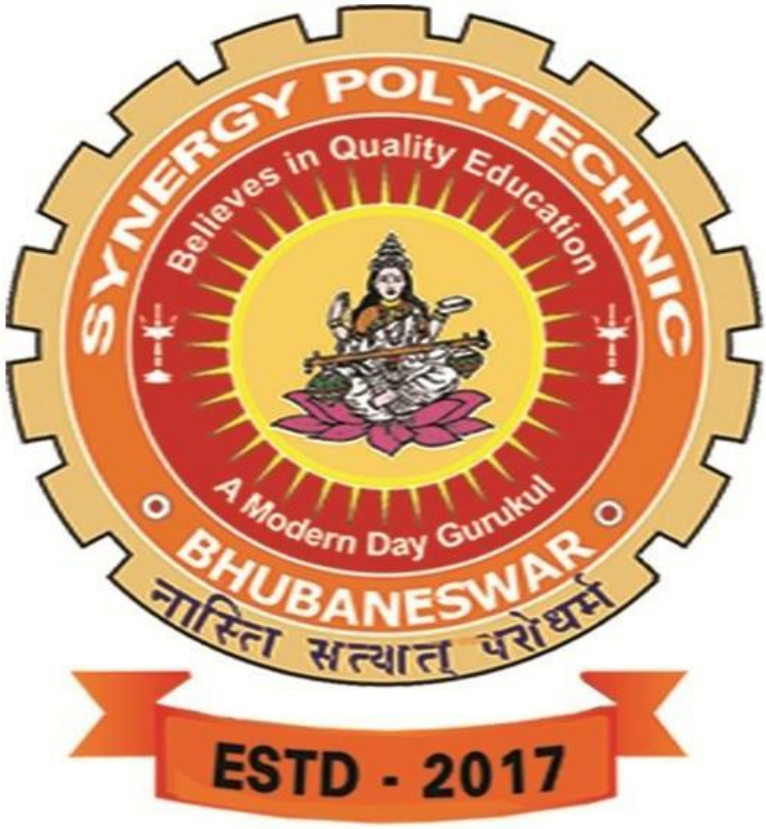

INDUSTRIAL ENGINEERING & MANAGEMENT

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6th Semester Diploma

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Plant Location

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Plant location is defined as that location which, in consideration of all the factors affecting product delivered-to-customers cost of products to be manufactured, will afford the enterprise the greatest advantages obtained by virtue of location.

The selection of location is the key-decision as large investment is made in building plant and machinery. It is not advisable or not possible to change the location very often. So an improper location of plant may lead to waste of all the investments made in building and machinery. Before a location for a plant is selected, a long range forecasts should be made for the anticipating future needs of the company.

Need for Selecting a Suitable location

1. When starting a new factory
2. In case of existing factory.

The existing factory will seek new locations in order to expand the capacity or to place the existing facilities. The increase in demand for the company's products can give rise to following decisions.

1) When ever to expand the existing capacity and facilities.

② When ever looking for new locations for additional facilities.

③ Whether to close down existing facilities to take advantages of some new locations.

Features governing plant location

① Proximity to markets: Every company is expected to serve its customers by providing goods and services at the time needed and at reasonable price organisations may choose to locate facilities close to the market or away from the market depending upon the product.

② Supply of raw material: It is essential for the company to get raw material in right quantity and quality and time in order to have an uninterrupted production. This factor becomes all the important if the materials are perishable and the cost of transportation is very high.

③ Transport facilities: Speedy transport facilities ensure timely supply of raw materials to the company and finised goods to the customers. The transport facilities are very important for a plant location.

There are five basic modes of physical transportation, Air, Road, Rail, Water and pipeline.

④ Infrastructure available: The basic infrastructure facilities like power, water and waste disposal etc becomes the prominent factors in deciding the location. The non availability of power, water and waste disposal becomes the survival problems for such industries.

⑤ Labour and Wages: The supply of labour at low cost is important. The importance of labour supply has not lessened inspite of automations and mechanisation.

⑥ Law and taxation: The policies of the state governments and local bodies concerning labour laws, building codes, safety etc are the factors that demand attention. In order to have a balanced regional growth of industries, both central and state governments in our country offers the package of incentives to companies and entrepreneurs in particular locations.

⑦ Suitability of land and climate: The geology of the area needs to be considered together with climatic conditions like temperature and humidity. Climate greatly influence

human efficiency and behaviors. Some industies required specific climatic conditions eg: textile mill will required humidity. Now with the developement in air-conditioning facilities the climatic conditions can be controlled but at a high cost.

⑧ Supporting Industries and Services:

In present World, the manufacturing companies will not make all the components and parts by itself and it subcontracts the work to vendors. So the sources of supply of components parts will be the one of the factors that influences the location.

⑨ Social infrastructure:

Availability of community facilites like ① Housing facility, ② Educational facilities ③ Recreational facilities ④ Medical facilities are considered while selecting a location.

Plant Layout

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

Objectives of plant layout

The objective of plant layout is the best relationship between output, space and the manufacturing cost.

Objectives

1) Streamline the flow of materials through the plant.

2) Facilitate the manufacturing process.

3) Maintain high turnover of in process inventory.

4) Minimise materials handling.

5) Effective utilization of men, Equipment and space.

6) Make effective utilisation of cubic space.

7) Flexibility of manufacturing Operations and arrangements.

8) Provide for employee convenience, safety and comfort.

Principles of Plant Layout

① Principle of integration: A good layout is one that integrates men, materials, machines and supporting services and others in order to get the optimum utilization of resources and maximum effectiveness.

② Principle of minimum distance: This principle is concerned with the minimum travel or movement of man and materials. The facilities should be arranged such that, the total distance travelled by the men and materials should be minimum as far as possible.

③ Principle of cubic space utilisation:

The good layout is one that utilise both horizontal and vertical space. It is not only enough if only the floor space is utilised optimally but the 3rd dimension ie, the height is also to be utilized effectively.

④ Principle of flow: A good layout is one that makes the materials to move in forward direction towards the completion stage. ie: there should not be any backtracking

⑤ Principle of maximum flexibility:

The good layout is one that can be altered without much cost and time. So the future requirments should be taken into account while designing the present layout.

⑥ Principle of Safety and security and satisfaction:

A good layout is one that gives due consideration to workers safety and satisfaction and satisfaction and safeguards the plant and machinery against fire, theft etc.

⑦ Principle of minimum handling: A good layout is one that reduces the material handling to the minimum.

Factors influencing Plant layout

1) Type of production → Engineering industry, process industry.

2) Production system → Job shop, batch production mass production.

3) Scale of production

4) Availability of the total area.

5) Arrangement of material handling system.

6) Types of building → Single storey or multi-storey.

7) Future expansion plan

8) Type of production facilities → dedicated or general purpose.

Types of Plant Layout

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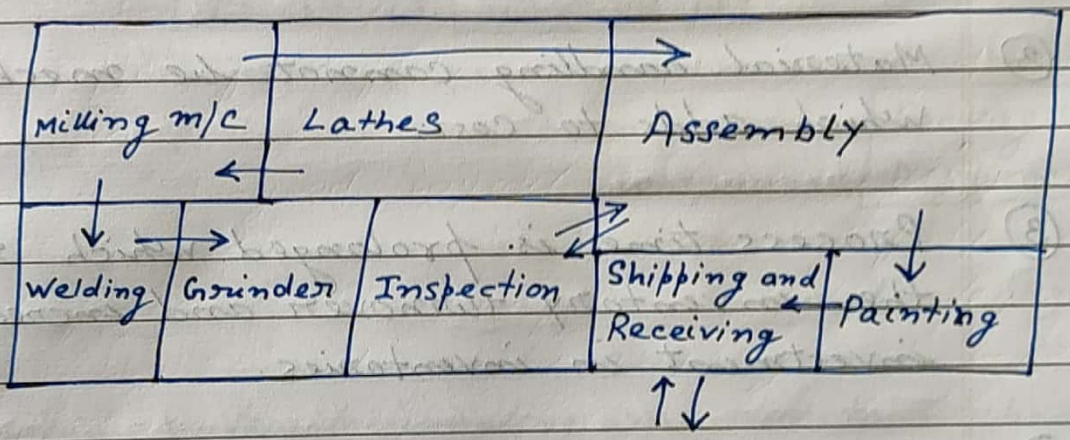
① Functional Layout (Process Layout)

This layout is recommended for batch production. All machines performing similar type of operations are grouped at one location in the process layout. eg: lathes, milling, drilling etc are grouped in the shop will be clustered in like groups.
Thus in process layout the arrangement of facilities are grouped together according to their functions.



Advantages

① Flexibility of equipment and personnel.

② Lower investment on account of comparatively less number of machines and lower cost of general purpose machines.

③ Higher utilisation of production facilities.

④ Greater flexibility with regards to work distribution to machineries and workers.

(5) Variety of Job makes the Job challenging and interesting.

(6) Supervisors will become highly knowledgeable about the functions under their department.

Disadvantages

(1) Backtracking and long movements may occur in the handling of materials thus reducing material handling efficiency.

(2) Material handling cannot be mechanised which adds to cost.

(3) Process time is prolonged which reduce the inventory turnover and increases the investment in inventories.

(4) Production planning and Control is difficult.

(5) More space is required

(6) Lowered productivity due to number of set-ups.

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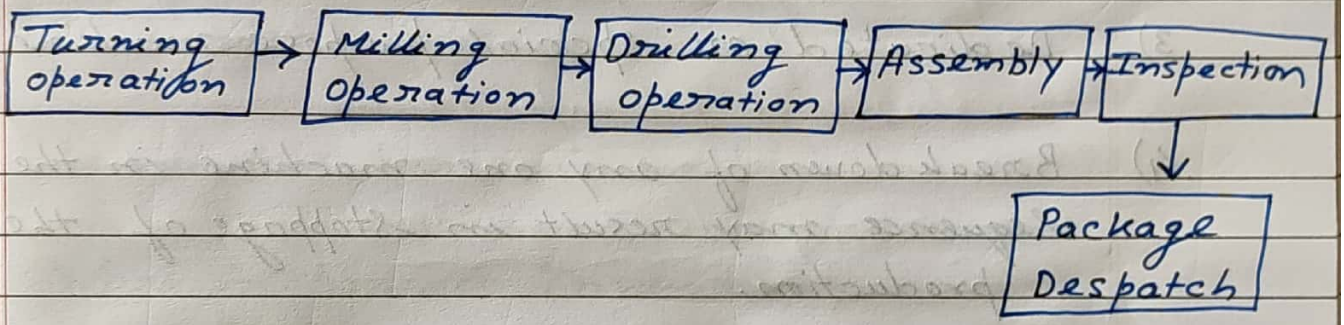
(2) Product Layout (Line layout)

In this type of layout, the machines are arranged in the sequence as required by the product. If the volume of production of one or more products is large, the facilities can be arranged to achieve efficient flow of materials and lower cost per unit.



Advantages

1. Reduced material handling cost due to ~~mechanical~~ mechanised handling systems and straight flow.
2. Perfect line balancing which eliminates bottlenecks and idle capacity.
3. Manufacturing cycle is short due to uninterrupted flow of materials.
4. Simplified production, planning and control.
5. Small amount of work in process inventory

⑥ Unskilled workers can learn and manage the production.

Disadvantages

1) Lack of flexibility. A change in product may require the facility modification.

2) Large capital investment

3) Dedicated or special purpose machine

4) Breakdown of any one machine in the sequence may result in stoppage of the production.

③ Combination layout

This is also called the hybrid or mixed type of layout, usually a process layout is combined with the product layout. For manufacturing various component parts, the process layout is used and for its assembly the product layout is used.

Inventory Control

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Inventory generally refers to the materials in stock. It is also called the idle resource of an enterprise. Inventory represent those items which are either stocked for sale or they are in the process of manufacturing or they are in the form of materials which are yet to be utilised.

Types of Inventories

1) Raw materials Inventory
2) Brough out parts Inventory
3) Work in process Inventory
4) Finished goods Inventory
5) Maintenance, repair and Operating Stores
6) Tools Inventory
7) Miscellaneous Inventory

Raw materials Inventory

Raw materials are those basic unfabricated materials which have not undergone any operations since they are received from the suppliers, eg: Round bars, Channels, pipes etc.

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Brought out parts Inventory

These parts refers to those finished parts, subassemblies which are purchased from outside as per company's requirments.

Work in process Inventory

These refer to the items or materials in partially completed condition of manufacturing eg: Semi-finised products at the various stages of manufacturing.

Finished goods Inventory

These refer to the completed products ready for dispatch.

Maintenance, repair and Operating Stores

These Inventories refer to those items which do not form the part of the final product but are consumed in the production process. eg: Machine spares, oil, grease etc

Tools Inventory

This includes both Standard tools and Special tools.

Miscellaneous inventory

This inventory is office stationaries and other consumable stores.

Objectives of Inventory Control

1) To ensure adequate supply of products to customers and avoid storage shortages as far as possible.

2) To make sure that the financial investment in inventories is minimum.

3) Efficient purchasing, storing, consumption, and accounting for materials is an important objective.

4) To maintain timely record of inventories of all the items and to maintain the stock within the desired limits.

5) To ensured timely action for replenishment.

6) To provide a reserve stock for variations in lead times of delivery of materials.

7) To provide a scientific base for both short term and long term planning of materials.

Functions of Inventories

1) To stabilise production: The demand of an item fluctuates because of the number of factors. Hence the inventory is kept to take care of this fluctuation so that the production is smooth.

2) To take advantages of price discounts: usually the manufacturers offer discount for bulk buying and to gain this price advantage the materials are brought in bulk even through it is not required immediately.

3) To meet the demand during the replenishment period: The lead time for procurement of materials depends upon many factors like location of the source, demand supply condition etc. So inventory is maintained to meet the demand during the procurement or replenishment period.

4) To prevent loss of Orders (Sales): In this competitive scenario, one has to meet the delivery schedules at 100% service level, this means they can not afford to miss the delivery schedule which may result in loss of sales. To avoid this the

Organisations have to maintain inventory.

5) To keep pace with changing market conditions:

The Organisations have to anticipate the changing market sentiments and they have to stock materials in anticipation of non-availability of materials or sudden increase in prices.

6) Sometimes the Organisations maintain inventories to meet problems related to seasonal demand ~~fluctions~~ fluctuations and sudden increase in prices.

Benefits of Inventory control

1) Improvement in customers relationship because of the timely delivery of goods and services

2) Smooth and uninterrupted production.

3) Efficent Efficient utilisation of Working capital.

4) Helps in minimissing loss due to detoriora-tion, obsolescence damage and prelifeage.

5) Eliminates the possibility of duplicate Ordering.

Inventory Control

1) Demand : It is the number of items or products required per unit of time. The demand may be deterministic or probabilistic in nature.

2) Order cycle : The time period between two successive orders is called order cycle.

3) Lead time : The length of time between placing an order and receipt of items is called lead time.

4) Safety Stock : It is also called the buffer stock or minimum stock. It is the inventory needed to account for delays in materials supply and to account for sudden increase in demand due to rush orders.

5) Inventory turnover : If the company maintains inventories equal to 3 months consumption, it means that inventory turnover is 4 times a year.

6) Re-Order level : It is the point at which the replenishment action is done or initiated. When the inventory level reaches R.O.L, the order is placed for the item.

7) Re-Order Quantity: This is the quantity of material or items to be ordered at the re-order level. Normally this quantity equals the economic order quantity.

ABC Analysis

In materials management, the ABC analysis is an inventory categorization technique. ABC analysis divides an inventory into three categories → "A items" with very tight control and accurate records. "B items" with less tightly controlled and good record, "C items" with the simplest controls possible and minimal records.

The ABC analysis provides a mechanism for identifying items that will have a significant impact on overall inventory cost.

- 'A' Class items: These items hardly consist of 5-10% of total items and account for around 70-75% of the total money spend on inventory. These items needs rigid and strict control and need to be stocked in smaller quantities.

- 'B' Class items: These items are generally 10-15% of total items and represent 10-15% of the total expenditure on materials. The control on ~~this~~ these items should be intermediate between 'A' and 'B' class.

- C class items: These are about 70-80% in number and constitude only 5-10% of total expenditure on materials.

Advantages of ABC Analysis

1) This approach helps the manager to exercise selective control and focus his attention only on a few items.

2) It results in reduced clerical cost, saves time and effort and results in better planning and control. This increase inventory turnover.

3) ABC analysis, thus tries to focus and direct the effort based on the merit of the items and thus becomes an effective management control tool.

Limitations of ABC Analysis

1) ABC analysis is a fundamental tool for exercising selective control over numerous inventory items but in present form it do not permit precise consideration of all relevant problems of inventory management.

2) This is not a one time exercise and items are to be reviewed and recategorised periodically

Table 22.2. Features and Policy Guidelines for ABC Analysis

	A Class (High Value)	*B Class (Moderate Value)*	*C Class (Low Value)*
1.	Tight control on stock levels	Moderate control	Less control
2.	Low safety stock	Medium safety stock	Large safety stock
3.	Ordered frequently	Less frequently	Bulk ordering
4.	Individual posting in stores	Individual posting	Collective postings
5.	Continuous check on schedules and revision when called for	Broad check on schedule revisions	Hardly any check required
6.	Weekly control statements	Monthly control reports	Quarterly control reports
7.	Procured from multiple sources	Two or more reliable sources	Two reliable sources for each item
8.	Minimise waste, obsolete and surplus	Quarterly control over waste	Annual review regarding waste
9.	Continuous effort to reduce lead time	Moderate efforts	Minimum efforts

Plant Maintenance

Plant maintenance is defined as a set of activities that are necessary to keep machinery, parts and types of equipment in good operating conditions to avoid production stoppage and losses.

Plant maintenance Objective

1) To increase functional reliability of production facilities.

2) To enable product or service quality to achieved through correctly adjusted, serviced and operated equipment.

3) To maximise the useful life of the equipment.

4) To minimise the total production or operation costs directly attributed to equipment service and repair.

5) To minimise the frequency of interruptions to production by reducing breakdown.

6) To maximise the production capacity from the given equipment resources

7) To enhance the safty of manpower

Preventive maintenance system

The preventive maintenance policy is a system of planned and scheduled maintenance. The basic principal involved in this system is "prevention is better than cure".

Preventive maintenance include

1. Proper identification of all items, their documentation and coding.
2. Inspection of plant and equipments at regular interval.
3. Proper cleaning, lubricating of equipments.
4. To keep upkeep the machine through minor repairs, major overhauls etc.
5. Failure analysis and planning for their elimination.

Breakdown Maintenance

Breakdown maintenance is the emergency repair and it involves higher cost of facilities and equipments that have been used until they fail to Operate. Breakdown maintenance stops the normal activities and the machine as well as the operators remain ideal

till the equipment is brought back to normal condition of Working.

Scheduled maintenance

Scheduled maintenance is also known as routine maintenance. This includes activities such as periodic inspection, cleaning, lubrication and repair of production equipments. This can be classified into two types.

i) Running maintenance:

In this, the maintenance work carried out while the equipment is in the operating conditions.

ii) Shutdown maintenance:

Here the maintenance work is carried out when the machine or equipment is out of service.

Predictive Maintenance

Predictive maintenance as the name implies simply means predicting the failure before it occurs, identifying the root causes for those failures symptoms and eliminating those cause before they result in extensive damage of the equipment.

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Duties, Functions and Responsibilities of Plant maintenance engineering department

1) Inspection

- Inspection is concerned with the routine schedule checks of the plant facilities to examine their condition and to check for needed repairs.
- Inspections ensure the safe and efficient operation of equipment and machinery.
- Frequency of inspections depends upon the intensity of the use of the equipment.
- Inspection section makes certain that every working equipment receives proper attention.
- Items removed during maintenance and overhaul operations are inspected to determine the feasibility of repairs.

2) Engineering

- This involves alterations and improvements in existing equipments and building to minimize breakdowns.
- Maintenance department also undertakes engineering and supervision of constructional

projects that will eventually become part of the plant.

- Engineering and Consulting services to production supervision are also the responsibilities of maintenance department.

3) Maintenance (including preventive maintenance)

- Maintenance of existing plant equipment.
- Maintenance of existing plant buildings, and other service facilities such as yards, central stores, roadways, sewers etc
- Engineering and execution of planned maintenance, minor installations of equipment, building and replacements.
- Preventive maintenance that is preventing breakdown by well conceived plans of inspection, lubrication, adjustments, repair, and Overhaul.

4) Repair

- Maintenance department carries out corrective repairs to alleviate unsatisfactory conditions found during preventive maintenance inspection.

- Such a repair is an unscheduled work often of an emergency nature and is necessary to correct breakdowns and it includes trouble calls.

5) Overhaul

- It is a planned, scheduled reconditioning of plant facilities such as machinery etc.
- It involves replacement, reconditioning reassembly etc.

6) Construction

- In some organisations, maintenance department is provided with equipment and personnel and it takes up construction jobs also.
- Maintenance department handles construction of Wood, Brick and steel structures, cement and electrical installations etc.

7) Salvage

Maintenance department may also handle disposition of scrap or ~~supp~~ surplus materials This function involves:

- Segregation, reclamation and disposition of production scrap

- The collection and disposition of surplus equipments, materials and supplies.

8) Clerical Jobs

Maintenance department keeps records of costs, time progress on jobs. It takes care of important features of buildings and production equipments, electrical installations,

9) Generation and distribution of power and other utilities.

10) Providing plant projection, including fire protection.

11) Insurance administration

12) Pollution and noise abatement.

Inspection and Quality Control

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Inspection

An item or product which is manufactured is required to perform certain functions. The act of checking whether a component or item or product actually does so or not is called Inspection.

In other words, Inspection means checking the acceptability of the manufactured product.

Inspection measured the qualities of a product or services in terms of predecided standards. Product quality may be specified by its strength, hardness, shape, surface finish, chemical composition, dimensions etc.

Purposes or Objectives of Inspection

(i) Inspection separates defective components from non-defective ones and thus ensures the adequate quality of product.

(ii) Inspection locates defects in raw materials and flaws or problems in manufacturing processes which otherwise cause problems at the final stage.

(iii) Inspection prevents further work being done on semi-finished products already detected as spoiled or damaged.

(iv) Inspection makes sure that the product works and it works without hurting anybody, ie, its operation is safe.

(v) Inspection detects sources of weakness and trouble in the finished products and thus checks the work of designers.

(vi) Inspection builds up the reputation of the concern as it helps reducing the number of complaints from the customers.

Types of Inspection

a) Roving, proces, patrolling or floor inspection
b) Fixed inspection
c) Key-point inspection
d) Final inspection

Roving inspection

The inspector walks around on the shop floor from machine to machine and checks samples of the work of various machine operators or workers.

(i) This helps catching errors during process itself, ie., before the final production is ready.

(ii) It is more effective and desirable because the work need not be transported to a centralized (inspection) place.

Fixed inspection

- The work is brought at intervals for inspection.
- Fixed inspection is used when inspection equipments and tools cannot be brought on the shop floor.
- Fixed inspection discovers defects after the job has been completed.
- It is a sort of centralized inspection, the worker and the inspector do not come in contact with each other.

Key-Point inspection

- A key point is a stage beyond which either the product requires an expensive operation or it may not be capable of rework.
- Inspection at a key point segregates and thus avoids unnessary further expenditure on poor and substandard parts, which are likely to be rejected finally.

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Final inspection

- The final inspection of the product may check its appearance and performance.
- Many destructive inspection and test methods such as tensile, fatigue, impact testing etc are available for final inspection.
- Many non-destructive inspection and test methods such as ultrasonic inspection, X ray radiography etc are available for final inspection of the final products.
- Final inspection is a centralized inspection and it makes use of special equipments.

* Inspection of Incoming raw materials

Incoming raw materials are inspected in order to:

i) Eliminate those materials which do not meet specifications and are likely to cause trouble during processing.

ii) Evaluate vendor's quality and ability to supply acceptable materials.

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Inprocess Inspections

An effective inprocess inspection eliminates,

(i) Defects so that the subsequent Operation is not badly affected.

(ii) a defect which may be concealed in the final product

(iii) extra work from being performed on rejectable materials.

Inprocess inspection is carried out by:

a) Workers doing the job
b) Inspectors from the inspection department

Inprocess inspection may check

a) A first few parts of the new machine set up, or a new Operation.

b) A part before it moves for the next operation.

c) A part before it goes for an expensive operation.

d) A part after a series of manufacturing operations.

e) Parts before sub-assembly or final assembly.

f) A part before it is being sent for plating and painting.

Inspection of Finished Goods

An unthrough inspection of finished and final goods may permit faulty products to be dispatched to the customers, so proper inspection of finished goods is very important to prevent supply of faulty or poor quality product to the customers.

→ The finished goods inspection is

a) Visual to ascertain appearance and dimensions
b) Functional to ensure that the product will Work to specification.

Quality Control

Quality: It is a relative term which is the collection of features and characteristics of a product that contribute to its ability to meet given requirments.
It is the ability of the product to fulfil and meet the requirments of customers.

Characteristics of Quality

(i) Performance (ii) Features (iii) Reliability

(iv) Conformance (v) Durability (vi) Serviceability

(vii) Aesthetics.

Control

Control is a system for measuring and inspecting a phenomenon. It suggests when to inspect, how often to inspect and how much to inspect. It also explores the cause of poor quality and takes corrective action.

Quality Control

A quality control system performs inspection, testing, and analysis to conclude whether the quality of each product is as per the required quality standard or not.

It is called statistical quality control when statistical techniques are employed to control quality or to solve quality control problems.

Statistical quality control makes inspection more reliable and at the same time less costly.

Factors that affect the Quality of Manufactured

(i) Money (ii) Materials (iii) Management

(iv) People (MAN) (v) Market

Money

Most important factor affecting the quality of a product is the money involved in the production itself. In the present day where the competition is so high, the companies are ~~fored~~ forced to invest a lot in maintaing the quality of products.

Materials

To produce a high quality product, the raw materials involved in production process must be of high quality.

Management

Quality control and maintenance programmes should have the support from top management. If the management is quality conscious, then the organisation can maintain adequate quality of product.

People or Man

Man/People employed in production and designing of the product must have knowledge and experience in their respective areas.

Market

Market for the product must exist before quality of the product is emphasized by management. It is useless to talk about market quality if there is no demand in market.

Statistical Quality Control (SQC)

- Statistical Quality Control refers to the use of Statistical methods in the monitoring and maintaining of the quality of the products and services.
- The term used to describe the set of Statistical tools used by quality personals or professionals.
- All the tools of SQC are helpful in evaluating the quality of products and services.

Categories of SQC

SQC encompasses three broad categories of:

1) Statistical Process Control (SPC)
2) Descriptive Statistics
3) Acceptance Sampling

Statistical Process Control (SPC)

The underlying concept of statistical process control is based on a comparison of what is happening today with what happened previously.

- We take a snapshot of how the process typically performs or build a model of how we think the process will perform and calculate control limits for the expected measurements of the output of the process.
- Then we collect data from the process and compare the data to the control limits.
- The majority of measurements must fall within the control limits.
- Measurements that falls outside the control limits are examined to see if they belong to the same population as our initial snapshort or model.

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The SPC Techniques

Key monitoring and investigating tools include:

1) Control Charts 2) Histograms 3) Run Charts 4) Pareto Charts 5) Flow Diagram 6) Cause and Effect Diagrams 7) Scatter Diagrams

Control Charts

Control charts recognizing recognises the sources of variation. The control charts monitor, control and improve process performance over time by studying variation and its source.

There are many types of control charts. The control charts that a team decides to use should be determined by the types of data the team have.

Data are of two types

(i) Variables (ii) Attributes

- Variables → Things we measure.

  ex: Length, Diameter, Volume, Time, temperature. etc.

- Attributes → Things we count

  ex: Number or percentage defective items, Number of defects per item, Types of defects etc.

Control Charts for Variables

- Use X-bar Charts to monitor the changes in the mean of a process.
- Use R-bar Charts to monitor the dispersion or variability of the process.

Numericals of X-bar & R-bar charts

A quality control inspector at the XYZ company has taken three samples with four observations each of the volume of bottles filled. If the Standard deviation of the bottling operation is 0.2 ~~liters~~ litre, use the below data to develop control charts with limits of 3 standard deviations for the 16 ~~liters~~ litre, bottling operation.

	Time 1	Time 2	Time 3
• Observation 1	15.8	16.1	16
• Observation 2	16	16	15.9
• Observation 3	15.8	15.8	15.9
• Observation 4	15.9	15.9	15.8
Sample means ($\bar{x}$- bar ($\bar{\bar{X}}$))	15.875	15.975	15.9
Sample ranges (R)	0.2	0.3	0.2

Center line and Control limits formulas

$$\bar{\bar{X}} = \frac{\bar{x}_1 + \bar{x}_2 + \dots \bar{x}_n}{k}, \quad \sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

Where (k) is the number of sample means and (n) is the number of observations in each sample.

$$UCL_{\bar{x}} = \bar{\bar{X}} + z\sigma_{\bar{x}}$$

$$LCL_{\bar{x}} = \bar{\bar{X}} - z\sigma_{\bar{x}}$$

z = Standard deviation ~~Limits~~ limits

$\sigma_{\bar{x}}$ = (Standard deviation of process mean) $\frac{\sigma}{\sqrt{n}}$

(Standard deviation of the process)

(Square root of number of Observations)

Sol^n:

Center line ($\bar{\bar{x}}$)

$$\bar{\bar{x}} = \frac{15.875 + 15.975 + 15.9}{3} = 15.92$$

Control limits for $\pm 3\sigma$ limits:

$$UCL_{\bar{x}} = \bar{\bar{x}} + Z\sigma_{\bar{x}} = 15.92 + 3\left(\frac{0.2}{\sqrt{4}}\right) = 16.22$$

$$LCL_{\bar{x}} = \bar{\bar{x}} - Z\sigma_{\bar{x}} = 15.92 - 3\left(\frac{0.2}{\sqrt{4}}\right) = 15.62$$

Control Chart for Range (R)

$$\bar{R} = \frac{0.2 + 0.3 + 0.2}{3} = 0.233$$

$$UCL_R = D_4 \bar{R} = 2.28\ (0.233) = 0.53$$

$$LCL_R = D_3 \bar{R} = 0.0\ (0.233) = 0$$

P Charts

Fraction defective P chart may be defined as the ratio of the number of defective articles found in any inspection to the total number of articles actually inspected.

Purpose of the P Chart

Because of the lower inspection and maintenance cost of P charts, they usually have a greater area of economical applications than do the control charts for variables. A control chart for fraction defective may have any one or all of the following purposes:

1) To discover the average proportion of defective articles submitted for inspection over a period of time

2) To bring to the attention of the management, any changes in average quality level.

3) To discover, identity and correct causes of bad quality.

4) It is used in a sampling inspection of large lots of purchased articles.

Control Limits for P Charts

$$UCL_p = P' + 3\sigma'_p = P' + 3\sqrt{\frac{P'(1-P')}{n}}$$

$$LCL_p = P' - 3\sigma'_p = P' + -3\sqrt{\frac{P'(1-P')}{n}}$$

n = Average sample size

$\bar{P}$ or p' = Average fraction defectives

σ'_p or $\bar{\sigma}_p$ = Standard deviation.

Total Quality Management (TQM)

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TQM refers to the total involvement of staff in an Organisation together, which includes suppliers, distributors and even customers. in brining about quality satisfaction by promoting quality cultures through quality circles, Job enrichment and effective purchasing. Workers and supervisors have to be trained to Solve the problems in product or process variations.

TQM can be seen as a process, used to manage the change in environment that will ensure that the company reaches the goal of total continuous improvement (TCI). TCI can be achieve by elimination of waste, reduction of variations and innovation.

Six Cs of TQM

i) Committment ii) Culture iii) Control

iv) Continous improvement v) Cooperation

vi) Customer Focus

Basic principles of TQM

1) The customers makes the ultimate determination of quality.

2) Top management must provide leadership and support for all quality initiatives.

3) Preventing variability is the key to producing high quality.

4) Quality goals are a moving target, so it requires a commitment toward continuous improvement.

The three Aspects of TQM

1) Counting : Tools, techniques and training in their use for analyzing, understanding and solving quality problems.

2) Customers : Quality for the customer as a driving force and central concern.

3) Culture : Shared values and beliefs, expressed by leaders, that define and support quality.

TQM System

Objective : Continuous Improvement

Principles : Customer Focus, Process improvement
Total involvement.

Seven Steps of TQM

1) Select a theme 2) Grasp the present system
3) Analyze the present situation.
4) Set countermeasures into motion.
5) Determine the effectiveness of the counter-measures.
6) Use standard Operating procedures
7) Plan for future action.

ISO 9000

ISO 9000 is a series of standards, development and publised by the ISO that define, establish and maintain an effective quality assurance system for manufacturing and service industries.

Objectives

- To facilitate international Trade of goods and Services.
- To Obtain Competitiveness by obtaining required quality in a cost effective way.
- Promoting a total Quality Control System.

ISO stands for International Organization for standardization. It was formed in 1947 in Geneva Switzerland. It is a federation of national standard bodies of 143 countries.

ISO 9000 Series

ISO 9000 → General terms and fundamentals
ISO 9002 → Manufacturing Standards.
ISO 9001 → Suppliers
ISO 9003 → Test houses
ISO 9004 → Systems and Elements

ISO 14000

ISO 14000 series is the set of standards relating to environmental management system The international Organization for standardization had led to the development of the international standard for environmental management system series (ISO 14000).

ISO 14000 deals with a company's system for managing its day to day operations and how they impact the environment.

The Environment management system and environment Auditing address a wide range of issues which include the followings.

1) Top management commitment to continuous improvement, compliance and pollution prevention

2) Creating and implementing environmental policies, including setting and meeting appropriate targets.

3) Integrating environmental considerations in operating procedures.

4) Training employees in regard to their environmental obligations.

5) Conducting audits of the environmental management system.

* ISO 9000 and ISO 14000 are tools to assist business and governments to insure the quality of their products and services and to manage the impact of their activities on the environment.

Just-in-Time (JIT)

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Just-in-time (JIT) is a highly coordinated processing system in which goods move through the system and services are performed Just as they are needed.

Objectives

i) Produce only the products the customers want.

ii) Produce products only at the rate that the customer wants them.

iii) Produce with perfect quality.

iv) Produce products with only those features the customer wants.

v) Produce with no waste of labour, material and equipment.

Benefits of JIT

1) Reduction of wastes (defects, scrap and rework) and increased ability to remain competitive through customer focus and delivering superior performance of both goods and services in terms of cost service and Quality.

2) There is a massive reduction in work in process which results in lower space requirments.

3) Stronger and more reliable working relations with suppliers.

4) Higher profits, reduction in lead time to customers and improved customer satisfaction.

5) Improved working relations between employees.

6) Less inventory of raw materials.

7) Increased flexibility, lower costs and higher productivity.

8) Improved Quality.

Six Sigma

Six Sigma is a disciplined, data-driven approach and methology for eliminating defects (driving toward six standard deviations between the mean and the nearest specification limit) in any process that is from manufacturing to transactional and from product to service.

- Six Sigma seeks to improve the quality of process outputs by identifying and removing the causes of defects.

Features of Six Sigma

- A Six Sigma process is one in which 99.9999966% of the products manufactured are Statistically expected to be free of defects.

- Six Sigma's aim is to eliminate waste and inefficiency, thereby increasing customer satisfaction by delivering what the customer is expecting.

- Six Sigma is a data driven methodology and requires accurate data collection for the processes being analyzed.

- Six Sigma is about putting results on Financial Statements.

- Six Sigma is a business driven, multi-dimensional structured approach for:
  i) Improving Processes
  ii) Lowering Defects
  iii) Reducing process Variability
  iv) Reducing Costs
  v) Increasing Customer Satisfaction
  vi) Increased profits.

Objectives of Six Sigma

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① Overall Business Improvement

Six Sigma methodology focuses on business improvement. Beyond reducing the number of defects present in any given number of products.

② Reduction of Defects or variability

Any business seeking success must reduce the number of defective products or services it produces. Defective products can harm Customer Satisfaction levels.

③ Reduce Costs

Reduced cost of production results in increase in profits. A company implementing Six Sigma principles has to look to reduce cost wherever it is possible without reducing quality.

④ Improve Cycle Time

Any reduction in the amount of time it takes to produce a product or perform a service means saves money both in personal wages and maintenance costs.

(5) Increase Customer Satisfaction

Customer satisfaction depends upon successful resolution of all Six Sigma Objectives. But customer satisfaction is the most important objective of Six Sigma.

Lean manufacturing

Lean manufacturing is a methodology that focuses on minimizing waste within manufacturing systems while simultaneously maximizing productivity.

Lean manufacturing is based on specific principles which focus on continuous improvement.

The benefits of lean manufacturing include reduced lead times, reduced operating cost and improved product quality.

Five principles of Lean manufacturing

1) Identify value from the customer's perspective
2) Map the value stream
3) Create flow
4) Establish a pull system
5) Pursue perfection with continuous improvement

PERT & CPM

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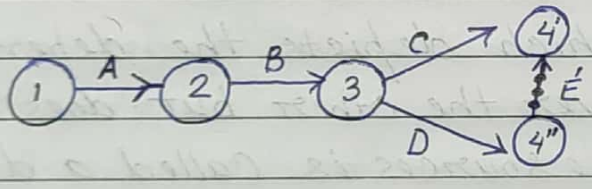
Network diagram

It is the graphical representation of logically and sequentially connected arrows and nodes representing activities and events of a project

Activity

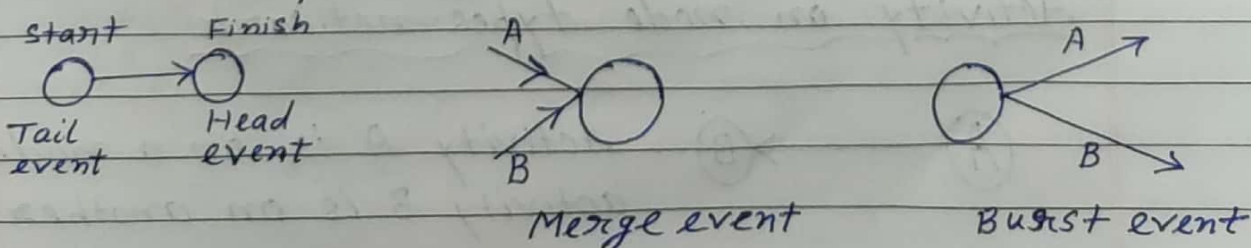
An activity is a physically identificable part of the project, which consumes time and resources. Each activity has a definite start and end. It is represented by an arrow.



A is the predecessor of B. C and D are the successor of B. (4') and (4") are dummy event. E' is the dummy activity.

Event

An event represents the start ~~and~~ or end of an activity. The beginning and end points of an activity are events.



Predecessor activities: All those activities, which must be completed before starting the activity under consideration are called its predecessor activities.

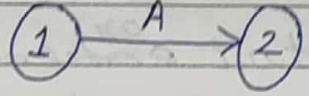
Successor activities: All the activities which have to follow the activity under consideration are called its successor activities.

An unbroken chain of activities between two events is called a path.

Dummy activity:

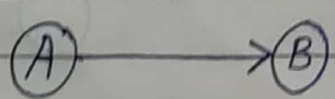
An activity which depicts the dependency or relationship over the other but does not consume time or resources is called a dummy activity. It is used to maintain the logical sequence. It is indicated by a dotted line.

Activity on arrow type Network



Activity A starts from node 1 and ends on node 2.

Activity on node types network



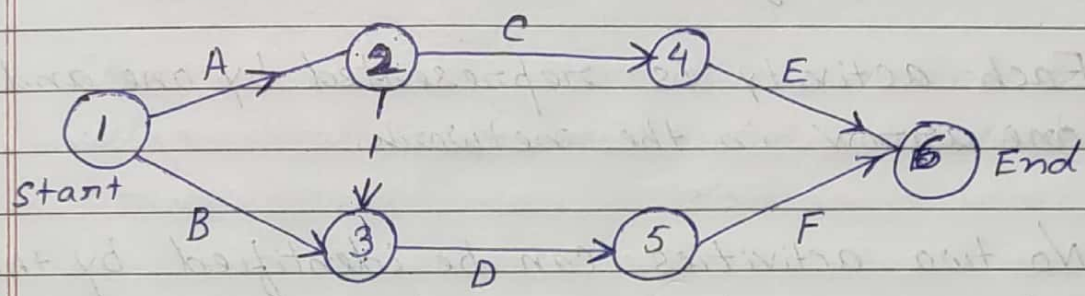
Activity A is on a node & activity B is on another node.

Network Diagrams

Q)

Activity	Predecessor
A	—
B	—
C	A
D	AB
E	C
F	D

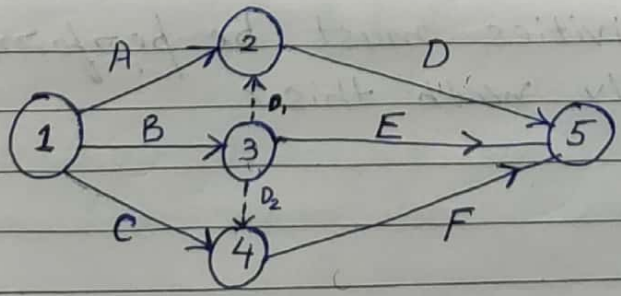
Soln:



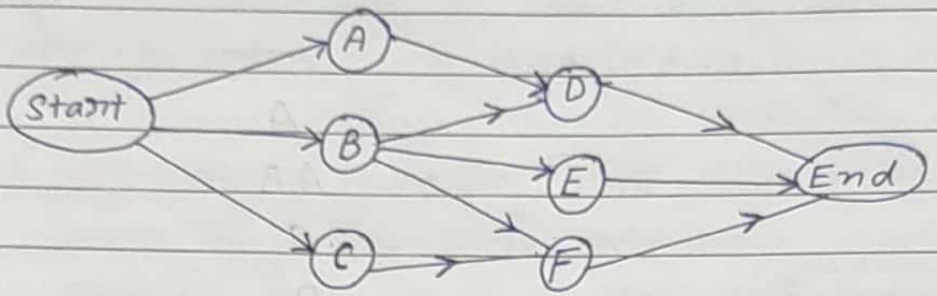
Q)

Activity	Predecessor
A	—
B	—
C	—
D	AB
E	B
F	BC

Soln: Activity on arrow (AOA)



Activity on node (AON)



Network diagram Construction rule

1) Each activity is represented by one and only one arrow in the network.

2) No two activities can be identified by the same start and end points or events.

3) In order to ensure the correct precedence relationship in the arrow diagram following questions must be checked

   (i) What activity must be completed immediately before a particular activity starts?

   (ii) What activities follow this?

   (iii) What activities must be performed concurrently with this?

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Suggestions

1) Time flows left to right

2) Arrows should be kept straight and not curved.

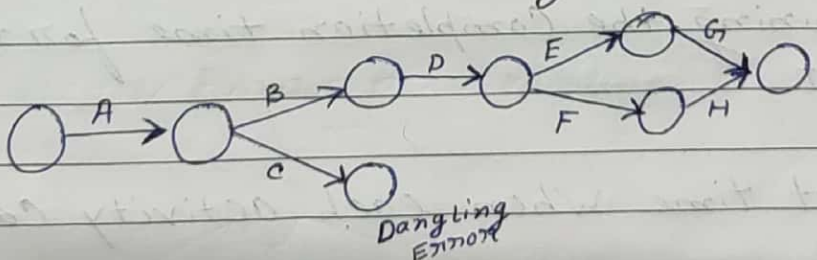
3) Use dummies freely in rough draft but final network should not have any redundant dummies.

4) Arrows should not cross each other, where crossing ~~is~~ cannot be avoided, then bridging should be done

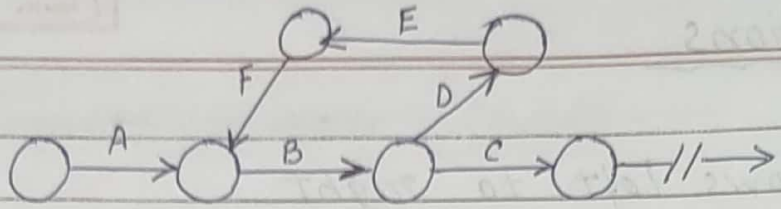
5) In a network diagram there should be only one initial event and one end event.

Common Errors in drawing Networks

① Dangling: To disconnect an activity before the completion of all activities in a network diagram is known as dangling.



② Looping: Drawing an endless loop in a network is known as an error of looping.



(3) Redundancy: unnessarily inserting the dummy activity in a network logic is known as the error of redundancy.

Critical path Method (CPM)

In CPM the activity times are known with certainty. For each activity earliest start time (EST) and latest start time (LST) are computed. The path with the longest time sequence is called Critical path. The length of the critical path determines the minimum time in which the entire project can be completed. The activities on the critical path are called Critical activities.

Objectives

1) Determining the Completion time for the project.

2) Earliest time when each activity can start

3) Latest time when each activity can start without delaying the total project

4) Determining float for each activities.

5) Identification of the critical activities and critical path.

- Earliest start time (ES): It is the earliest event time of the tail and event.
- Earliest Finish time (EF) is the earliest Starting time + Activity time.

Critical Path method

Basic Scheduling Computations :-

(i,j) = Activity (i,j) with tail event i and head event j.

E_i = Earliest occurence time of event i

L_j = Latest allowable occurence time of event j.

D_{ij} = Estimated completion time of Activity (i,j)

$(E_s)_{ij}$ = Earliest Starting time of activity (i,j)

$(E_f)_{ij}$ = Earliest finished time of activity (i,j)

$(L_s)_{ij}$ = Latest Starting time of activity (i,j)

$(L_f)_{ij}$ = Latest finished time of activity (i,j)

Forward pass computations | Earliest Event time

(i) $(E_s)_{ij} = E_i$ $(E=0)$

(ii) $(E_f)_{ij} = (E_s)_{ij} + D_{ij}$

or

$(E_f)_{ij} = E_i + D_{ij}$

(iii) $E_j = \max_i [E_i + D_{ij}]$

Backward pass computations

(Latest Allowable time)

(i) For ending event $(E=L)$

(ii) $(L_f)_{ij} = L_j$

(iii) $(L_s)_{ij} = (L_f)_{ij} - D_{ij}$

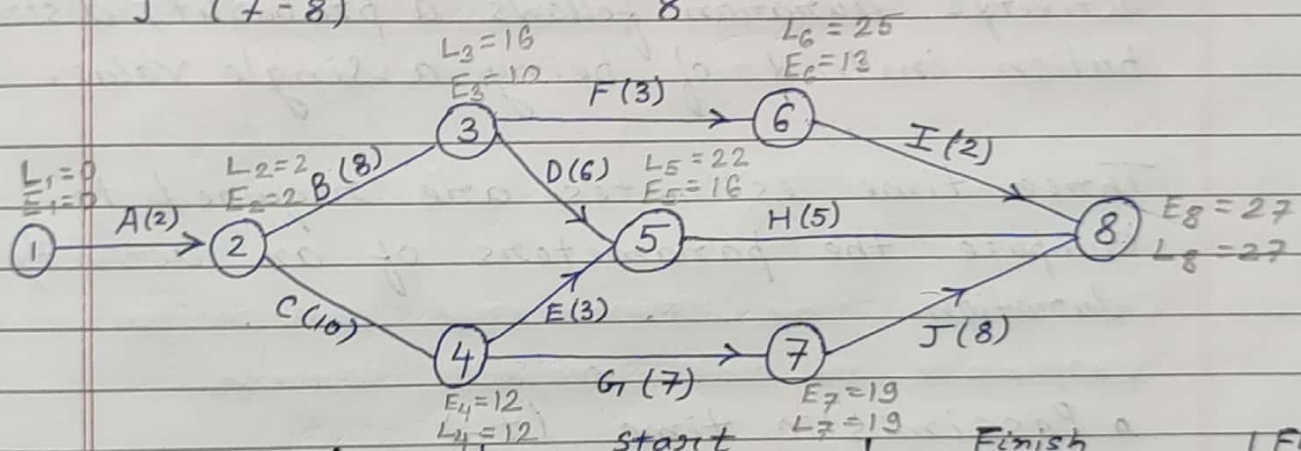
or

$L_j - D_{ij}$

(iv) $L_i = \min_j [L_i - D_{ij}]$

Q)

Activity	Duration
A (1-2)	2
B (2-3)	8
C (2-4)	10
D (3-5)	6
E (4-5)	3
F (3-6)	3
G (4-7)	7
H (5-8)	5
I (6-8)	2
J (7-8)	8



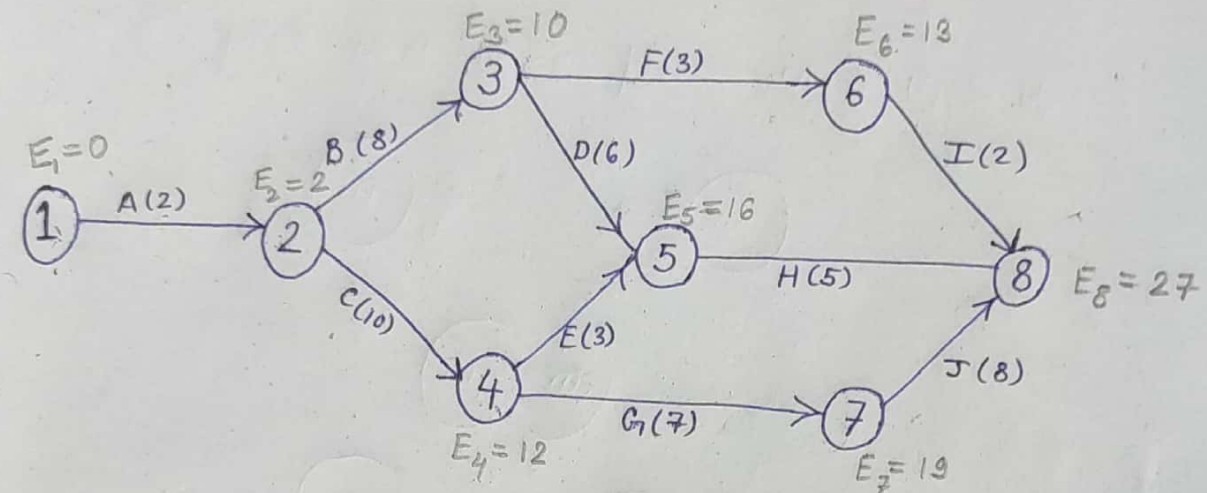
Activity	D_{ij}	Start: Earliest (E_i)	Start: Latest	Finish: Earliest	Finish: Latest (L_j)	Float: Total
1-2	2	0	0	2	2	0
2-3	8	2	8	10	16	6
2-4	10	2	2	12	12	0
3-5	6	10	16	16	22	6
3-6	3	10	22	13	25	12
4-5	3	12	19	15	22	7
4-7	7	12	12	19	19	0
5-8	5	16	22	21	27	6
6-8	2	13	25	15	27	12
7-8	8	19	19	27	27	0
			$L_j - D_{ij}$	$E_i + D_{ij}$		Latest start − Earliest start

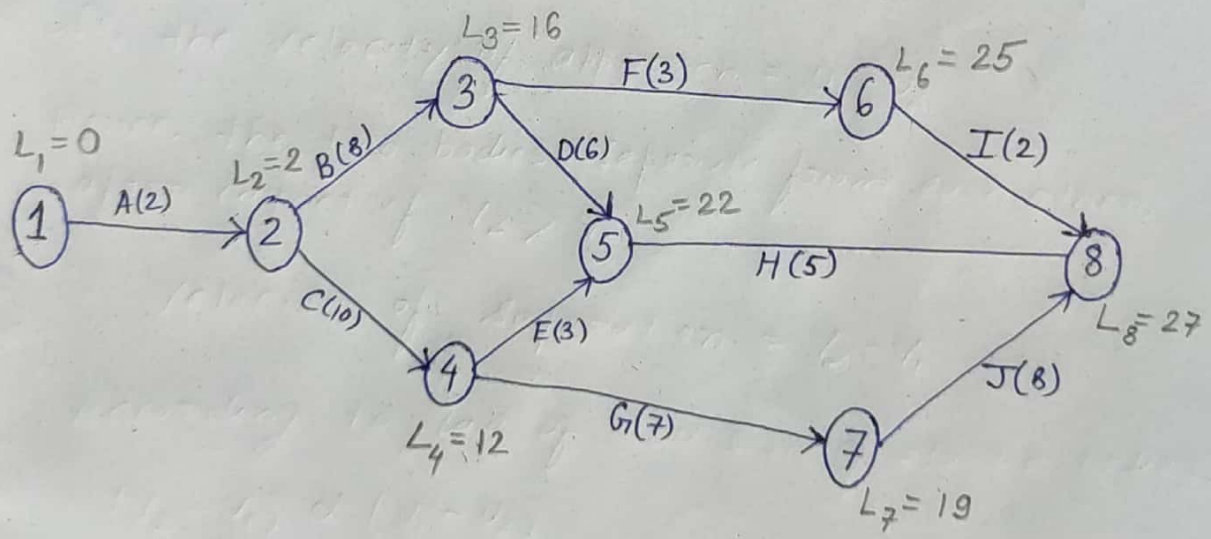
Dij

E_i = earliest start

L_j = Latest Finish

CPM Numerical on Page No = 63





Critical path is 1 → 2 → 4 → 7 → 8

Project length: 2 + 10 + 7 + 8

= 27

Program Evaluation and Review technique :

PERT is a project management tool used to schedule, organize and coordinate task within a project.

- It is basically a method to analyze the tasks involved in completing a given project, especially the time needed to complete each task and to identify the minimum time needed to complete the total project.

PERT is based on the assumption that, an activity's duration follows a probability distribution instead of being a single value.

Three time estimates are required to compute the parameters of an activity's duration.

- Pessimistic time (t_p)
- Most likely time (t_m)
- Optimistic time (t_o)

1) Pessimistic time (t_p) is the longest time taking into consideration all the odds. This is the time estimate if everything goes wrong.

2) Optimistic time (t_o) is the shortest possible time, if everything goes perfectly without any complications.

3) Most likely time (t_m) is the best estimate of the activity time. This lies between the optimistic and pessimistic time estimates.

Mean or Expected time: $t_e = \frac{t_o + 4t_m + t_p}{6}$

Variance: $V_t = \sigma^2 = \left(\frac{t_p - t_o}{6}\right)^2$

Standard deviation (σ) = $\frac{t_p - t_o}{6}$

Characteristics of PERT

1. PERT uses event oriented Network.
2. It is mostly used in research and development projects
3. In this concept of probabilistic model is used
4. PERT is basically a tool for planning and it do not consider the cost factor.

Q) The time estimates (in weeks) for the activities of PERT network are given below:

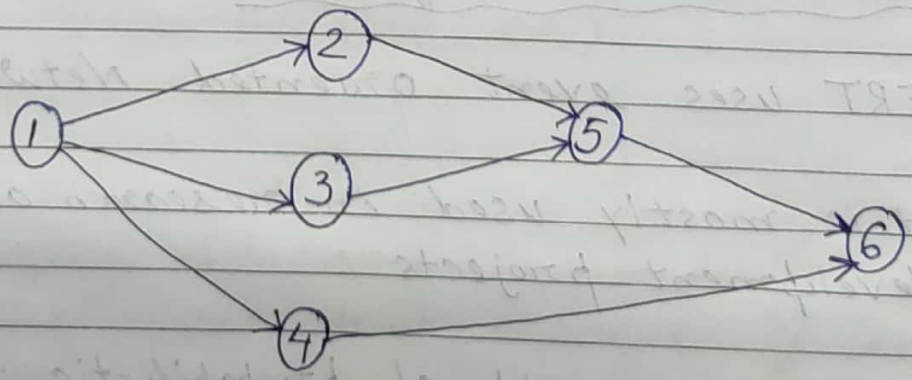
Activity	t_o	t_m	t_p
1-2	1	1	7
1-3	1	4	7
1-4	2	2	8
2-5	1	1	1
3-5	2	5	14
4-6	2	5	8
5-6	3	6	15

a) Draw the project Network

b) Determine the expected project length

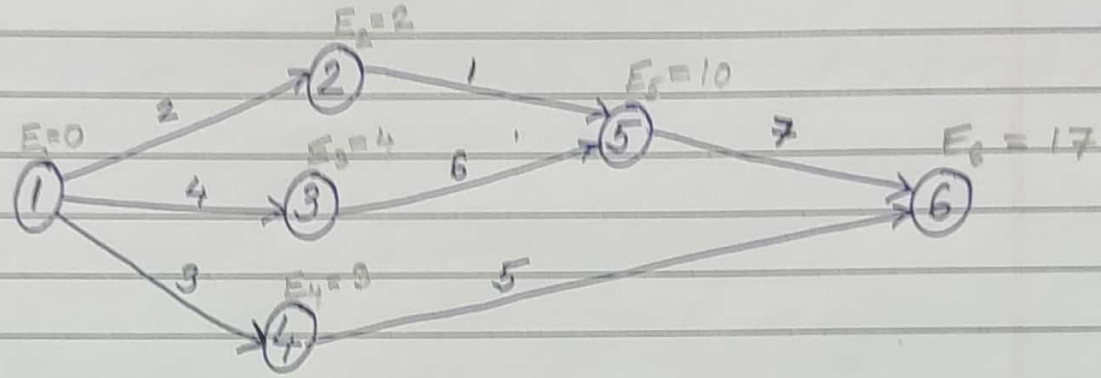
c) Calculate the standard deviation and variance of the project length.

a) Soln



b) Sol^{n}

Activity	t_o	t_m	t_p	Expected time (t_e) $\frac{(t_o + 4t_m + t_p)}{6}$	Variance $(\sigma)^2$ $\left(\frac{t_p - t_o}{6}\right)^2$
1-2	1	1	7	2	1
1-3	1	4	7	4	1
1-4	2	2	8	3	1
2-5	1	1	1	1	0
3-5	2	5	14	6	4
4-6	2	5	8	5	1
5-6	3	6	15	7	4



$L_6 = 17$, $L_5 = 10$, $L_4 = 12$, $L_3 = 4$

$L_2 = 9$, $L_1 = 0$

Critical path : (1) → (3) → (5) → (6)

Expected project length = 4 + 6 + 7 = 17 Weeks

c) The critical path is 1-3, 3-5, 5-6
its variences

1-3 → 1
3-5 → 4
5-6 → 4

So, the variance of the project

Variance $(\sigma)^2 = 1 + 4 + 4$

$= 9$

Standard deviation $(\sigma) = 3$

11
Operations Research

11.1. CONCEPT OF OPTIMISATION

An industrialist has two industries (A and B) at different locations. He is interested to send the finished goods to five different stations. There are several alternate ways of accomplishing this task. From industry A he can send F_1, F_2, F_3, F_4 and F_5 number of finished goods to each of the five stations or he can send N_1, N_2, N_3, N_4 and N_5 numbers of goods to each station or any other number of goods ; and similarly from industry B. But, the point is which of the several alternatives will be the best and the most favourable. In this case, it is the one for which the industrialist has to pay the minimum transport charges. Such problems are solved through the use of *Optimisation* techniques. The word optimisation is from *Optimum* which implies, a point at which the conditions are best and most favourable. An optimum point may represent a maximum position or a minimum position.

The approach of optimisation involves the following :

(*a*) The criteria which will judge the best of the several alternatives.

(*b*) Characteristics of various alternatives being judged.

(*c*) Methods available to judge the best performance for the selected criteria.

Methods of Optimising

(*a*) Search,

(*b*) Differential calculus,

(*c*) Calculus of variations,

(*d*) Statistical methods, and

(*e*) Linear programming :

1. Graphical method,
2. Transportation method, and
3. Simplex method.

(*f*) Queuing theory,

(*g*) Dynamic programming, and

(*h*) Hill climbing.

Applications of Optimisation. Some of the processes to which optimisation is applicable are load allocation problems, component selection, dynamic load sharing, dynamic terminal value problems, etc.

11.2. OPERATIONS RESEARCH

Introduction. Historically, the term *Operations Research* originated during second world war when U.S.A. and Great Britain's Armed Forces sought the assistance of Scientists to solve complex and very difficult strategical and tactical problems of warfare, like making mines harmless or increasing the efficiency of antisubmarine aerial warfare, etc.

Operations research employs mathematical logic to complex problems requiring managerial decisions.

Operations research aids, in solving diverse business problems and in planning and investigation of major operational decisions. A few **applications of operations research** are as under :

(*a*) Locating factories and warehouses to minimize transportation costs,

(*b*) Work allocation to machines for minimizing production time and costs,

(*c*) Inventory problems,

(*d*) Material handling,

(*e*) Dealing with waiting times,

(*f*) Equipment replacements,

(*g*) Dividing advertising budget,

(*h*) Establishing equitable bonus systems,

(*i*) Routing of tankers,

(*j*) Traffic control,

(*k*) Petrochemical mixes,

(*l*) Municipal and hospital administration, and

(*m*) Marketing, etc.

Definition and Concept. Operations Research signifies research on operations. However, it takes into consideration a particular view of operations and a particular kind of research. Operations research is the organised application of modern science, mathematics and computer techniques to complex military, government, business or industrial problems arising in the direction and management of large systems of men, materials, money and machines. The purpose is to provide the management with explicit quantitative understanding and assessment of complex situations ; to have sounder basis for arriving at best decisions. Operations research seeks the optimum state in all spheres and thus provides optimum solution to organisational problems. It is of considerable value in Production Management.

Methodology of Operations Research. Various steps involved are as follows :

(1) Understand the actual real situation, capture the same and define the problem.

(2) Formulate a mathematical model :

A model is of great help in facilitating the investigations of operations and operations research expresses a problem by a model. The model covers the relationship of the variables. Generally two types of models are employed. An *analogue* model which takes the form of an electronic circuitry or (it may be) a mechanical system. The other, called *symbolic* model is in the form of a matrix, a graph or an equation. This is also known as *mathematical* model. Models provide solutions in quantitative form (cost, weight, etc.), depending upon the problem.

Operations research models can also be classified as *probabilistic* and *exact* models. Probabilistic models rely upon the probability theory and contain obvious recognition of uncertainty. They are very useful in advertising problems. In exact models, chance or uncertainty plays a very minor role, for example, as in long range production planning with orders already in hand.

(3) Develop a mathematical solution :

Data is supplied to the model. Information is computed, and results are analysed to find the mathematical solution for alternative policies.

(4) Interpret the solution and prepare the information in such a form that it is meaningful, intelligible and quantitative. Translate it into a decision.

(5) Implement the decision to the real (actual) situation.

(6) Verify the results :

After applying the solution to real situation, the actual results produced by the model must be tested

statistically and verified to explore any significant deviation from the expected results. If found so, the model can be modified and again the cycle is repeated (Fig. 11.1).

11.3. METHODS OF OPERATIONS RESEARCH

Various techniques used in Operations Research to solve *Optimisation* problems are as follows :

1. Linear programming :
   - (*a*) Graphical linear programming,
   - (*b*) Transportation Method :
     - (*i*) Vogel's Approximate Method.
     - (*ii*) North-West Corner Method.
   - (*c*) Simplex method,
2. Waiting line or Queuing theory.
3. Game theory.
4. Dynamic programming.

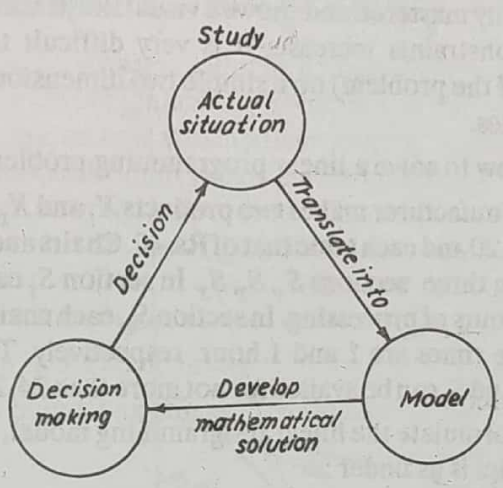


Fig. 11.1. Operations Research Procedure.

11.4. LINEAR PROGRAMMING

Linear programming is one of the classical Operations Research techniques. It had its early use for military applications but presently it is employed widely for business problems. It finds applications as resource allocation like crude oil distribution to refineries, production distribution ; in agricultural works like blending fertilizers, selecting the right crop to be planted ; in army such as bombers placements, troops deployment ; and in finance, personnel and advertising.

Linear programming is powerful mathematical technique for finding the best use of the limited resources of a concern. It may be *defined* as a technique which allocates scarce available resources under conditions of certainty in an optimum manner, (*i.e.*, maximum-minimum) to achieve the company objectives which may be, maximum overall profit or minimum overall cost.

Linear programming can be *applied effectively* only if,

(*a*) The objectives can be stated mathematically.

(*b*) Resources can be measured as quantities (number, weight etc.).

(*c*) There are too many alternate solutions to be evaluated conveniently.

(*d*) The variables of the problem bear a linear (straight line) relationship, *i.e.*, a change in one variable produces proportionate changes in other variables. In other words, doubling the units of resources will double the profit. Problem solving is based upon the system of linear equations.