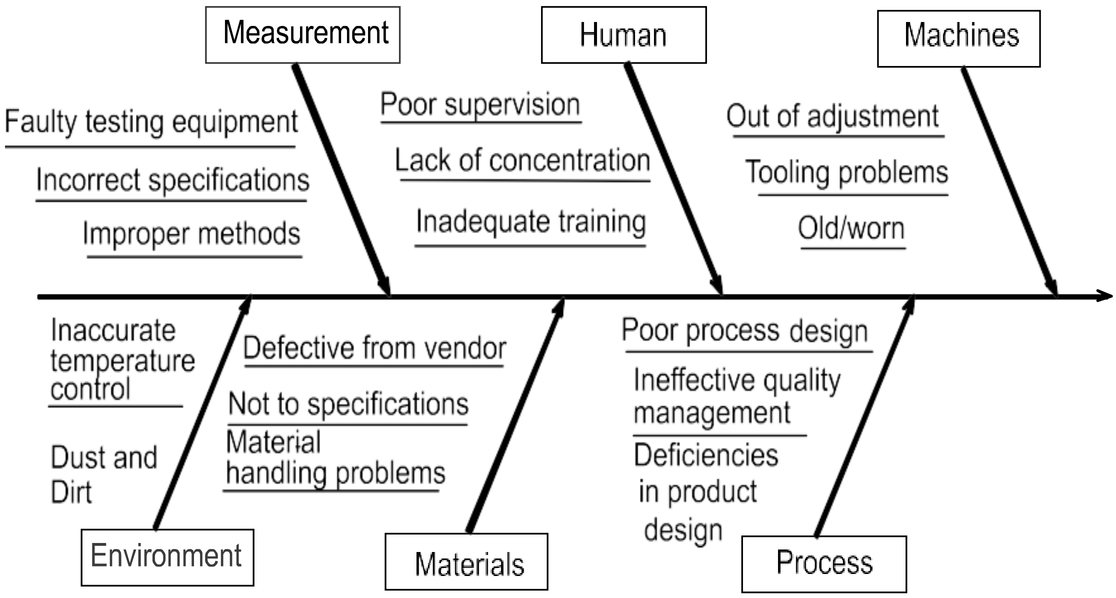
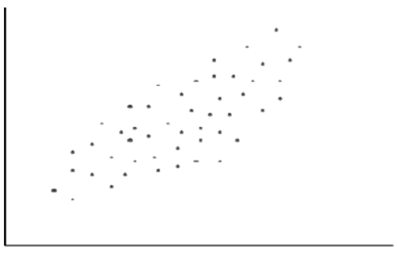


Fig. 5 Fishbone diagram

7.1.4.4 SCATTER DIAGRAM (SCATTER PLOTS)

It often indicates the relationship between two variables. They are often used as follow-upsto a cause-and-effect analysis to determine whether a stated cause truly does impact the quality characteristics.



Example: The above figure plots to advertise expenditure against company sales and indicates a strong positive relationship between the two variables. As the level of advertising expenditure increases sales tend to increase.

HISTOGRAM (OR) BAR CHARTS

It displays large amounts of data that are difficult to interpret in their raw form. A histogram summarizes data measured on a continuous scale showing the frequency

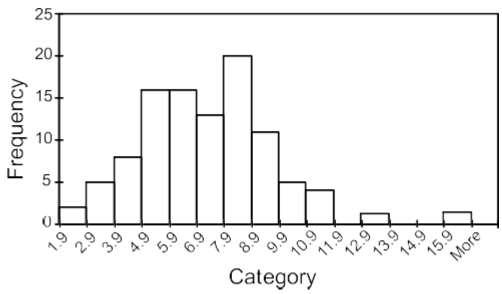


Fig. 7 Histogram

distribution of some quality characteristics (in statistical terms the central tendency and thedispersion of the data).

Often the mean of the data is indicated on the histogram. A bar chart is a series of bare representing the frequency of occurrence of data characteristics, the bar height indicates the number of times a particular quality characteristic was observed.

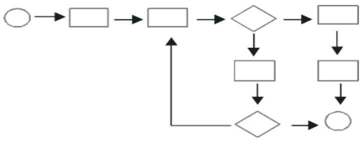


Fig. 8 Flowchart

7.1.4.5 FLOW CHARTS (OR) GRAPHS

It shows the sequence of events in a process. They are used for manufacturing and serviceoperations. Flow charts are often used to diagram operational procedures to simplify the system. They can identify bottlenecks, redundant steps and non-value-added activities. A realistic flow chart can be constructed by using the knowledge of the person who are directly involved in the particular process. The flow chart can be identified where delays can occur

CONTROL CHARTS

Control charts are a very important quality control tool. These charts are used to evaluate whether a process is operating within expectations relative to some measured value such as weight, width, or volume. For example, we could measure the weight of a sack of flour,the width of a tire, or the volume of a bottle of soft drink. When the production process operates within expectations, we say it is “in control.” To evaluate whether or not a process is in control, we regularly measure the variable of interest and plot it on a controlchart. The chart has a line down the center representing the average value of the variable we are measuring. Above and below the center line are two lines, called the Upper Control Limit (UCL) and the Lower Control Limit (LCL). As long as the observed values fall within the upper and lower control limits, the process is in control and there is no problemwith quality. When a measured observation falls outside of these limits, there is a problem.

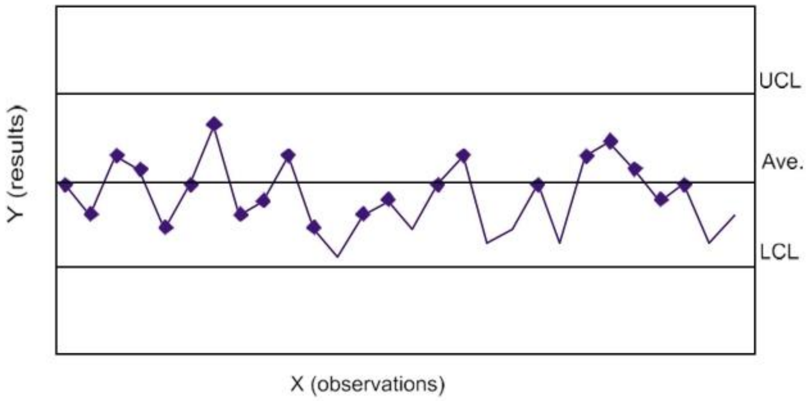


Fig. 9 Control charts

7.2 STATISTICAL PROCESS CONTROL

Statistical process control (SPC) is the application of statistical techniques to determine whether the output of a process conforms to the product or service design. It aims at achieving good quality during manufacture or service through prevention rather than detection. It is concerned with controlling the process that makes the product because if theprocess is good, it will automatically be good.

Control Charts

SPC is implemented through control charts that are used to monitor the output of the process and indicate the presence of problems requiring further action. They have two basic purposes: to establish the control limits for a process and then to monitor the process to indicate when it is out of control. There are two types of control charts: Variable control chart and attribute control chart.

Variable control charts: A characteristic that is continuous and can be measured like Weight, length, voltage, and volume.

- Mean (x bar – chart)
- Range (R-chart)

Attributes chart :

A characteristic which is evaluated with a discrete response like good/bad; yes/no; correct/incorrect.

- P-chart
- C-chart

All the charts look alike, with a line through the center of a graph that indicates the process average and lines above and below the center line that represent the upper and lower limits of the processes, as shown in figure 10.

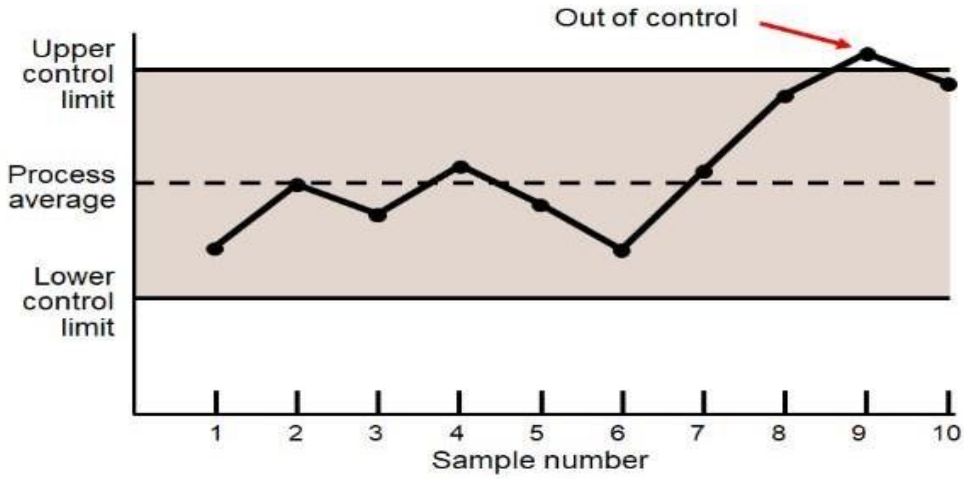


Fig 10 Process Control Chart

The formulas for conducting upper and lower limits in control charts are based on a number of standard deviations, Z, from the process average (e.g., center line) according to a normal distribution. A z value of 2.00 corresponds to an overall normal distribution of 95% and z= 3.00 corresponds to a normal distribution of 99.73%. Control charts using z=2.00 are often referred to as having 2-sigma (2σ) limits, whereas z=3.00 means (3σ) limits.

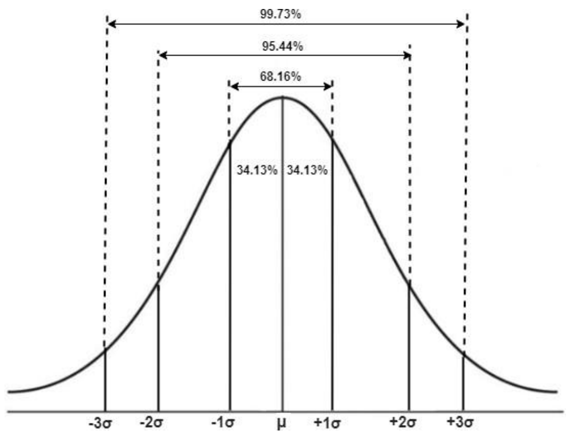


Fig 11 Normal Distribution Curve

7.2.1.1 CONTROL CHART FOR ATTRIBUTES

The quality measured used in attribute control charts are discrete values reflecting a simple decision criterion such as good or bad. A p-chart uses the proportion of defective items in a sample as the sample statistics; a c chart uses the actual number of defects per item in a sample. A p chart can be used when it is possible to distinguish between defective and non-defective items and to state the number of defectives as a percentage of the whole.

7.2.1.1.1 P – Chart

With a p-chart, a sample of n items is taken periodically from the production or service process and the proportion of defective items in the sample is determined to see of the proportion falls within the control limits on the chart. It is assumed that as the sample size(n) gets larger, the normal distribution can be used to approximate the distribution of the proportion defective. This enables us to use the following formulas based on the normal distribution to compute the upper control limit (UCL) and Lower control limit (LCL) of a p-chart.

$UCL = \bar{P} + z\sigma_P$

$LCL = \bar{P} - z\sigma_P$

The sample standard deviation is computed as

Where

Z = number of standard deviations from process average

p = sample proportion defective; estimates process mean

σp = standard deviation of sample proportion

n = sample size

Example 1:

The Indian Jackets Company produces denim jackets. The company wants to establish a p- chart to monitor the production process and maintain high quality. The company believes that approximately 99.74% of the variability in the production process (corresponding to 3-sigma limits or z = 3.00) is random, whereas 0.26% is not random and suggests that the process is out of control. They have taken 20 samples, each containing 100 pairs of jackets, the company wants to construct a p chart to determine when the production process is outof control.

Table-1

Sample No.	Defective Items	Proportion Defectives	Sample No.	Defective Items	Proportion Defectives
1	6	0.06	11	12	0.12
2	0	0.00	12	10	0.10
3	4	0.04	13	14	0.14
4	10	0.10	14	8	0.08
5	6	0.06	15	6	0.06
6	4	0.04	16	16	0.16
7	12	0.12	17	12	0.12
8	10	0.10	18	14	0.14
9	8	0.08	19	20	0.20
10	10	0.10	20	18	0.18

Solution:

Since *p* is not known, it can be estimated from the total sample :

$$\bar{p} = \frac{total\ defectives}{total\ sample\ observations}$$

$$\bar{p} = \frac{200}{20\ (100)}$$

$$\bar{p} = 0.10$$

The control limits are calculated as follows:

$$UCL = \bar{p} + z\sqrt{p\frac{(1-\bar{p}}{n}}$$

$$UCL = 0.10{+}3.00\sqrt{0.10\frac{(1-0.10}{100}}$$

UCL = 0.190

$$LCL = \bar{p} - z\sqrt{p\frac{(1-\bar{p}}{n}}$$

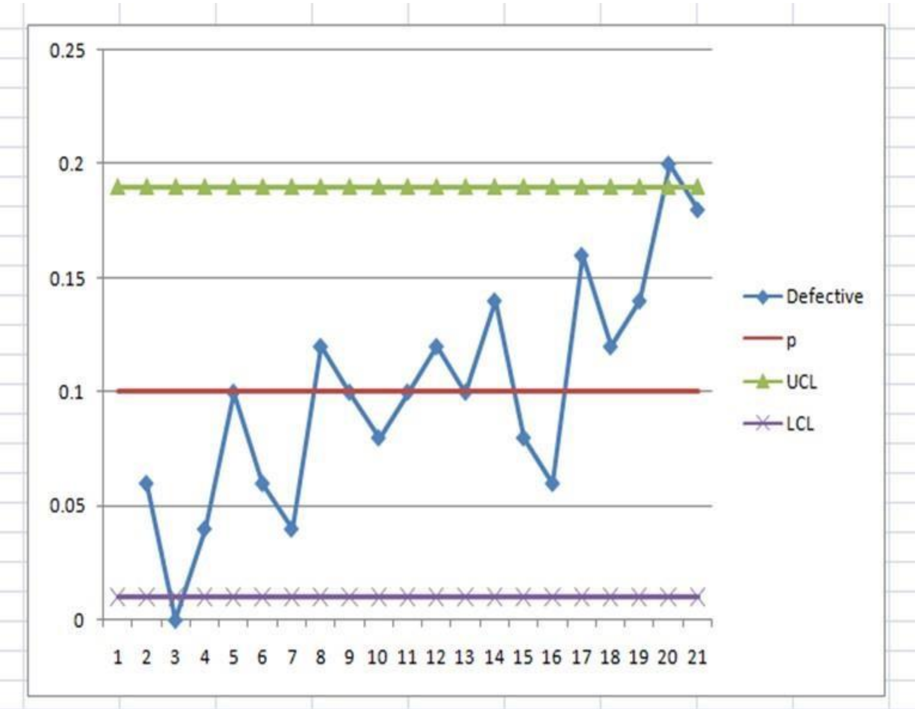
$$UCL = 0.10{+}3.00\sqrt{0.10\frac{(1-0.10)}{100}}$$

UCL = 0.190

$$LCL = \bar{p} - z\sqrt{p\frac{(1-\bar{p}}{n}}$$

$$LCL = 0.10 - 3.00\ 0.10\frac{(1-0.10)}{100}$$

LCL = 0.010



7.2.1.1.2 Chart

A chart is used when it is not possible to compute a proportion defective and the actual number of defects must be used. For example, when automobiles are inspected, the numberof blemishes (i.e., defects) in the paint job can be counted for each car, but a proportion cannot be computed, since the total number of possible blemishes is not known.

Where c= number of defects per sample

Example 2:

The Ambar hotel has 240 rooms. The following are the results from 15 inspection samples conducted at random during a one-month period. The hotel believes that approximately 99% of the defects (corresponding to 3-sigma limits or z = 3.00) are caused by natural variability and the rest are caused by non-random variability. It wants to construct a *c*-chart to monitor housekeeping service.

Table-2

Sample No.	No of defects	Sample No.	No of defects	Sample No.	No of defects
1	12	6	11	11	12
2	8	7	9	12	10
3	16	8	14	13	14
4	14	9	13	14	17
5	10	10	15	15	15

Solution:

Because *c*, the population process average, is not known, the sample estimate, $\bar{c}$ can be used instead.

$$\bar{c} = \frac{total\ defectives}{total\ sample\ observations}$$

$$\bar{c} = \frac{190}{15}$$

$$\bar{c} = 12.67$$

The control limits are calculated using *z* = 3.00, as follows:

$$\text{UCL} = \bar{c} + \sqrt[z]{c}$$

$$\text{UCL} = 12.57 + \sqrt[3]{12.57}$$

$$\text{UCL} = 23.35$$

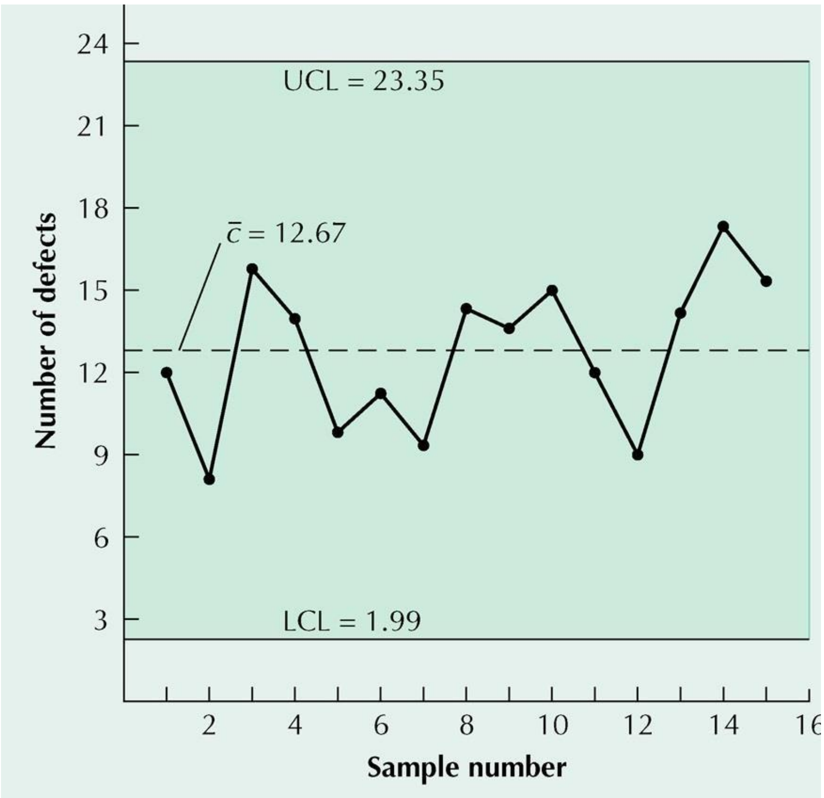
&

$$\text{UCL} = \bar{c} + \sqrt[z]{c}$$

$$\text{UCL} = 12.57 + \sqrt[3]{12.57}$$

$$\text{UCL} = 1.99$$

The resulting *c*-chart, with the sample points, is shown in the following figure. All the sample observations, are within the control limits, suggesting that the room quality is in control. This chart will be considered reliable for monitoring the room quality in the future.



7.2.1.2 Control Charts for Variables

Variable control charts are used for continuous variables that can be measured such as weight or volume.

Mean (X) chart

In a mean control chart, each time a sample of a group of items is taken from the process, the mean of the sample is computed and plotted on the chart. Each sample mean ($\bar{X}$) pointon the control chart. The $\bar{X}$ chart is based on the normal distribution. it can be constructed in two ways depending on the information that is available about the distribution. If the standard deviation of the distribution is known from past experience or historical data, then formulas using the standard deviation can be used to compute the upper and lower controllimits. If the standard deviation is not known, then a table of values based on sample ranges is available to develop the upper and lower control limits. The formulas for computing theupper control limit (UCL) and lower control limit (LCL) are

$\mathbf{UCL} = \bar{\boldsymbol{x}} + \boldsymbol{Z}\bar{\boldsymbol{\sigma}}\,\bar{\boldsymbol{x}}$

LCL = $\bar{\bar{x}}$– -

Where

$\bar{x}$ = process average = $\frac{\bar{x}1 + \bar{x}2 + \cdots + \bar{x}n}{k}$

σ = process standard deviation

$\sigma_{\bar{x}} = \sigma / \sqrt{n}$ =standard deviation of sample mean

k = number of samples

n = sample size

Example 3:

Texas Company produces slip ring bearings. Employees have taken 10 samples of five slip ring bearings and measured the diameter of the bearings. The individual observations from each sample are given below. If σ = .08, develop a control chart with 3-sigma limits to monitor the process in the future.

Table-3

Observations (Slip-ring diameter, cm), x

Sample (k)	1	2	3	4	5	$\bar{x}$
1	5.02	5.01	4.94	4.99	4.96	4.98
2	5.01	5.03	5.07	4.95	4.96	5.00
3	4.99	5.00	4.93	4.92	4.99	4.97
4	5.03	4.91	5.01	4.98	4.89	4.96
5	4.95	4.92	5.03	5.05	5.01	4.99
6	4.97	5.06	5.06	4.92	5.03	5.01
7	5.05	5.01	5.10	4.93	4.99	5.02
8	5.09	5.10	5.00	4.99	5.08	5.05
9	5.14	5.10	4.99	5.08	5.09	5.08
10	5.01	4.98	5.08	5.07	4.99	5.03
						50.09

The process average is computed as below:

$$\bar{\bar{x}} = \frac{\sum \bar{x}}{k}$$

$$\bar{\bar{x}} = \frac{50.09}{10}$$

$\bar{\bar{x}}$ 5.009 ≅ 5.01

The control limits are:

$\text{UCL} = \bar{\bar{x}} + z\bar{\sigma}\,\bar{x}$

$\text{UCL} = 5.01 + 3(0.08/\sqrt{5})\text{UCL} = 5.12$

$\text{LCL} = \bar{\bar{x}} - z\sigma_{\bar{x}}$

$\text{LCL} = 5.01 - 3(0.08/\sqrt{5})$

$\text{LCL} = 4.90$

None of the samples means $(\bar{x})$, fall outside these control limits, which indicates that theprocess is in control and this is an accurate control chart.

In the second approach to developing a $\bar{x}$-chart, the following formulas are used to calculatethe control limits:

$\text{UCL} = \bar{\bar{x}} + A_2\bar{R}$ $\text{UCL} = \bar{\bar{x}} - A_2\bar{R}$

where, $\bar{\bar{x}}$ is the average of the sample means and $\bar{R}$is the average range value. A_2 is a tabular value that is used to establish the control limits.

Values of A_2 are included in Table-4 below:

Table-4: Factors for Determining Control Limits for $\bar{x}$-chart and *R*-Charts

Sample Sizen	Factor for $\bar{x}$ chart A_2	Factors for *R*-chart	
		D3	D4
1.	1.88	0.00	3.27
2.	1.02	0.00	2.57
3.	0.73	0.00	2.28
4.	0.58	0.00	2.11
5.	0.48	0.00	2.00
6.	0.42	0.08	1.92
7.	0.37	0.14	1.86
8.	0.34	0.18	1.82
9.	0.31	0.22	1.78
10.	0.29	0.26	1.74
11.	0.27	0.28	1.72
12.	0.25	0.31	1.69
13.	0.24	0.33	1.67
14.	0.22	0.35	1.65
15.	0.21	0.36	1.64
16.	0.20	0.38	1.62
17.	0.19	0.39	1.61
18.	0.19	0.40	1.60
19.	0.18	0.42	1.59
20.	0.17	0.43	1.58
21.	0.17	0.43	1.57
22.	0.16	0.44	1.56
23.	0.16	0.45	1.55
24.	0.15	0.46	1.54

They were developed specifically for determining the control limits for $\bar{x}$-charts and are comparable to three standard deviations (3σ) limits. These table values are frequently used to develop control charts.

Example 4:

Texas Company desires to develop an $\bar{x}$-chart using table values (as given in Table-4 above). The sample data collected for this process with ranges is show in the following table (Table-5):

Table-5

Sample k	Observations (Slip-ring diameter, cm), x 1	2	3	4	5	$\bar{x}$	R
1	5.02	5.01	4.94	4.99	4.96	4.98	0.08
2	5.01	5.03	5.07	4.95	4.96	5.00	0.12
3	4.99	5.00	4.93	4.92	4.99	4.97	0.08
4	5.03	4.91	5.01	4.98	4.89	4.96	0.14
5	4.95	4.92	5.03	5.05	5.01	4.99	0.13
6	4.97	5.06	5.06	4.92	5.03	5.01	0.10
7	5.05	5.01	5.10	4.93	4.99	5.02	0.14
8	5.09	5.10	5.00	4.99	5.08	5.05	0.11
9	5.14	5.10	4.99	5.08	5.09	5.08	0.15
10	5.01	4.98	5.08	5.07	4.99	5.03	0.10
						50.09	1.15

The company what to develop and $\overline{R}$ chart to monitor the process.

Solution:

$\overline{R}$ is computed by first determining the range for each sample by computing the difference between the highest and lowest values as shown in the last column in Table-5 above. Theseranges are summed and then divided by the number of samples, k, as follows:

$$\bar{R} = \sum\frac{R}{k}$$

$$\bar{R} = \frac{1.15}{10}$$

$$\bar{R} = 0.115$$

$\bar{\bar{x}}$ is computed as follows:

$$\bar{\bar{x}} = \sum\frac{\bar{x}}{k}$$

$$\bar{x} = \frac{50.09}{10}$$

$$\bar{x} = 5.01cm$$

Using the value of A_2 = 0.58 for n = 5 from Table-4 above and $\bar{R}$= 0.115, we compute the control limits as

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

$$\text{UCL} = 5.01 + (0.58)(0.115)$$

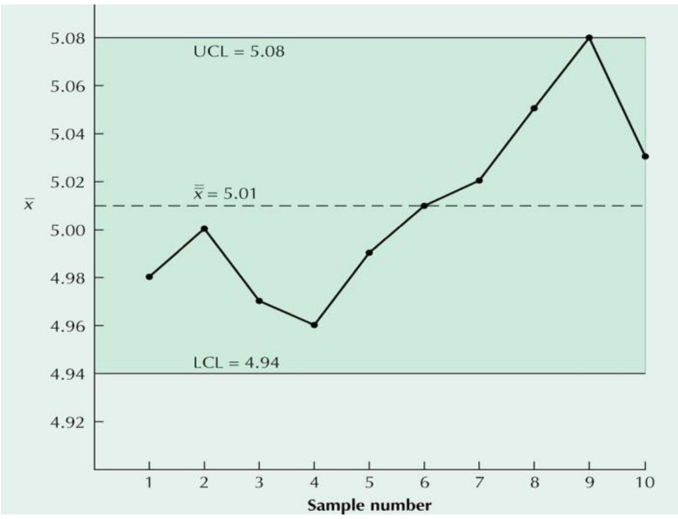
$$\text{UCL} = 5.08$$

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

$$\text{LCL} = 5.01 - (0.58)(0.115)$$

$$\text{LCL} = 4.94$$

The $\bar{x}$-chart defined by these control limits is shown in the following figure. Notice that theprocess is on the UCL for sample 9; in fact, samples 4 to 9 show an upward trend. This would suggest that the process variability is subject to nonrandom causes and should be investigated.



7.2.1.2.2 Range chart

In an R chart, the range is the difference between the smallest and largest values in asample. The formulas for determining the control limits are

UCL $= D_4\bar{R}$

LCL $= D_3\bar{R}$

$\bar{R}$ is the average range (and center line) for the samples,

Where

R= range of each sample

K= number of samples $\bar{R} = \sum \frac{R}{k}$

D3 and D4 are table values like A2 for determining control limits that have been developed based on range values rather than standard deviation. Table includes values for D3 and D4 for sample size up to 25.

Example 5:

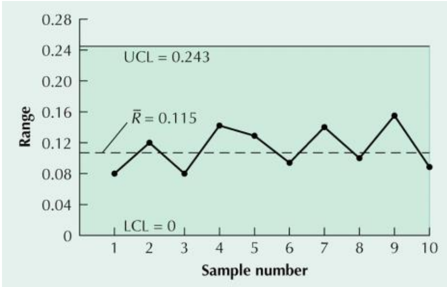
Texas Company wants to develop an *R*-chart to control process variability. Use the data available in Example 3 and Example 4.

Solution:

From Example 4, $\bar{R}$= 0.115; from Table-4 for $n = 5$ $D_3 = 0.00$ and $D_4 = 2.11$. Thus, the control limits are

UCL $= D_4\bar{R}$ = 2.11 (0.115) = 0.243

LCL $= D_3\bar{R}$ = 0.00 (0.115) = 0



These limits define the *R*-chart shown in the following figure. The chart indicates that the process appears to be in control; any variability observed is a result of natural randomoccurrences.

This example illustrates the need to employ the *R*-chart and the $\bar{x}$-chart together. The *R*-chart in this example suggests that the process is in control, since none of the ranges for the samples are close to the control limits. However, the $\bar{x}$-chart in Example 4 suggests that the process is not in control. In fact, the ranges for samples 8 and 10 were relatively narrow, whereas the means for these samples were relatively high. The use of both the charts together provided a more complete picture of the overall process variability.

7.3 ACCEPTANCE SAMPLING

The process of performing a check of raw materials, components and parts supplied by vendors is called incoming inspection. Similarly, before dispatching a batch of finished goods to the customers, an outgoing inspection is done. This inspection may be done in two ways. One way to check each and every item in the lot. This requires considerable time, effort and resources. The other way is to reset sampling. One or more samples may be drawn out of the lot and tested for quality. A decision may be made to accept or reject the lot or consignment depending on upon the number of defective items found in the samples. This process of using sampling in incoming or outgoing inspection is called acceptance sampling.

7.4 SIX SIGMA

It is the application of six sigma principles in maintenance. Six sigma is a maintenance process that focuses on reducing the variation in business production processes. Byreducing variation, a business can achieve tighter control over its operational systems, increasing their cost effectiveness and encouraging productivity breakthroughs.

Six sigma is a term created at Motorola to describe the goal and process used to achievebreakthrough levels of quality improvement. Sigma is the Greek symbol used by statisticians to refer to the six standard deviations. The term six sigma refers to a measure of process variation (six standard deviations) that translates into an error or defect rate of

3.4 parts per million. To achieve quality performance of six sigma level, special sets of quality improvement methodologies and statistical tools developed. These improvement methods and statistical tools are taught to a small group of workmen known as six sigma champions who are assigned full-time responsibility to define, measure, analyze, improve and control process quality. They also facilitate the improvement process by removing the organizational roadblocks encountered. Six sigma methodologies improve any existing business process by constantly reviewing and re-tuning the process. To achieve this, six sigma uses a methodology known as DMAIC (Define opportunities, Measure performance, analyze the opportunity, Improve performance, Control performance). This six-sigma processis also called the DMAIC process.

Six sigma relies heavily on statistical techniques to reduce failures and it incorporates the basic principles and techniques used in Business, Statistics, and Engineering. Six sigma methodologies can also be used to create a brand-new business process from the ground up using design for six sigma principles.

7.4.1 Six Sigma Maintenance Process

The steps of six sigma maintenance are the same as the DMAIC process. To apply six sigma in maintenance, the work groups that have a good understanding of preventive maintenance techniques in addition to a strong leadership commitment. Six sigma helps with two principals inputs to the maintenance cost equation: Reduce or eliminate the need to do maintenance (reliability of equipment), and improve the effectiveness of the resources needed to accomplish maintenance. Following are the steps involved in the six sigma maintenance process.

Define

This step involves determining benchmarks, determining availability and reliability requirements, getting customer commitments and mapping the flow process.

Measure

This step involves the development of failure measurement techniques and tools, data collection process, and compilation and display of data.

Analysis

This step involves checking and verifying the data and drawing conclusions from the data. It also involves determining improvement opportunities, finding root causes and mapping causes.

Improve

This step involves creating a model equipment and maintenance process, a total maintenance plan and schedule and implementing those plans and schedule.

Control

This step involves monitoring the improved programme. Monitor improves performance and assesses the effectiveness and will make necessary adjustments for the deviation if exists.

Goal: 3.4 defects per million opportunities (DPMO)

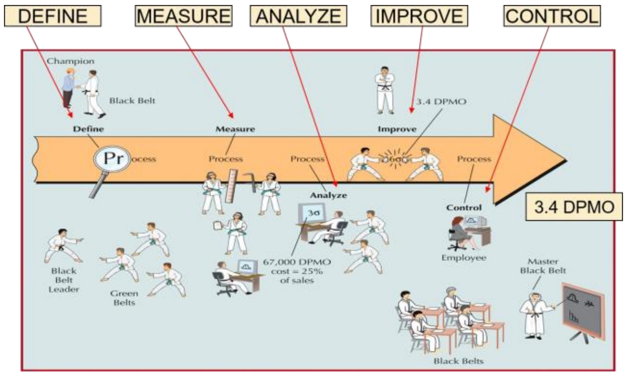


Fig 12 Six Sigma

7.4.1.1 BLACK BELTS AND GREEN BELTS

The project leader who implements the DMAIC steps is called a black belt. Black belts hold full-time positions and are extensively trained in the use of statistic and quality controltools, as well as project and team management.

Master black belts monitor, review and mentor black belts across all projects. They are primarily teachers who are selected based on their qualitative skills and their teaching andmentoring ability. Project team members are green belts, which is not a full-time position;they do not spend all of their time on projects. Green belts receive similar training to blackbelts but somewhat less of it.

7.5 QUALITY STANDARDS

Various quality standards are discussed below.

7.5.1 ISO 9000 Standards

- Increases in international trade during the 1970s created a need for the development of universal standards of quality. Universal standards were seen asnecessary in order for companies to be able to objectively document their qualitypractices around the world.
- Then in 1977 the International Organisation for Standardisation (ISO) published its first set of standards for quality management is called ISO 9000.
- The International Organisation for Standardisation (ISO) is an international organisation whose purpose is to establish an agreement on international quality standards.
- It currently has members from 91 countries, including the United States. To develop and promote international quality standards, ISO 9000 has been created.
- ISO 9000 consists of a set of standards and a certification process for companies. By receiving ISO 9000 certification, companies

demonstrate that they have metthe standards specified by the ISO.

- The standards are applicable to all types of companies and have gained global acceptance.
- In many industries ISO certification has become a requirement for doing business. Also, ISO 9000 standards have been adopted by the European Community as a standard for companies doing business in Europe.

- In December 2000 the first major changes to ISO 9000 were made, introducing the following three new standards:

② ISO 9000:2000 Quality Management Systems Fundamentals and Standards: Provides the terminology and definitions used in the standards. It is the Starting point for understanding the system of standards.

② ISO 9001:2000 Quality Management Systems Requirements: This is the standard used for the certification of a firm's quality management system. It is used to demonstrate the conformity of quality management systems to meetcustomer requirements.

② ISO 9004:2000 Quality Management Systems Guidelines for Performance: Provides guidelines for establishing a quality management system. It focuses not only on meeting customer requirements but also on improving performance.

7.5.2 ISO 14000 Standards

- The need for standardisation of quality created an impetus for the development of other standards. In 1996 the International Standards Organisation introduced standards for evaluating a company's environmental responsibility. These standards, termed ISO 14000, focus on three major areas:
- Management systems standards measure systems development and integration of environmental responsibility into the overall business.
- Operations standards include the measurement of consumption of natural resources and energy.
- Environmental systems standards measure emissions, effluents, and other waste systems.

Summary:

- Quality is defined in two ways- fitness for purpose and conformance to specification. The fitness for purpose criterion is suitable only in the design stage ofthe product. The conformance to the specification criterion is suitable in the rest of the stages of a product, namely, engineering, manufacturing, distribution and after-salesservice. The quality of a product has various dimensions such as performance, features, reliability, appearance etc. quality has costs such as the costs of preventingdefects, detecting detects, scrap/rework and warranty claims.

- During the production process, statistical process control (SPC) should be used to ensure that whenever a variation takes place in the process, it is immediately detected and corrected. Various types of control charts, such as the $\bar{X}$ chart, $\bar{R}$ chart, P chart and c chart are used in SPC. Most organizations operate at three sigma level but companies such as Motorola and GE have saved billions of dollars by implementing the six- sigma quality level. Six Sigma is a rigorous application of statistical methods in the whole organization in order to measure and decrease variations in any process critical to the quality of the product.
- ISO 9000 is a certification based on a set of quality standards established by the International Organization for Standardization. Its goal is to ensure that quality is built into production processes. ISO 9000 focuses mainly on quality ofconformance.

Keywords:

- Acceptance sampling: it is a method of ensuring that the inputs, such as rawmaterials, parts, components, labour skills etc. are of desired quality levels
- Control limits: control limits are certain limits established inside the specificationlimits in order to ensure that these limits are never exceeded.
- ISO 9000: It is a series of international quality standards, which serve as a guide to suppliers and purchasers for the minimum requirements of a quality system.
- Quality control: It is defined as maintaining requisite standards in products orservices.
- Quality: it is defined as the degree of excellence.
- Six sigma: Six sigma is quality initiative. It means going from approximately 35,000 defects per million operations, which is average for most companies, to fewer than four defects per million in every element in every process that a company engages in every day.
- Statistical process control (SPC): it is a method of ensuring the quality of a productduring the transformation process.

Check Your Progress

1. What is six sigma? How it is implemented?
2. What are the various types of certifications in quality standards?
3. Explain ISO 9000 standards.
4. Explain ISO 14000 standards.
5. Define quality and quality control.
6. A number of quality management philosophies hold that prevention costs are the most critical quality-related costs.

Explain the logic behind this premise.

7. Select the service provider and discuss the dimension of quality on which a customermight evaluate it.
8. Develop the six-sigma-type project employing the DMAIC steps for improving any phaseof your personal life that you feel may be "defective".
9. Describe the difference between a black belt, green belt and a master black belt in the six sigmaprocess.
10. Develop the fishbone diagram for the possible causes of your car not starting.
11. Samples of each of the 250 radios are inspected for 12 days. The number of defective radios found in different samples is given below. Prepare p chart and state your conclusion.

Date	**No. of defective items**	**Date**	**No. of defective items**
1	25	7	39
2	47	8	32
3	23	9	35
4	30	10	22
5	24	11	45
6	34	12	40

12. Vadodara furniture is a manufacturer of executive tables for corporate institutions. In order to control the quality of its tables, the QC manager selects 15 tables at random and inspects for the number of scratches on each one of them. The result given in the following table are obtained. Develop a C chart with 3-sigma limits to monitor the process in the future.

Sample no	**No. of defective tables**	**Sample no**	**No. of defective tables**
1	13	9	2
2	9	10	5
3	19	11	7
4	7	12	11
5	8	13	9
6	10	14	13
7	12	15	1
8	0		

Short Questions

- What is SPC? Define with examples
- Define quality criteria
- Which are the costs of quality?
- What is six sigma?

- What is scatter diagram?
- What is pareto analysis?
- Define C chart.
- What is acceptance sampling?

MCQ:

1. The category consists of costs necessary for achieving high quality, which is called __Costs.
   a. quality control costs
   b. prevention costs
   c. appraisal costs
   d. quality failure costs
2. A control chart consists of
   a. Points representing a statistic
   b. Upper and lower control limits
   c. standard deviation
   d. All of the above
3. What is the UCL of the standardized R chart for short production runs?
   a. D1
   b. D2
   c. D3
   d. D4
4. _________is the sequence of steps involved in an operation or process.
   a. Checklist
   b. Flowchart
   c. Control charts
   d. Cause and effect diagrams
5. Technique used to identify quality problems based on their degree of importance isknown as___.
   a. Parreto analysis
   b. Statistical process control
   c. Histogram
   d. Scatter diagrams
6. In which type of diagrams or charts are the upper control limit and the lower controllimit reflected?
   a. Scatter charts
   b. Histograms
   c. Control charts
   d. Statistical Process control

7. The concept of Six Sigma was developed by the following company.
   a. General Electric
   b. Motorola
   c. Honeywell
   d. DuPont
8. In “DMAIC”, M stands for
   a. Method
   b. Measure
   c. Machine
   d. Manpower
9. “DMAIC” is used for projects aimed at
   a. improving an existing business process
   b. creating new product or process designs
   c. Both (a) and (b)
   d. None of the above
10. Processes that operate with “six sigma quality” over the short term are assumed toproduce long-term defect levels below_________________defects per million opportunities (DPMO)
   a. 2.4
   b. 3.4
   c. 4.4
   d. 5.4
11. Six Sigma strategies seek to improve the quality of the output of a process by
   a. identifying the causes of defects
   b. removing the causes of defects
   c. minimizing variability in manufacturing
   d. all of the above

UNIT : 8 JIT & LEAN MANUFACTURING

8.1 MEANING

In manufacturing, speed to market and costs of production can make or break a company. Just in time (JIT) manufacturing is a workflow methodology aimed at reducing flow times within production systems, as well as response times from suppliers and to customers.

JIT manufacturing helps organizations control variability in their processes, allowing them to increase productivity while lowering costs. JIT manufacturing is very similar to Lean manufacturing, and the terms are often used synonymously.
In this post, we'll discuss the ins and outs of JIT manufacturing, including its history, the basic concepts included in this methodology, and its potential risks.

8.2 HISTORY OF JUST-IN-TIME MANUFACTURING

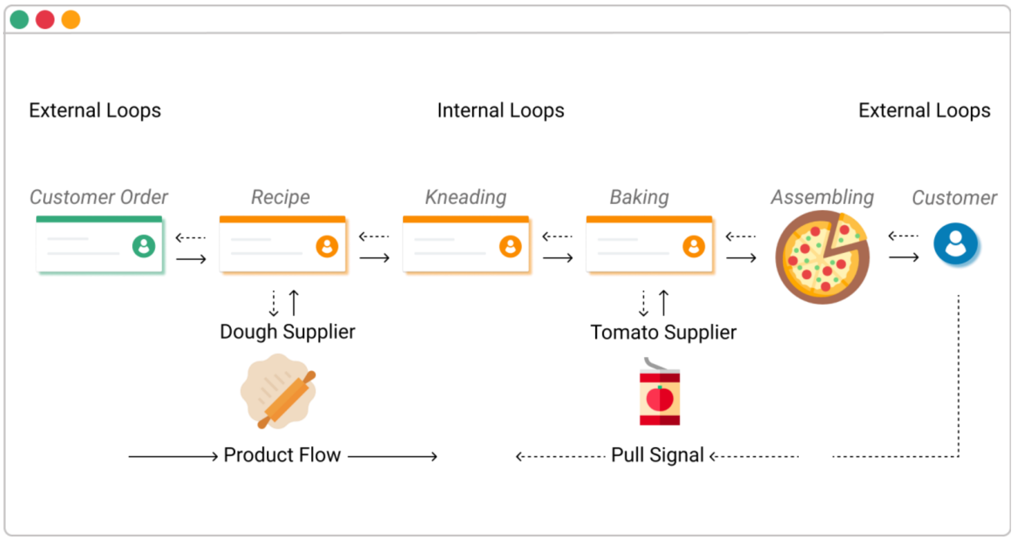
It's unknown exactly when Japanese manufacturers began adopting JIT manufacturing practices, but it is certain that they were triggered by the economic climate of the post-World War II era. Following the war, Japan lacked the cash to finance big-batch, large inventory production methods used by other developed countries. They also had high unemployment and a lack of abundant natural resources.

In order to survive, they had to "lean out" their processes. They built smaller factories, which focused on quickly turning small amounts of

raw materials into small amounts of physical products. Processing smaller batches allowed the manufacturers to reduce financial risk, while slowing generating sustainable levels of working capital.
The system that they used came to be known as just in time manufacturing, popularized in Western media as the Toyota Production System.

8.3 BENEFITS OF JUST-IN-TIME MANUFACTURING

When done well, adopting a Lean manufacturing or just in time manufacturing system can have a drastic impact on an organization's productivity, risk management, and operating costs.



Here are just a few of the quantitative benefits experienced by manufacturers worldwide:

1. **Reduction in the order to payment timeline**; cash, as they say is king in business. Many businesses will suffer with cash flow problems as they will often have to purchase large amounts of raw materials prior to manufacturing and subsequent payment by the customer. Often this gap is many months. Through implementing JIT you are able to considerably reduce that time period.
2. **Reduction in Inventory costs**; one of the main aims with any JIT implementation is to improve stock turns and the amount of stock being held. Personal experience has seen reductions of more than 90% stock in some industries. Along with the reduction in the stock come many other associated benefits.
3. **Reduction in space required**; by removing large amounts of stock from the system and moving processes closer together we will often see a significant reduction in the amount of floor space being used. Results from 100's of projects run within companies in the UK through the Manufacturing Advisory Service saw

average reductions of 33% for simple 5 day implementation projects.

4. **Reduction in handling equipment and other costs**; if you don't have to move large batches there is less need for complex machinery to move them and all of the associated labor and training.
5. **Lead time reductions**; one of the most significantly impacted areas is that of the time it takes for products to flow through the process. Instead of weeks or months most JIT implementations result in lead times of hours or a few days.
6. **Reduced planning complexity**; the use of simple pull systems such as Kanban, even with your suppliers, can significantly reduce the need for any form of complex planning. With many implementations the only planning is the final shipping process.
7. **Improved Quality**; the removal of large batch manufacturing and reduction in handling often results in significant quality improvements; often in the region of 25% or more.
8. **Productivity increases**; to achieve JIT there are many hurdles that must be overcome with regards to how the process will flow. These will often result in productivity improvements of 25% upwards.
9. **Problems are highlighted quicker**; often this is cited as being a negative aspect of JIT in that any problems will often have an immediate impact on your whole production process. However this is the perfect way to ensure that problems are highlighted and solved immediately when they occur.
10. **Employee empowerment**; one requirement of JIT as with most other aspects of Lean manufacturing is that employees are heavily involved in the design and application of your system.

8.4 REQUIREMENTS FOR IMPLEMENTING JUST IN TIME

Just in Time is just one of the pillars of a lean manufacturing system and as such it cannot be implemented in isolation and without a firm foundation on which to build. Trying to reduce batch sizes without tackling setup times for instance cannot be done. The following are some of the things that must be implemented for JIT to be able to work:

- **Reliable Equipment and Machines**; if your machinery is always breaking down or giving you quality problems then it will frequently manifest in big issues with any JIT flow. The implementation of Total Productive Maintenance is required to ensure that you can rely on your equipment and to minimize the impact that any failures have on your processes.

- **Well designed work cells**; poor layout, unclear flow, and a host of other issues can all be cleared up by the implementation of 5S within your production. This simple and very easy to implement lean tool will make a significant improvement in your efficiencies all by itself.
- **Quality Improvements**; an empowered workforce that is tasked with tackling their own quality problems with all of the support that they need is another vital part of any lean and JIT implementation. Setting up kaizen or quality improvement teams and using quality tools to identify and solve problems is vital.
- **Standardized Operations**; only if you know how each operation is going to be performed can you be sure what the reliable outcome will be. Defining standard ways of working for all operations will help to ensure that your processes are reliable and predictable.
- **Pull Production**; Just in time does not push raw materials in at the front end to create inventory (push production), it seeks to pull production through the process according to customer demand. It achieves this by setting up "supermarkets" between different processes from which products are taken or by the use of Kanbans which are signals (flags) to tell the previous process what needs to be made.
- **Single piece Flow**; the ideal situation is one in which you will produce a single product as ordered by the customer. This for some industries is not immediately possible but should always be your end goal. To achieve this you will need to work on reducing batch sizes significantly through the use of Single Minute Exchange of Die (SMED) which seeks to significantly reduce the time taken for any setup. It will also often require the use of smaller dedicated machines and processes rather than all singing all dancing mega machines.
- **Flow at the beat of the customer**; the demand of your customer is often referred to as your Takt time. You need to ensure that your cells and processes are organized, balanced and planned to achieve the pull of the customer. This is achieved through Heijunker and Yamazumi charts.

Potential Risks with JIT

In general, companies employing JIT manufacturing practices enjoy reduced cycle times, faster times to market, and reduced operating costs, although there are some potential risks, especially for smaller organizations. In order to find success with JIT, it's important to find suppliers that are close by, or that can supply materials quickly with limited advance notice. Sometimes, minimum order policies can pose a risk to smaller manufacturers who might order smaller quantities of materials.

8.5 PRACTICAL APPLICATIONS OF JUST-IN-TIME PRODUCTION PHILOSOPHY

The idea of having the right materials, at the right time, in the right quantities sounds perfect. However, are there other examples, except Toyota, of successful JIT implementation?

The answer is yes. Furthermore, Just-in-time has also been successfully applied in other industries different than manufacturing.

Dell is one of the most famous examples of the JIT's triumph. The company revolutionized the way computers are built.

Dell started to offer customized computers to customers in the 1990s, as the company never stocked raw materials needed to build a computer until an order is placed.

Image Source: www.achievement.org

The company was able to order materials, build a machine with exact specifications, and deliver it faster than competitors who had pre-made computers in stock.

This lowered Dell's inventory costs and made them one of the most successful computer manufacturers.

There are many other examples, but the important thing is that Just-in-time production changed the way companies operate and understand the business. This Lean philosophy allowed countless organizations to utilize their resources more effectively and achieve sustainability.

8.6 LEAN MANUFACTURING

Although manufacturing today looks quite different from the shop floors of the early to mid-twentieth century, many of the basic principles still hold true. These modern Lean manufacturing principles are helping organizations drastically reduce time to market, increase innovation, and add more value for their customers in a fast-paced and ever-changing global marketplace.

Why Lean Manufacturing?

In order to remain competitive, manufacturing organizations have to be in a constant mode of continuous improvement, finding ways to improve time to market (TTM) and increase innovation, while lowering costs, streamlining processes, and adapting new technologies. Lean manufacturing provides a holistic approach to systematically eliminating waste from processes and systems so organizations can sustainably deliver quality products more quickly to their customers.

The Principles of Lean Manufacturing

The following Lean manufacturing principles can be applied to virtually any industry and team type.

Optimize the Whole

There's a famous quote from Aristotle that applies well to Lean manufacturing: "The whole is greater than the sum of its parts." Lean manufacturing is rooted in systems thinking–the practice of studying the system and each of its individual parts, in order to make decisions that enable the organization to do its best work.

Otherwise, the value stream mapping exercise risks optimizing one part of the system at the cost of sub-optimizing another.

Optimizing the whole means:

Defining and visualizing the value stream and all of its respective parts

Forming cross-functional teams that work towards shared goals and objectives

Conducting strategic planning across the entire organization

Amplifying the voices of frontline workers / the people closest to the work

Making decisions with respect to the entire value stream

Eliminate Waste

In Lean thinking, waste refers to any activity, product, or service that does not add value to the customer. In Lean manufacturing, most of the waste comes from inefficiency; it's the excessive time, energy, labor, and money spent developing products that don't meet market demands. The Toyota Production System outlines eight types of waste, which can be a helpful model for identifying waste in an organization that is practicing Lean manufacturing principles:

Waste of overproduction	Producing more than is necessary
Waste of time on hand	Delays or idle time (often in handoffs between steps in the process)
Waste of transportation	Moving goods or materials from one place to another unnecessarily
Waste of processing	Happens when a poor process or tool results in more processing than is necessary
Waste of excess inventory	Purchasing materials or manufacturing products ahead of demand
Waste of movement	Unnecessary motion of materials, people, or products
Waste of making defective products	The effort involved in inspecting for and fixing defects; can be avoided by building quality into the system
Waste of underutilized workers	Not balancing capacity effectively; underutilizing some team members or teams while overburdening others

All of this process waste results in a more expensive and lower quality product for the customer.

Eliminating waste across the value stream, instead of at isolated points, helps manufacturers create processes that require less human effort, less space, less capital, and less time to deliver products and services that cost less and have fewer defects.

Deliver Fast by Managing Flow

Manufacturers have notoriously long design and production cycles, which equate to huge cost of delay and a crippling lack of agility. Some of this is due to the complexity of products or the liability involved, especially for auto or aerospace manufacturers. Some of it is due to a lack of organizational focus; many manufacturers produce hundreds of products, making it difficult to analyze performance or leverage feedback from customers to make meaningful improvements.

A key element of Lean manufacturing is that in order to deliver value quickly, companies must focus on managing the flow of ideas, products, services, and improvement efforts across their value streams.

In an industry where cost of delay can be measured in millions of dollars per day, improving flow with Lean manufacturing principles can make a significant impact on the bottom line.

A tangible and effective way to deliver faster is to implement WIP, or work-in-process, limits. WIP limits are fixed constraints that enable teams to stay focused on their top priorities. Instead of spreading their attention, energy, and time across hundreds of things at once, WIP limits encourage teams to focus on a handful of products at once and deliver them as quickly as possible.

This means that employees can dive deeper and add more value to the tasks at hand, which can improve job satisfaction and boost employee retention rates. This is especially important in an industry with a seasoned workforce and steep competition from the tech industry for top talent.

Practice Iterative Development

Iterative development is a hallmark of Lean software development and one of the key Lean manufacturing principles. Lean development is based on this concept: Build a simple solution, put it in front of customers, and enhance it incrementally based on customer feedback.

Build Quality In

Building quality and reliability into the design and manufacturing process is the accepted norm (or at least, goal) for manufacturers that are applying Lean manufacturing principles. For many companies, quality equals safety, which means things have to work correctly the first time. Generally, the approach to ensuring quality is to test defects out – to run rigorous tests to ensure that quality meets a certain predefined standard.

In recent decades, many Lean development teams have found success by applying the following Lean development tools to build quality into their work. In Lean development, quality is everyone’s job, not just QA’s.

Here are a few practical examples of the principle of building quality in:

Pair programming: Avoiding quality issues by combining the skills and experience of two developers instead of one

Test-driven development: Writing criteria for a product / feature / part before creating it to ensure it meets business requirements

Incremental development and constant feedback

Minimize wait states: Reducing context switching, knowledge gaps,

and lack of focus
Automation: Automate any tedious, manual process or any process prone to human error

Defer Commitment

Lean manufacturing principles apply as much to planning as they do to work that's in process. In fact, in a world where market realities can shift literally overnight, one of the greatest sources of waste is planning. This is not to say that Lean organizations do not plan–but they do avoid spending time creating extensive, detailed plans that might never happen.

The Lean principle of Defer Commitment says that Lean organizations should function as just-in-time systems, waiting until the last responsible moment to make irreversible decisions. To use an analogy, instead of writing books of plans for years ahead, Lean organizations draft up outlines, and fill in the bullets as they go. Doing this allows Lean manufacturers to maintain the agility to make informed decisions, with the most relevant, up-to-date information available.

Create Knowledge

A Lean organization is a learning organization; it grows and develops by analyzing the results of small, incremental experiments. One of the Lean manufacturing principles that emphasizes learning over perfection is the action of "creating knowledge," which encourages transparency and thoughtful experimentation.

Respect for People

A seasoned workforce and competition for top talent from tech companies are forcing manufacturers to change their talent management philosophies to nurture a culture of innovation.

Top engineering candidates are seeking work experience that is as stimulating, engaging, challenging, and enriching as the tech-enabled world they live in. These candidates know they can get a high salary, good benefits, and startup-y perks anywhere – what they really crave is to do meaningful work in a forward-thinking organization that is making a difference in the world.

Embracing the Lean concept of respect for people, as many tech companies have, could be key to fulfilling this lofty vision. In this case, respect for people means that organizations do everything they can to create value for both prospective and existing employees. This means finding ways to attract and retain new talent by adding value to their experience. It also means supporting existing employees through cultural adjustment.

Advantages of Lean Manufacturing

1. Waste Minimization

Lean manufacturing can efficiently minimize waste within a production facility. This is arguably the most significant benefit of lean manufacturing. Waste is defined by any activity that does not add value to the process. Common waste areas include: motion, inventory, waiting, overproduction, defects, transportation, and over-processing. As companies sit on large amounts of inventory and waste, this process eliminates outdated or aged inventory. In addition, this process reduces the costs within the operation.

2. Enhanced Customer Relationships

Lean focuses on loyal customers' concerns and suggestions to cut some wasteful processes. Rather than focusing on the needs of all customers, companies are able to focus on their loyal customers to build strong and reliable relationship. This way, your customer interactions will improve and the relationships with your trusted customers will offer a steady flow of revenue coming in.

3. Lean Infrastructure

A lean infrastructure means that you are only dealing with a few components: building, tools, supplies, equipment, and labor to fulfill near-term inventory demand. The facility does not waste space within the operation and enables the facility to come as close as it can to production efficiency.

Disadvantages of Lean Manufacturing

1. Equipment Failure

Lean has very little room for error. Equipment or labor failure can lead to major inconsistencies and can make the entire operation fall behind. In other mass production facilities, employees could move from one machine to another in the event of a breakdown. In lean, there are not many other places for employees to move to because everything within the operation is being utilized. In addition, the breakdown of a machine must be fixed immediately as there are usually no alternative resources that can do the work. This is why it is important to stay on top of all machine maintenance and inspections.

2. Delivery Inconsistencies

In correlation with equipment failure, lean manufacturing can lead to delivery inconsistencies. Using lean techniques means that you have a smaller error margin. If your supply deliveries are late, you may not have enough raw materials to meet your customer demands, leading to late deliveries. This disadvantage can hinder customer relationships, push customers towards your competitors, and cost you revenue.

3. Employee Dissatisfaction

Adopting lean manufacturing processes requires change among employees to more efficient production processes to ensure that quality products are being made. This can be risky if employees reject the new methods. Having good managers that can help support and persuade the change from one technique to another can be helpful.

Lean Manufacturing vs Just in time manufacturing

Just in time is a system and idea with has seen wide acceptance within the business and manufacturing community. When the competition is heated up between companies and the pressure from Asian manufacturers' continuous cultural improvement takes a toll on manufacturers. This forces the firms to seek more innovative methods to reduce costs and cope with the competition.

The tendency has been there to identify or include JIT with Lean operations. Of course, there are similarities between the two; there are also some differences between the two methodologies. This means that they play perfectly well together and there are many advantages of using both methodologies at the same time.

In JIT methodology, the processes exhibit some level of stability and consistency. Stability means a decrease of systematic errors in this case and the results gained must remain quite consistent. This is not that easy to achieve at the beginning of the Lean initiative. The objective of JIT is to highlight all the problems in the process. Lean focus to eliminate the problems relating to the process so as to increase production.

JIT has the fundamental component of eliminating waste along with adding value. A firm must monitor series of processes as a target to minimize waste. Value is not added with things like unreasonable waste times, exaggerated inventories, excess manpower, and unnecessary movement of material or any other activity.

JIT alone is not effective to eliminate waste completely as manufacturers realized that items were brought only when they are needed and in required quantities is only one part. The need for JIT to become Lean is always there. Lean has its own range of specific procedures. The task of lean is to define a project that will be beneficial at minimal costs. Lean's focus is on manufacturing and operations management whereas JIT focuses more on inventory management. The two methodologies share some tools and all aim at creating value for the end-user, the customer. Generally, Lean tools are now often used to achieve JIT, such as the 'flow' based approach.

Similarities Between Just-in-Time and Lean Manufacturing

Cornerstone to JIT and lean manufacturing methodologies is the need to eliminate waste and improve efficiency. In both philosophies, waste equates to anything that doesn't add value to the customer.

By removing unnecessary items like excess inventory or the need for production storage, throughput is optimized for faster delivery throughout the production process.

Another similarity between JIT and lean manufacturing involves the priority on customer demand. This begins by understanding what the customer actually wants.

A major challenge faced by manufacturers is creating an accurate, real-time picture of where components are in the manufacturing cycle. With product variety expanding, delivery times shortening, mounting financial pressures and increasing customer demand and expectations, manufacturers must innovate or risk falling out of the competitive race altogether.

JIT and lean both fit in today's emphasis on agility as well as the notion that supply chains and manufacturing processes must be responsive, flexible, and dynamic. This is critical to providing customer value throughout the manufacturing and inventory process.

This type of agility and visibility can be achieved with the right solution. Mobile data collection and manufacturing enablement solutions can help automate out dated paper processes and workflows. In addition, they can integrate existing business applications, create end-to-end material visibility, and empower real-time access via mobile devices.

Summary

Lean production has truly changed the face of manufacturing and transformed the global economy. Originally known as just-in-time (JIT); it began at Toyota Motor Company as an effort to eliminate waste (particularly inventories), but it evolved into a system for the continuous improvement of all aspects of manufacturing operations. Lean production is both a philosophy and a collection of management methods and techniques. The main advantage of the system is derived from the integration of the techniques into a focused, smooth-running management system.

In lean systems, workers are multifunctional and are required to perform different tasks, as well as aid in the improvement process. Machines are also multifunctional and are arranged in small, U-shaped work cells that enable parts to be processed in a continuous flow through the cell. Workers produce parts one at a time within the cells and transport parts between cells in small lots as called for by subassembly lines, assembly lines, or other work cells. The environment is kept clean, orderly, and free of waste so that unusual occurrences are visible.

Schedules are prepared only for the final assembly line, in which several different models are assembled on the same line. Requirements for component parts and subassemblies are then pulled through the system with kanbans. The principle of the pull system is not to make anything until requested to do so by the next station.

The “pull” system will not work unless production is uniform, setups are quick, and lot sizes are low. The pull system and kanbans are also used to order materials from outside suppliers. Suppliers are fewer in number and must be very reliable. They may be requested to make multiple deliveries of the same item in the same day, so their manufacturing system must be flexible, too. Deliveries are made directly to the factory floor, eliminating stockrooms and the waste of counting, inspecting, recording, storing, and transporting. Lean production does not produce in anticipation of need. It produces only necessary items in necessary quantities at necessary times.

Inventory is viewed as a waste of resources and an obstacle to improvement. Because there is little buffer inventory between workstations, quality must be extremely high, and every effort is made to prevent machine breakdowns. When all these elements are in place, lean systems produce high-quality goods, quickly and at low cost.

These systems also are able to respond to changes in customer demand. Lean production systems are most effective in repetitive environments, but elements of lean can be applied to almost any operation, including service operations. Lean retailing, lean banking, and lean health care are good examples.

Key Words

Andons call lights installed at workstations to notify management and other workers of a quality problem in production.

Breakdown Maintenance a maintenance activity that involves repairs needed to make a failed machine operational.

External Setup setup activities that can be performed in advance while the machine is operating.

5 WHY’S: repeatedly ask “why?” until a root cause is identified.

Internal Setup setup activities that can be performed only when the machine is stopped.

Jidoka authority given to the workers to stop the assembly line when quality problems are encountered.

JUST-IN-TIME (JIT) smoothing the flow of material to arrive just as it is needed; evolved into a system for eliminating waste.

Kaizen a Japanese term for a system of continuous improvement.

Kanban a card corresponding to a standard quantity of production (or size container) used in the pull system to authorize the production or withdrawal of goods.

Kanban Square a marked area designated to hold a certain amount of items; an empty square is the signal to produce more items.

Lean Production both a philosophy and an integrated system of management that emphasizes the elimination of waste and the continuous improvement of operations.

Lean Six Sigma a combination of lean's principles for eliminating waste with Six Sigma's reduction of variability. manufacturing cell a group of dissimilar machines brought together to manufacture a family of parts with similar shapes or processing requirements.

Material Kanban a rectangular-shaped kanban used to order material in advance of a process.

muda anything other than the minimum amount of equipment, materials, parts, space, and time that are absolutely essential to add value to the product.

Pull System a production system in which items are manufactured only when called for by the users of those items.

Push System a production system in which items are manufactured according to a schedule prepared in advance.

Signal Kanban a triangular kanban used as a reorder point to signal production at the previous workstation.

Supplier Kanban a kanban that rotates between a factory and its supplier. take time the cycle time of an operation paced to the rate of customer demand.

Total Productive Maintenance (Tpm) an approach to machine maintenance that combines the practice of preventive maintenance with the concepts of total quality and employer involvement.

- **Check Your Progress**

1. What is JIT and why is it evolved?
2. Discuss various benefits of JIT.
3. What are the requirements for implementing the JIT?
4. What are the potential risk associated with JIT implementation?
5. Discuss various application of JIT.
6. What is the purpose of lean production?
7. How did lean production evolve into a system of continuous improvement?
8. Why are flexible resources essential to lean production?
9. What does a cellular layout contribute to lean production?
10. Differentiate between a push and a pull production system.
11. How are lean production and quality related?
12. What are the various principles of lean manufacturing?
13. In what type of environment is lean production most successful?
14. Give examples of lean services.
15. Lean has been applied extensively in the automobile industry. Report on other industries who use lean production.

UNIT : 9 SERVICE DESIGN & SERVICE BLUEPRINTING

9.1 PRODUCT AND SERVICE PRODUCT

Product

"Anything that can be offered into the market for attention, acquisition or consumptionand that might satisfy individual needs and wants" – **Dr. Philip Kotler**

Service Product

"A service product comprises of all of the elements of the service performance, bothphysical and tangible, that create value for customers." **- Dr. Christopher Lovelock**

Planning and creating the Service Product can be seen majorly by designing theService Concept.

9.2 DESIGNING SERVICE CONCEPT

Service Concept can be further designed in 4 different ways.

1. Core Benefits
2. Supplementary Benefits
3. Delivery Processes
4. Delivery Sequence over time

9.2.1 Core Benefits

- Core Product is the central component that provides principal or problem-solvingbenefits that customers seek.
- Core product is mainly a primary or basic benefit which customers at least seekfrom any particular service.
- E.g. **Transportation Services** satisfies the need of a person to move from one place to another, **Management Consulting Service** gives expert advice, **Repair Service** gives the client good conditioned equipment from damaged / non-workingequipment.

9.2.2 Supplementary Benefits

- Delivery of core product is usually accompanied by a variety of other service-relatedactivities referred to collectively known as Supplementary services.
- Supplementary Services are mainly provided with core products.
- Supplementary Services mainly augment (improve) core products, facilitate their useand add value to the products.
- Supplementary services also increase the brand image of the company as well as itappeals to the customers to buy the services. Also providing supplementary services gives a firm a competitive advantage over competitors.

9.2.3 Process of Delivery

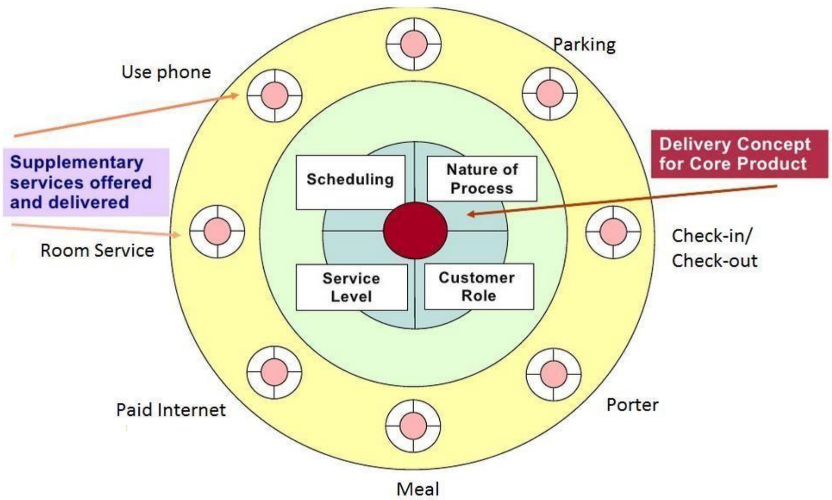
- Delivery processes are mainly used to deliver both the core product as well assupplementary products.
- Delivery processes mainly address the following issues.

How different components of service will be distributed to customers?

- ✓ The nature of the customer's role in service (People, Possession, Mental Stimulus,Information Processing)
- ✓ How long the service will last?
- ✓ The level & style of service to be offered to the customers
- ✓ The following figure will explain to us the combination of all core products, supplementary services and delivery processes used to deliver a service of an overnight stay at the hotel of the customer.

Here in the following diagram,

- Overnight rental of a hotel room is the level of the service
- How long the room shall be occupied by him shows the scheduling part
- People processing is the nature of service
- What elements of services are performed by customers shows their role inservice delivery Reservation



Source: Adopted from "Service Marketing, 7th Edition, and Christopher Lovelock et. al

9.2.4 Service Sequencing

A very important part of service process design is the sequence in which customers will use each of the core & supplementary services and also, and they decide the approximate length of time required in each of the core & supplementary elements.

By creating the delivery sequence, a service provider can know the needs, habits, patterns and expectations of the customers and accordingly, they can allocate their resources, can do planning and human resource management accordingly.

Service Blueprinting

9.3 INTRODUCTION TO SERVICE BLUEPRINTING

Services are made up of processes. Service Process means a definite sequence of activities and a method in order to create value that has been promised to the customers. It is one of the 7Ps of service marketing.

Services can differentiate on many numbers of factors. One of the very important factors in differentiating services from competitors is to create and deliver a better service through a better process. For example, a hotel stay or a dentist appointment can differentiate each other in many ways, but a distinctive characteristic among them is how services are created and delivered to the customers. It is therefore important to study how is service process designed (and redesigned) in order to create and deliver value to the customers.

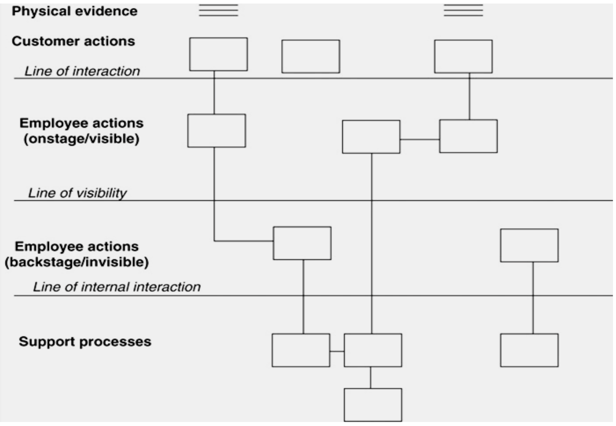
9.4 DEFINITION OF SERVICE BLUEPRINTING:

"A service blueprint is a picture or a map that accurately shows how service will be created anddelivered".

A service blueprint is a tool for simultaneously depicting the service process, the points of customer contact, and the evidence of the service from the customer's point of view. All the components of the service are shown in a flowchart. This detailed flowchart is known as Service Blueprint and the process of creating the service blueprint is known as service blueprinting.

The service blueprint technique was first described by Lynn Shostack, a bank executive, in the "Harvard Business Review" in 1984. The blueprint shows processes within the company, dividedinto different components which are separated by lines as shown in the figure below. It consists of drawing a detailed flowchart of the service. A flowchart describes an existing process in a simple form, but a blueprint specifies in some detail how a service process should be constructed. An important tool to design new services or redesign existing services is known as blueprinting.

9.5 VARIOUS COMPONENTS OF SERVICE BLUEPRINT



To develop a service blueprint, we need to identify all the key activities/components involved in creating and delivering the service and then specify the link between these activities. Let us first understand the key components of the service blueprint. There are five components of a service blueprint. They are;

1. Customer action
2. On stage contact employee action
3. Backstage contact employee action
4. Support process
5. physical evidence

The above 5 key action areas are separated by 3 horizontal lines and a vertical line. Theyare;

1. Line of interaction
2. Line of visibility
3. Line of internal Interaction
4. Vertical line cutting across

Customer Actions:

These include all the steps a customer takes during the service delivery process. In a Service Blueprint, customer actions are usually shown in a sequence, from start to finish. Customer actions are most important to the Service Blueprint, so they are described first.

Onstage Actions (visible actions taken by employees):

Onstage visible actions by employees are face-to-face contact with the customer during the service delivery. These are separated from the customer by the line of interaction. Each time the line of interaction is crossed through an interaction between a customer and a contact employee (or self-service technology), a moment of truth occurs. During these moments of truth, customers judge your quality and make decisions regarding future purchases.

Backstage Actions (Taken By Employees That Are Not Visible To The Customer) :

The next part of the Service Blueprint is the "backstage" invisible actions of employees that impact customers. Actions here are separated from onstage service delivery by the line of visibility. Everything above the line of visibility is seen by the customer while everything below it is invisible.

Support Processes:

The fourth critical component of a Service Blueprint is the "support processes" that customer contact employees depend upon to effectively interact with the customer. These processes are all the activities contributed by employees within the company who do not contact customers.

Physical Evidence:

Finally, for each customer moment of truth, the physical evidence of the service delivery at each point of customer contact is recorded at the top of the blueprint.

The following figure is an example of a blueprint of an overnight hotel stay by a customer. It shows all the steps customers and employees undertake when service is being delivered.

Creating a Script for Employees and Customers

A well-planned script can provide a full description of the service encounter and can help in identifying potential or existing problems in a specific service process. By examining the scripts, service managers can discover different ways to modify customers' and employees' roles to improve service delivery, increase productivity, and enhance the nature of customer'sexperience.

Identifying Fail Points

A good blueprint should draw attention to points in services where the failure risks are bigger. From a customer point of view, the most serious failure points are in enjoying the core product.

Setting Service Standards

Through research and experience, service managers can learn the nature of customer expectations at each step in the process. Service providers should design standards for each step that are sufficiently high to satisfy customers; if that is not possible, they will need to modify customer expectations. It's important to remember that standards must be measurable.

Failure Proofing Can Improve Reliability of Service Process

Services might fail due to the following types of errors;

treatment errors human failures during contact with customers tangible errors failures in physical elements of service. These errors must be carefully studied, analysed and reduced in order to make sure that service does not fail. This is known as fail proofing of services. Careful analysis of the reasons for failure in service processes often reveals opportunities for "failure proofing" certain activities in order to reduce or even eliminate the risk of errors. Fail-safe methods need to be designed not only for employees but also for customers.

9.6 ADVANTAGES / IMPORTANCE / BENEFITS OF SERVICE BLUEPRINT

The service blueprint is helpful to the service provider because it;
Provides a customer orientation overview

- It provides an idea to the employees about how they are related to the delivery of theservice and what they have to perform at each step.
- Identifies Fail points- weak links in the chain of service activities
- Acts as the basis for identifying costs, revenues, and capital investment required
- Facilitates top-down, bottom-up approach to quality improvements.
- If a service blueprint is created, it helps in all the stages of service creation and delivery. Hence, we can say that blueprints can be helpful in designing, implementing and communicating services to customers. Service blueprints are helpful.

For designing:

- It helps in the development of new services, assessment and improvementof existing services
- It helps in calculating the time and cost required for the service delivery.
- It helps in the comparison of differences in basic services and standards.
- It helps in testing assumptions on paper to identify failure points andthoroughly solve the problems
- It helps in cutting down time and inefficiency of random service development

For implementing:

- Becomes a reference for planning and change
- Forms a common point of reference for all parties (project team, affected staff and management) concerned with achieving a successful launch – also serves as the focal point for last-minute changes
- Can be stored electronically for later reference, available for everyone involved

- Facilitates comparison of the desired and actual service

As a communication tool:

- It provides a focus for conversations
- It is more precise than verbal descriptions.
- There are Fewer chances of misinterpretation
- It can be a formalized way to inspire corporate-wide change directed at integratingcustomer focus across the organisation
- It can help convince the organisation that changes are in order.

9.7 PROCESS TO DEVELOP A SERVICE BLUEPRINT

The following are the steps necessary to create a service blueprint;

1. Identify the service process to be blueprinted
2. Map the service process from the customer's point of view
3. Map Contact Employee Actions – Onstage - **Line of External** Interaction Backstage – **Line of Visibility** what customers should see and which employees are in contact with the customers.
4. Map Internal Support activities- **Line of Internal Interaction** clarify interfaces across departmental lines, their inter dependencies
5. Add Evidence of Service at each Customer Action Step

❖ **Check Your Progress**

- **Long Answer Questions:**

1. Distinguish between product and service. Also, explain how to design the service.
2. Define Service Blueprint. Discuss various components of a service blueprint with the help ofskeleton structure of a service blueprint.
3. Explain the various advantages of a service blueprint.

- **Short Notes:**

1. Supplementary services
2. Advantages of Service Blueprint
3. Designing Service Concept

- **Short Questions:**

1. Define service.
2. Define service product.
3. What do you mean by supplementary benefits?
4. Differentiate between core benefits and supplementary benefits.

5. What do you mean by service blueprint?
6. Mention any three advantages of a service blueprint.
7. What is the role of support processes in service blueprint?
8. What is physical evidence?
9. What is the relevance of physical evidence in service blueprint?
10. What do you mean by line of visibility?

❖ **Multiple Choice Questions:**

1. Anything that can be offered into the market for attention, acquisition or consumption andthat might satisfy individual needs and wants is known as?

A. Product B. Price C. Distribution D. None of these

2. A______________comprises of all of the elements of the service performance, both physicaland tangible, that create value for customers.

A. Service B. Service Product

B. Service Promotion D. None of these

3. Delivering__________the basic product increases the value in the service.

A. Supplementary Benefits B. Core Benefits

C. Core and Supplementary Services D. Potential Product

4. If a college is providing a wi-fi facility to students then the wi-fi facility is considered a?

A. Supplementary Benefits B. Core Benefits

C. Core and Supplementary Services D. Potential Product

5. Service blueprint is a part of the service _______.

A. Product B. Operation C. Price D. Distribution

6. In a service blueprint, the line that lies between consumer actions and visible employees isknown as?

A. Line of Visibility B. Line of Interaction

C. Line of Internal Interaction D. None of these

UNIT : 10 GREEN MANUFACTURING & ETHICS IN OPERATIONS

10.1 INTRODUCTION TO CONCEPT OF GREEN MANUFACTURING:

Manufacturing is an activity involvedinton turning raw materials to finished products by some desired process to be used for some useful purpose.

In this global world environment, resources and population are major problems. Environment is crucial one with and a change in climate at any point leads to the imbalance of the earth. The main era is to minimize the environmental damage due to industries. There is a need of new manufacturing process i.e. Green Manufacturing which is suitable a sustainable development strategic X.C.Tan.,et.al(.2002).

The concept of "Green for growth" states that, with an increase in Global warming industrial wastes, non-biodegradable production; green is becoming an important strategy in the manufacturing sector. This gives rise to the concept of Sustainability in green manufacturing as a competitive tool.

10.2 MEANING AND DEFINATION

Green stands for ecological sustainability and encompasses many different concerns including, but not limited to, air, water and land pollution, energy usage and efficiency, and waste generation and recycling. Green initiatives aim to minimize the impact of human activities on the environment.

Definitions of Green manufacturing:

Green manufacturing is method of manufacturing that minimizes waste and pollution. These goals are often achieved through product and process design.

Green manufacturing is the renewal of production processes and the establishment of environmental-friendly operations within the manufacturing field. Essentially, it is the "greening" of manufacturing, in which workers use fewer natural resources, reduce pollution and waste, recycle and reuse materials, and moderate emissions in their processes.

It is basically an economized manufacturing process that tends to exploit all the available resources leaving behind reusable or consumable (bio-degradable) waste and thus reliving the concept of environmental sustainability. It is a term used to describe manufacturing practices that do not harm the environment during any part of the manufacturing process.

10.3 NEED FOR AND IMPORTANCE OF GREEN MANUFACTURING

Categories for society's rising concern for Green can be grouped as:

1) Rising emissions and associated climate change
2) Fast depletion of scarce natural resources

3) Growing waste generation and pollutionTransformation to Green Manufacturing

Manufacturing companies can address these concerns by focusing on three areas:

1) Green energy

Green energy involves the production and use of cleaner energy. This is the first and most obvious step given the dependence of industry on energy. Green energy includes deploying renewable energy sources like CNG, wind, solar and biomass, and achieving higher energy efficiency in operations.

2) Green products

Developing greener products is the second step in this transformation. 'Recycled', 'Low carbon footprint', 'Organic' and 'Natural' are becoming popular buzzwords which are associated with Green products. Developing Green products can often mean higher costs. However, by developing Green products that are sought by consumers, and effectively marketing them, companies can derive additional volumes and price premiums, which can offset their cost of development.

3) Green processes in business operations

The third area is implementing Green processes in operations. This entails efficient use of key resources, reducing waste generation through lean operations, bringing down the carbon print and conserving water. Employing Green processes improves operational efficiency and lowers costs.

10.4 FORCES DRIVING GREEN MANUFACTURING

A number of companies have started adopting Green initiatives as an integral part of their operations. These initiatives are driven by five factors:

- Rising energy and input costs
- Growing consumer pull for Green products
- Increasing regulatory pressures as policy makers introduce new and stricter environmental and waste management laws
- Technological advances which open up new attractive business opportunities
- The need to enhance competitive differentiation, particularly for first movers or those who are able to break the compromise between short–term higher costs and numerous benefits (for example: brand premium, new customer segments)

10.5 GOALS OF GREEN MANUFACTURING

The purpose is to support future generations by attaining sustainability by the means of preserving natural resources.

It emphasises manufacturing processes that do not pollute the environment or harm consumers, employees, or other members of the community.

It stresses reducing parts, rationalizing materials and reducing components, to help make products more efficient to build.

It highlights the road map of the industries for achieving performance improvement through sustainable development and its impact on organizational competitive outcomes.

10.6 HOW DOES GREEN MANUFACTURING WORKS?

The practical aspect for the working of green manufacturing can be described as follows:

1) Rethink product and process innovation technology development programs to includesustainable consumption factors.
2) Explore the market potential of substituting traditional products with new environmental services in repair (including upgrading), recycling and remanufacturing.
3) Supply goods and services with a product declaration containing information on key environmental parameters (e.g. durability, reparability, energy and water use, toxic contents).
4) Extend producer responsibility, through increasing product life spans and improved after-sales provision, followed by upgrading, reuse or recycling.

REAL WORLD EXAMPLES: The examples are based on the thought of reducing the use of non renewable or exhaustible source of energy and developing alternative source of energy as mentioned below:

1. **The need for fossil fuels has to lead to discoveries of different methods of manufacturing that replace renewable resources.**
2. **Manufacturers have started the production of Bio-Degradable poly bags as an alternative of that of**

conventional poly bags which were Non-bio-Degradable.

10.7 GREEN MANUFACTURING STRATEGIES AND PRACTICES

Strategic practices specify how to utilize GM practices to compete in the market and how these practices will be implemented and sustained. These may be typically a set of objectives, environmental awareness plans and policies established by top management. A sustainable strategy involves planning to reduce a company's environmental footprint. This implies using resources efficiently and effectively, categorisation of products for 4R, optimise raw material use, and energy saving. Green manufacturing requires a systems-level approach that starts with a strategic plan, which identifies goals, sets targets, and monitors progress.

The various green manufacturingpproaches/methodology/strategies issues and their references are as under.

Green manufacturing practices:

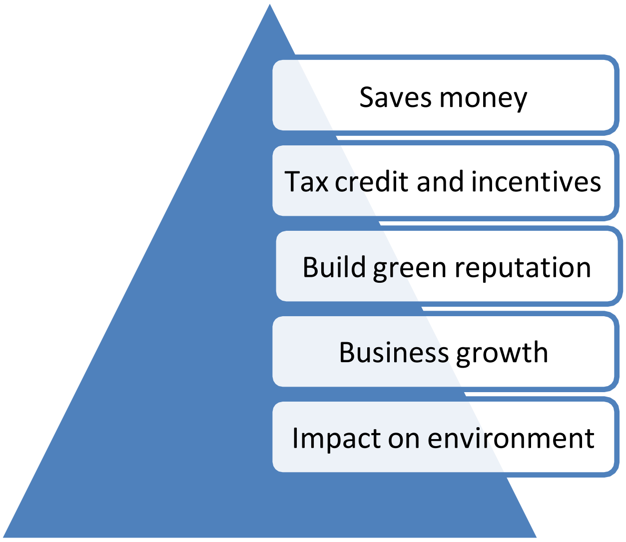
1. *Energy from renewable sources.* Workers may generate electricity, heat, or fuel from renewable sources for use within their establishment. These sources may include wind, biomass, geothermal, solar, ocean, hydropower, landfill gas and municipal solid waste.
2. *Energy efficiency.* Workers will utilize specific technologies and practices to improve energy efficiency within their establishment.
3. *Pollution reduction and removal, greenhouse gas reduction, and recycling.* Workers will use green technologies and practices to:
    - Reduce or remove the creation or release of pollutants in their operations
    - Reduce greenhouse gas emissions
    - Reduce or eliminate the creation of waste materials
    - Collect, reuse, recycle or compost waste materials
4. *Natural resources conservation.* Workers will use specific technologies and practices to conserve natural resources, such as those related to organic agriculture, land management, and soil, water, or wildlife conservation.

10.8 BENEFITS AND CHALLENGES OF GREEN MANUFACTURING

Manufacturers today face a range of pressures that force them to look for effective ways to improve the quality of their goods, while also looking for ways to cuts costs. For many of these companies, the mere thought of going green seems nearly impossible. The fact is, however, that as the pressure keeps building from consumers and the government, many manufacturers are left without a choice.

These benefits can actually help to boost sales while lowering overall operating costs. It is the realization of these great benefits that has enticed numerous companies to make environmentally- friendly changes in their workplaces.

Below (Fig: 1) is a look at the top 5 benefits of green manufacturing.



Save Money

If planned out carefully, many green changes in the workplace can help reduce the manufacturer's overall operating costs. Things like solar and wind energy, along with energy-efficient equipment and machinery, can help greatly reduce money utility bills. In addition, green manufacturing strategies, such as recycling and going paperless can save on supply costs. When looking at the bottom line, green manufacturing investments can provide a great ROI.

Tax Credits and Incentives

To help companies make the switch to green manufacturing alternatives, the government has developed a series of tax credits and incentives to help manufacturers offset the costs of implementing green policies. These credits are offered at both the federal and state level, so the exact incentives offered may vary by state. In addition, many utility companies also offer certain incentives and rebates for green manufacturers.

Built a Green Reputation

With so many consumers today concerned about the environment, making the choice to go green can help boost the manufacturer's reputation. Companies can easily rebrand their green manufacturing image to entice a whole new customer based to their goods. This can certainly help to increase the manufacturer's overall sales.

Business Growth

Competition among manufacturers to win various governmental bids is very fierce, but just one government contract can be a great benefit for the company. Making the decision to go green, can not only help improve the chances of earning the contract but it may also many manufacturers eligible for more types of governmental contracts. This is because some contracts are limited to only working with companies that meet certain green manufacturing standards.

Impact on the Environment

There is no doubt that making green manufacturing choices will have a positive impact on the environment. It will allow the manufacturer to have a smaller carbon footprint and reduce the number of toxins released into the atmosphere. This lets that manufacturer know that they are making the right decisions to protect the environment and keep it safe.

Many manufacturers have already made the decision to go green and the majority of these are reaping all of the benefits listed above. Between the tax benefits, incentives, reduction in costs, and a boost in sales, green manufacturing may no longer be just an option but may be a necessity for any manufacturer hoping to stay competitive in today's market.

10.8.1 Advantages and Disadvantages of Green Manufacturing

When a business makes the decision to become a green, or environmentally friendly, manufacturer, it consciously decides to promote certain values. These values centre on the goal of protecting the environment but can also focus on things such as technological innovation and progress.

Benefiting the Environment: Green manufacturing can directly benefit the environment. For example, green manufacturing can help to reduce waste and harmful emissions and work toward preserving resources that are finite and nonrenewable. Many customers want to support businesses that implement green manufacturing, so by implementing this process, a business can also gain new customers.

Benefiting the Business: Because of the public's consensus about the need to protect the environment, a company can directly improve its public relations by implementing green manufacturing. Additionally, this process can lower costs for the business over the long term through the implementation of more efficient systems and fostering of a company culture dedicated to innovation in processes. Further, these more efficient processes can result in lowering the amount of waste a business produces.

Surviving the Transition: One of the disadvantages of green manufacturing a business can experience relates to the transition to green manufacturing. Businesses will need to locate funding sources to finance the switch to green manufacturing. Although the process should ultimately save the business money, in the short-term implementing green manufacturing can cost a business significant amount of money. Further, the transition generally requires not only the implementation of new manufacturing processes but also the ability to design and build the necessary technology and machinery to support green manufacturing. Additionally, a business will typically have to find new talent to come in and educate current employees on how to work in the new green manufacturing environment.

International Trade Disadvantages

Another potential disadvantage to going green relates to international trade. Many businesses hesitate to implement a green manufacturing system because they fear that this process will become an impediment to the free flow of goods and profitable trade deals. This hesitation can apply to a wide range of manufactured products and industries. For example, a business might hesitate to implement green manufacturing because it fears losing an international supplier that does not participate in green manufacturing.

10.9 PRESENT SCENARIO AND IMPLEMENTATION

Currently green manufacturing is been practised green manufacturing invarious industries like Power Generation, Transportation, emerging technologies like carbon sinks, efficient fuels, solar applications in industries, green production methods in traditional industries like steel and cement etc.

We can promote greener products by phasing out harmful subsidies, reforming policies and incentives, strengthening market infrastructure, introducing new market-based mechanisms, redirecting public investment, and greening public procurement.

Implementation of Green marketing:

There is a lack of awareness both from the industry as well as the consumer segment. It can be implemented in a systematic three tier framework as below:

A simple three-step implementation framework can be followed covering all three areas of action – Green energy, Green products and Green processes :

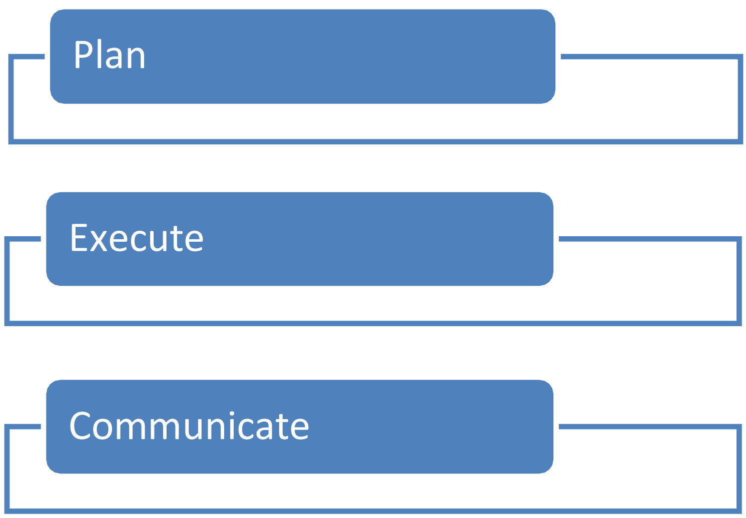


Fig.2

1) **Plan :** Green initiatives must be factored into the business strategy, future resource planning and budgeting exercises. For example, companies need to plan comprehensively to increase the use of Green energy, shift the product portfolio to Green products and overhaul business operations towards Green processes. A sustainability charter, based on short-term and long-term goals,

must be laid out with Green targets and metrics. Companies should develop Green indices or scorecards quantifying the impact of the Green initiatives they have undertaken, set specifictargets on those indices and track progress against those targets.

2) **Execute:** With a robust plan in place and targets clearly defined and monitored, Green needs to be integrated across the value chain and made a part of the core business.

- **Green Energy:** Manufacturing companies with high energy consumption need to shift towards using cleaner energy and planning for increasing the efficiency of its use. Setting up captive wind or solar power generation units and using energy-efficient practices, such as installing LED lighting or better use of daylight in building design, can go a long way towards reducing the energy intensity of operations.

Green products: To move towards a Green product portfolio, companies should conduct an evaluation of their products based on (a) how Green are the resources and energy being used, (b) how Green is the product during the lifecycle of its use, and (c) how Green is the manufacturing process. By quantifying these parameters, companies can assess the Green value of their productoffering. In the planning stage itself, companies should set out targets for this metric, and then periodically assess progress against those targets.

Green processes in business operations: Companies need to gradually redesign business

processes used in different parts of the value chain. This could include shifting to more sustainable manufacturing options, making changes towards reducing waste, increasing recycling, reusing resources and incentivising all suppliers, channels, customers and employees to adopt similar measures.

3) **Communicate:** Along with well thought–through implementation, a well-formulated promotion campaign for green initiatives is equally important to fully leverage their potential benefits. Customer education campaigns about Green product offerings and the Green orientationof the firm in terms of energy and processes, can translate into increased revenues.

CONCLUSION

- Adoption of Green Manufacturing technologies is not just a social obligation but a growth catalyst. It has the potential to achieve sustainable development and eradicate poverty. A green manufacturing economy substitutes clean energy and low-carbon technologies for fossil fuels, which addresses climate change, creates jobs and reduces import dependencies.

10.10 ETHICS IN OPERATIONS MANAGEMENT MEANING

Meaning of ethical behaviour:

"A company's ethical behaviour is the mirror image of its culture, a shared set of values and guiding principles deeply ingrained throughout the organization and the ethical behaviour and culture become part of the definition of corporate identity." (D'Amato, Henderson & Florence 2009)

10.11 OPERATIONS MANAGEMENT AND ETHICS

Although Ethics is covered under the section of the plan, it cuts across every aspect of the business. A Comprehensive look at operations management would not be complete without looking at ethics and operations management. Ethics is doing the right things the right way – Always. Almost every company has an Ethics Department and Ethics Statements. Just because a company has an Ethics Statement or Ethics Advisor does not mean that they are following ethical behaviour. Ethics is usually defined as doing the right thing.

One of the latest views of ethics concerns corporate responsibility and ethics. The Green Movement in businesses is an outcropping of that view. This view states that companies are responsible for the environment as part of their ethics. The Trinchero Family Wineries30 (http://tfewines.com/tfe-green/) took this concept to the next level. This company plants a tree for every bottle of wine that they sell. To date, they have planted over one million trees.

It has long been thought that a business should focus on its one and only goal: to make profits. It is also one of the biggest arguments people use when discussing on the matter of whether the business should operate in an ethical way. It is true that business managers should focus on their prime motive: satisfying their investors and shareholders. However, while operating, there will be times when managers and employees face situations in which they must make decisions which will reflect the corporate ethical culture and personal ethics.

10.12 IMPORTANCE OF BUSINESS ETHICS

a) Control business malpractices
b) Better relationship with employees
c) Improves customer satisfaction
d) Increase profitability
e) Improves business goodwill
f) Better decision making
g) Protection of society

10.13 FUNCTIONS OF BUSINESS ETHICS

1) Protect consumer rights
2) Enhance relations with the society
3) Safeguard interest of industry
4) Improves business goodwill
5) Assist in decision making

Ethics is a matter of right or wrong according to society. A business leader that compromises his or her ethics in the name of making a profit or personal gain compromises his or her ability to be a competent leader. There is no right way to do something that is ethically wrong. Unethical decisions usually lead to the corporate scandal which in turn leads to corporate ruin. The collapse of Enron in 2001 is a classic example of this sequence of events.
Unethical Decisions in business lead to corporate scandals which as we saw with Enron,leads to corporate ruin.

❖ **Case Study On Product Design, Ethics & Decision Making**:

In the 1970s Ford developed the Pinto. The Pinto was Ford's attempt to put an economy car on the Mustang chassis. The Pinto had two problems in the design of the car. The first was that it was a uni-body construction. When rear-ended, the doors could be jammed shut.

The second problem was worse. The Pinto apparently had a problem with the location of the gas tank at the rear of the car that would burst into flames when experiencing a rear-end collision. The problem was known but not fixed before the Pinto was introduced.

Ford's initial analysis showed that it would cost less than $10 per vehicle to fix the problem but instead decided to place $175,000 times the projected number of deaths into a trust fund to cover liability expenses. The final result was deaths and lawsuits and the removal of the Pinto from the Ford Fleet.

Therefore ethics is important in business decision-making and in product design. Ford took the easy wrong approach over the harder right approach.

Hence it is said that ethics is very critical in any business. Every decision made in business must be viewed from an ethical point of view.

Hopefully, this new ethical movement will not prove to be a fad but a true focus on ethicalstewardship of the environment.

- **Check Your Progress**

Short questions:

Q.1 Define the term Green manufacturing

Q.2 List down the forces driving green manufacturing

Q.3 List down the importance of business ethics

Q.4 How can you define the ethical behaviour of the company? Give real-life examples supporting the fact.

Long questions:

Q.1 Explain the goals of green manufacturing and green manufacturing practices

Q.2 Discuss the benefits and limitations of green manufacturing

યુનિવર્સિટી ગીત

સ્વાધ્યાયઃ પરમં તપઃ
સ્વાધ્યાયઃ પરમં તપઃ
સ્વાધ્યાયઃ પરમં તપઃ

શિક્ષણ, સંસ્કૃતિ, સદ્ભાવ, દિવ્યબોધનું ધામ
ડૉ. બાબાસાહેબ આંબેડકર ઓપન યુનિવર્સિટી નામ;
સૌને સૌની પાંખ મળે, ને સૌને સૌનું આભ,
દશે દિશામાં સ્મિત વહે હો દશે દિશે શુભ-લાભ.

અભણ રહી અજ્ઞાનના શાને, અંધકારને પીવો ?
કહે બુદ્ધ આંબેડકર કહે, તું થા તારો દીવો;
શારદીય અજવાળા પહોંચ્યાં ગુર્જર ગામે ગામ
ધ્રુવ તારકની જેમ ઝળહળે એકલવ્યની શાન.

સરસ્વતીના મયૂર તમારે ફળિયે આવી ગહેકે
અંધકારને હડસેલીને ઉજાસના ફૂલ મહેંકે;
બંધન નહીં કો સ્થાન સમયના જવું ન ઘરથી દૂર
ઘર આવી મા હરે શારદા દૈન્ય તિમિરના પૂર.

સંસ્કારોની સુગંધ મહેંકે, મન મંદિરને ધામે
સુખની ટપાલ પહોંચે સૌને પોતાને સરનામે;
સમાજ કેરે દરિયે હાંકી શિક્ષણ કેરું વહાણ,
આવો કરીયે આપણ સૌ
ભવ્ય રાષ્ટ્ર નિર્માણ...
દિવ્ય રાષ્ટ્ર નિર્માણ...
ભવ્ય રાષ્ટ્ર નિર્માણ

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