NM INSTITUTE OF ENGINEERING & TECHNOLOGY
BHUBANESWAR
Estd. 2004

Education for a World Stage

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INDUSTRIAL ENGINEERING
&
MANAGEMENT NOTE.
DIPLOMA SYLLABUS.
6th SEMESTER.

TH-1-INDUSTRIAL ENGINEERING & MANAGEMENT.

1. PLANT ENGINEERING.

1.1: Selection of suitable location.

→ The need for selecting a suitable location arises because of two situations.

(i) when starting a new organisations.

(ii) In case of existing organisation.

→ The existing firms 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 ~~decesions~~ decisions.

a) wheather to expand the existing capacity & facilities.

b) wheather to look for new locations for additional facilities.

c) wheather to close down existing facilities to take advantage of some new location.

Reasons for Replacement of Existing facilities to New locations.

→ Changes in location of demand.

→ changes in availability of materials.

→ changes in availabitity of transport.

→ changes in the cost and /or supply of labour.

→ changes in regulations and law.

→ changes in availability of raw materials.

→ changes in policy of industries to relocation on which the firm is dependent

1.2 Define Plant layout.

→ Plant layout refers to the physical arrangement of production facilities.

→ The arrangement of machinery, equipment & other industrial facilities for achieving quest & smooth production.

→ The subject of plant layout covers the initial layout of machines and other facilities but encompanes improvement in, or revision of, the existing layout in the light of subsequent developments in the methods of production.

Plant layout problem

→ Each one in the organisation is connected with the plant layout some way. So the need the plant layout change arise because of the following reasons:

i) changes in the product design or introductio of the new product.

ii) changes in the volume of demand for the company's product.

iii) Increasing frequency of accidents because of existing layout.

iv) Plant and machinery becomes outdated & is to be replaced by new one.

v) Poor working environment affecting worker efficiency & productivity.

vi) Change in the location or markets.

vii) Minimising the cost through effective facilities location.

1.3: Describe the objective & principles of plant layout.

* Objectives of Plant layout.

→ The primary goal of the plant layout is to maximise the profit by arrangement of all the plant facilities to the best advantage of total manufacturing of the product.

The objectives of plant layout are:

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 & cost.
5) Effective utilisation of men, equipment & space.
6) Make effective utilisation of cubic space.
7) Flexibility of manufacturing operations & arrangements.
8) Provide for employee convenience, safety & comfort.
9) Minimise investment in equipment.
10) Minimise overall production time.
11) Maintain flexibility of arrangement & operation.
12) Facilitate the organizational structure.

Principles of Plant layout

1. **Principle of Integration**:- A good layout is one that integrates men, materials, machines & supporting services & others in order to get the optimum utilisation of resources & maximum effectiveness.

2. **Principle of minimum Distance**:- This principle is concerned with the minimum travel (or movement) of man & materials. The facilities should be arranged such that, the total distance traveled by the men & materials should be minimum & as far as possible straight line movement should be preferred.

3. **Principle of cubic space utilisation**:- The good layout is one that utilise both horizontal & verticle space. It is not only enough if only the floor space is utilised optimally but the third dimension, i.e the height is also to be utilised effectively.

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

5. **Principle of maximum Flexibility**:- The good layout is one that can be altered without much cost & time, i.e future requirements should be taken into account while designing the present layout

6. Principle of Safety & Security & Satisfication
A good layout is one that gives due consideration to workers safety & satisfication & safeguards the plant & machinery against fire, theft. etc.

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

Advantages of Plant layout:

1. Advantages to the worker: A good layout will reduce the effort of the workers & minimises the manual material handling. It reduces the number of accidents & provide better working conditions.
2. Advantages to the management: Effective plant layout reduce the labour costs & enhances the productivity thus ultimately reducing the cost per unit. This helps the management to gain competitiveness in manufacturing.
3. Advantages to manufacturing: Minimises the movement between work centres & also results in reduced manufacturing cycle.
4. Advantages to production control: A good layout facilitates production through uniform & uninterrupted flow of materials & helps to carry out production activities within the predetermined time period & with effectiveness

Factor Influencing plant layout

1. Type of production - Engineering industry, process industry
2. Production System - Jobshop, batch production/ mass production.
3. Scale of production.
4. Availability of the total area.
5. Arrangement of material handling system.
6. type of building - Single store or multi store.

1.4 Types of layout

Layouts can be classified into the following four categories.

a) process layout.
b) product layout
(iii) Fixed position layout.
d) combination layout or Hybrid layout.

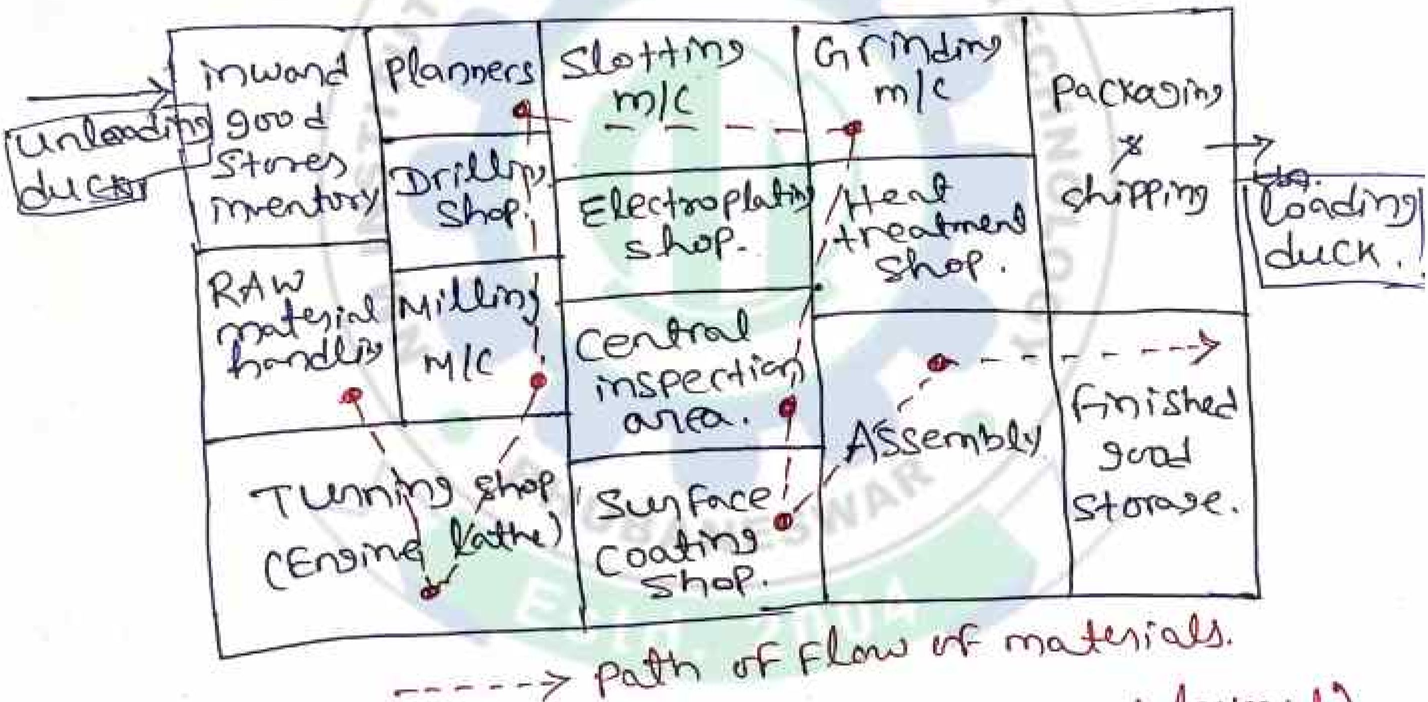
a) Process layout :

→ Process layout is recommended for batch production. All machines performing similar type of operations are grouped at one location in the process layout e.g. all lathe, milling machines, etc. are grouped in the shop will be clustered in like groups.

→ Thus, tn process layout the arrangement of facilities are grouped together according to their functions. A typical process layout is flow paths of material through the facilities from one functional area to another vary from product to product.

→ Process layout is normally used when the production volume is not sufficient to justify a product layout. Typically, job shops employ process layouts due to the variety of products manufactured & their low production volumes.

→ For example, engine lathe will be arrangement in one dept., milling machine in a second department, grinding machine in a third department & surface coating in the fourth department the material should be transported to different departments for treatment. Thus materials would move long distances & along crisis crossing paths.



(Figure: Process layout or functional layout or Job shop layout)

Advantages of Process layout :-

i) In process layout machines are better utilized & fewer machines are required.

ii) Flexibility of equipment & personnel is possible is process layout.

iii) Lower investment on account of comparatively less number of machines & lower cost of general purpose machines.

iv) Higher utilisation of production facilities.

v) A high degree of flexibility with regards to work distribution to machineries & workers.

vi) The diversity of tasks & variety of job makes the job challenging & interesting.

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

Limitations of process layout:-

i) Backtracking & long movements may occur in the handling of materials thus, reducing material handling efficiency.

ii) Material handling cannot be mechanised with adds to cost.

iii) Process time is prolonged which reduce the inventory turnover & increases the in-process inventory.

iv) Lowered productivity due to number of set-ups.

v) Throughput (time gap between in & out in the process) time is longer.

vi) Space & capital are tied up by work in process.

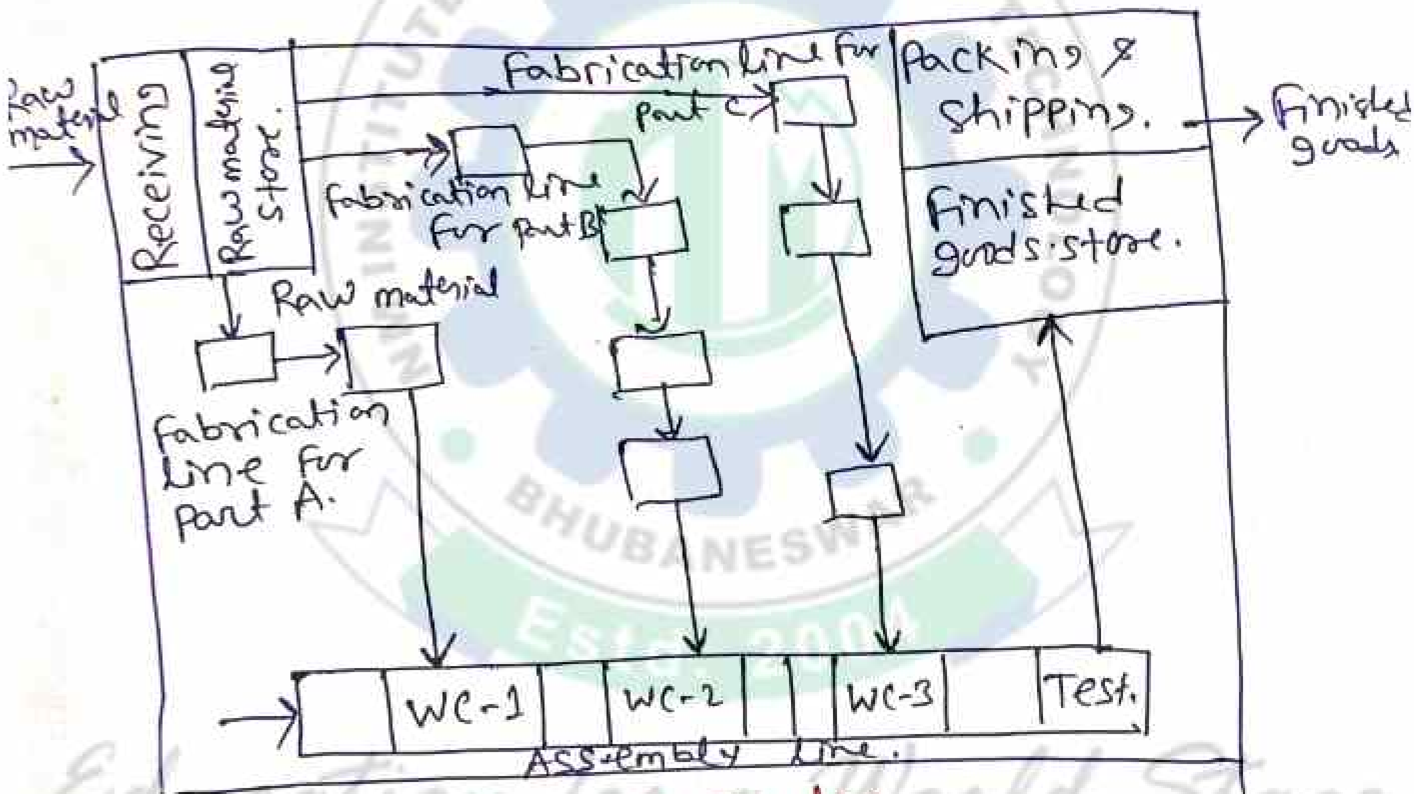
b) Product layout:

→ A product layout involves the arrangement of machines in one line depending on the sequence of operations. Raw materials are supplied to the first machine in the sequence & the finished products come out of the last machine in this production line, the output of one machine (semi finished product) becoming the input to the next machine.

Example: Automobile manufacturing plant, paper mill, Sugar mill, rice mill.

→ In this type of layout, machines & auxiliary services are located according to the processing sequence of 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 & lower cost per unit.

→ The product layout is selected when the volume of production of a product is high such that a seperate production line to manufacture it can be justified. The typical product layout is shown below.



WC = work centre.

(Figure : Line layout or Product layout)

Advantage of Product layout.

(i) The flow of product will be smooth & logical in flow lines.

(ii) In-process inventory is less.

(iii) Through put time is less.

(iv) Minimum material handling cost.

(v) Simplified production, planning & control system are possible.

(vi) Less space is occupied by work transit & for temporary storage.

(vii) Reduced material handling cost due to mechanised handling systems & straight flow.

(viii) Perfect line balancing which eliminates bottole necks & idle capacity.

(ix) Manufacturing cycle is short due to uninterrupted flow of materials.

(x) Small amount of work-in-process inventory.

(xi) Unskilled workers can learn & manage the production.

Limitations of product layout.

(i) A breakdown of one machine in a product line may cause stoppages of machines in the down stream of the line.

(ii) A change in product design may require major altertions in the layout.

(iii) The line output is decided by the bottleneck machine.

(iv) Comparatively high investment in equipments is required.

(v) lack of flexibility – A change in product may require the facility modification.

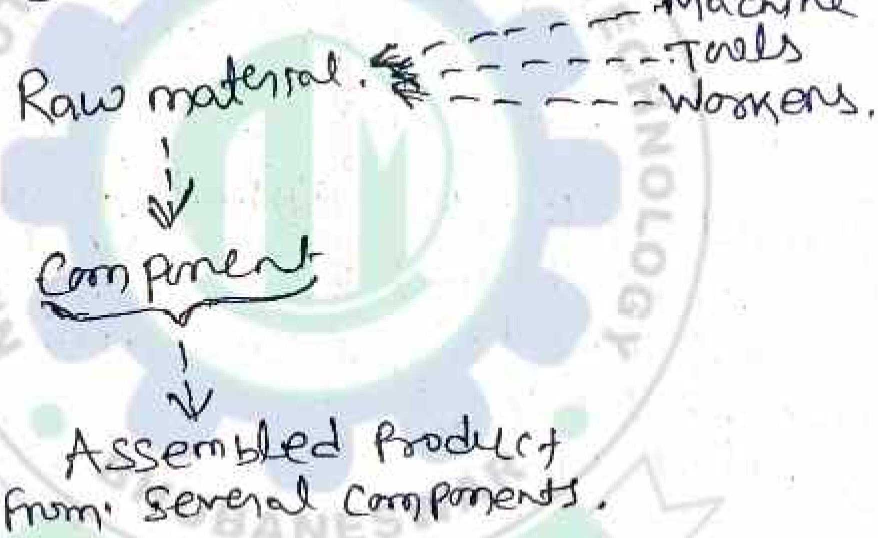
Difference between Product & Process layout

Product layout	Process layout
i) Flexibility is less, one of few standard productions can be possible	i) There is a flexibility in equipment or manpower allotment for specific fasera many types or kind of product can be possible.
ii) Total production time per unit is shortened.	ii) Total production time/unit is more as compared to product layout.
iii) Little skill is usually required by the production line hence training is simple, short & inexpensible	iii) Highly skilled workmen is necessary for each production shop.
iv) Reduced material handling since the machines are so located as to minimize distance betn consecutive operation.	iv) Better equipment utilization. Because of better utilization of machines, less machines are required.
v) Small amount of work in process as the work from one process is directily fed into the next.	v) Comparatively large amounts of work in process, waiting for the next operation.
vi) A breakdown of one machine may lead to complete stoppage of the line.	vi) A break-down of one or more machine may not lead to complete stoppage of the line.
vii) The pace is determined by the slowest machine, hence speed of machine is deliberately reduced or machines have excessive idle time.	vii) Long flow lines hence more expensive handling. Production planning & control systems becomes more complicated.

c) Fixed Position layout

→ Static Product layout or layout by fixed position, is adopted when workpiece is very big or too heavy to move from one position to the other & is consequently fixed in one place. The machine & men move with respect to the work to perform the required operation.

For example:- In construction work, ship-building, in fabrication of large tanks, pressure vessels, locomotives, Air craft etc.



(Figure: Fixed position layout)

Advantage:-

(i) Man & machines can be used for a wide variety of operations producing different products.
(ii) It involves least ~~amount~~ movement of material.
(iii) The investment on layout is very small.
(iv) There is maximum flexibility for all sorts of change in products & process.
(v) The workers identifies himself with the product & takes pride in it when the work is complete.
(vi) A number of quite different projects can be taken with the same layout.

Disadvantage :-

(i) Highly skilled workers are required.

(ii) There is low utilization of labour & equipment.

(iii) Highly skilled workers are required.

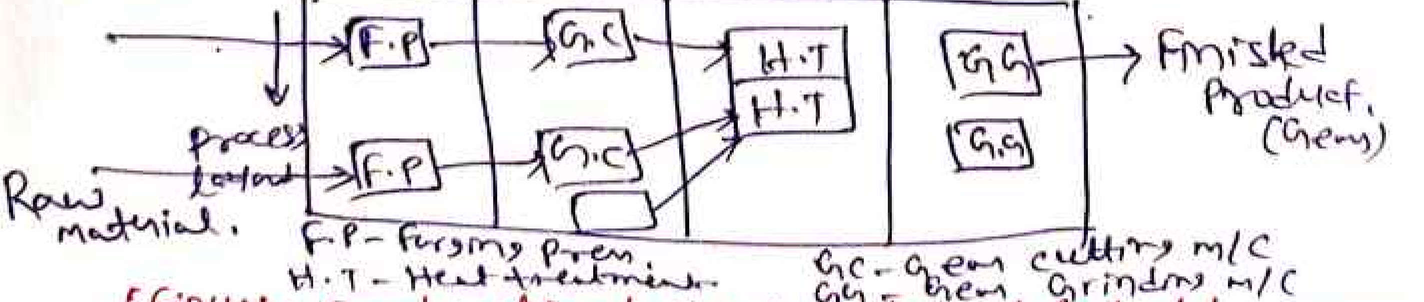
d) Mixed or combined layout :-

→ Pure process or pure line layouts are rare. The combination of these are very commonly used in industry. The combined layout incorporates the benefits of process & product layout. Combined layout is developed as under.

i) The production shops may be arranged by process layout, while the assembly is accomplised on line.

ii) Product layout for the main product with a process layout for by-product, utilizing the idle capacity of the product layout along with the marginal investment required in process layout.

For example :- In soap manufacturing plants, the machinery manufacturing soap is arranged on the product line principle; but ancillary service such as heating, the manufacturing of glycerine, the power house, the water treatment plant are arranged on a functional basis.



(Figure: Combination layout or Hybrid layout)

1.5 Techniques to improve layout:

→ Layout of an existing plant may have to be revised & improved with alterations & additions deemed necessary in keeping pace with there of technological & competitive changes occuring in the industry.

→ Revision of plant layout becomes necessary due to following reasons:

(a) Expansion in production capacity due to permanent increase in demand involves provisions of new physical facilities to increase the output of the product.

(b) Adoption of technological innovations & improvements in order to enhance the competitive standing of the firm will obviously require major revision of the layout.

(c) Plant layout may also have to be revised as the part of work simplification compaigns for betterment of production techniques & systematized & simplified sequence of plant operations.

1.6) Principle of material handling equipment.

→ It is the movement, storage, control & protection of materials, goods & products throughout the process of manufacturing, distribution process including their consumption & disposal.

→ Material handling is the art & science of moving, storing, protecting & controlling material.

→ It is the movement & stroage of materials at the lowest possible cost through the use of proper methods & equipments.

→ It is the art & science of conveying, elevating, positioning, transporting, packaging & storing of materials.

→ It is the function of moving right material to the right place in the right time, in the right amount, in sequence & in the right condition to minimize the production cost.

Equipment :-

These can be classified into five major categories:

(i) Transportation Equipment.

→ Equipment used to move material from one location to another.

ex: Between workplaces, between a loading dock & a storage area etc.

→ The major subcategories of transport equipment are conveyors, cranes & industrial truck.

(ii) Positioning Equipments. :-

→ Equipment used to handle material at a single location.

→ ex.- to feed &/or manipulate materials so that they are in the correct position for subsequent handling, machining, transport.

→ unlike transport equipment, positioning equipment is usually used for handling at a single workplace.

(iii) Unit Load Formation Equipment :-

→ Equipment used to restrict material so that they maintain their integrity when handled a single load during transport & for storage.

→ If material are self restraining (i.e. then they can be formed into a unit load with no equipment

(iv) Storage Equipment. :-

→ Equipment used for holding or buffering materials over a period of time.

→ Some storage equipment may include the transport of materials.

(v) Identification & control equipment :-

→ Equipment used to collect & communicate the information that is used to coordinate the flow of material within a facility & between a facility & its suppliers & customers.

1.7 Plant maintenance :-

→ In modern industry, the equipment & machinery are a very important part of total productive system.

→ The development of special purpose & sophisticated machines, equipment & machinery cost much more expensive, so its maintenance is required for easy & smooth running of plant.

→ In other word, the plant maintenance means taking of corrective action for plant machinery & equipment.

Objectives of Plant maintenance :-

(i) To achieve minimum breakdown & to keep the plant in good working condition at the lowest possible cost.

(ii) The machines & other facility will be kept in such a condition which permits them to be used at their optimum capacity.

(iii) The maintenance department of the factory ensures the availability of machine, service buildings required by other section of factory for their performance.

1.7.1 Importance of Plant maintenance:

(i) It varies with the type of plant & its production
(ii) Equipment breakdown leads to loss of production
(iii) An unproper maintain plant will require expensive & frequent repair.
(iv) The maintenance of plant placed an important role because the breakdown creates the problem.

Like
- → Less in production time.
- → Rescheduling of production.
- → Spoilt material (because sudden stoppage of process damages in process material)
- → Failure to recover overheads (because of loss in prodn hours.)

(v) Need for overtime.
(vi) Need for subcontracting work.
(vii) Temporary work shortages - workers require alternative work.

Duties, Functions & Responsibilities of Plant maintenance Engineering department.

(i) Depending upon the size of the maintenance department, it has a wide variety of duties or functions to perform.

The work is under the control of plant engineer or maintenance engineer who normally reports to the works manager.

(ii) The different duties, functions & responsibilities of the maintenance department are as follows:

(a) Inspection :-

(i) Inspection is concerned with the routine schedule checks of the plant facilities to examine their condition & to check for needed repairs.

(ii) Inspections ensure the safe & efficient operation of equipment & machinery.

(iii) Frequency of inspections depends upon the intensity of the use of the equipment.

(iv) Inspection section makes certain that every working equipment receives proper attention.

(v) Items removed during maintenance & overhaul operations are inspected to determine the feasibility of repairs.

(vi) Maintenance item received from vendors are inspected for their fitness.

(b) Engineering :-

(i) Engineering involves alternations & improvements in existing equipments & building to minimize breakdowns.

(ii) Maintenance department also undertakes engineering & supervision of constructional projects that will eventually become part of the plant.

(iii) Engineering and consulting services to production supervision are also the responsibilities of maintenance department.

(c) Maintenance :-

(i) Maintenance of existing plant equipment

(ii) Maintenance of existing plant buildings & other ~~others~~ service facilities. Such as yards, central stores, roadways, sewers etc.

(iii) Engineering & execution of planned maintenance, minor installations of equipment, building & replacements.

(iv) Preventive maintenance, i.e preventing breakdown (before it occurs) by well conceived plans of inspection, lubrication, adjustments, repair & overhaul.

(d) Repair :-

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

(ii) Such a repair is an unscheduled work often of an emergency nature, & is necessary to correct breakdowns & it includes trouble calls.

(E) Overhaul :-

(i) Overhaul is a planned, scheduled reconditioning of plant facilities such as machinery, etc.

(ii) Overhaul involves replacement, reconditioning, reassembly etc.

(F) Construction :-

(i) In some organizations, maintenance department is provided with equipment & personnel & it takes up construction job also.

(ii) Maintenance department handles construction of wood, brick & steel structures, cement & asphalt paving, electrical installations etc.

(G) Salvage :-

(i) Maintenance department may also handle disposition of scrap or surplus materials.

This function involves,

→ Segregation, reclamation & disposition of production scrap etc.

→ The collection & disposition of surplus equipments, materials & supplies.

H) Clerical Jobs:-

(I) Maintenance department keeps records.

→ of costs.

→ of time progress on jobs.

→ Pertaining to important features of building & production equipments; electrical installations; water, steam, air & oil lines; transportation facilities (such as elevators, conveyors, powered ~~truck~~ trucks, cranes etc.

(II) Generation & distribution of power & other utilities.

(J) Administration & supervision of labour force (of maintenance department)

(K) Providing plant protection, including fire protection.

(L) Insurance administration.

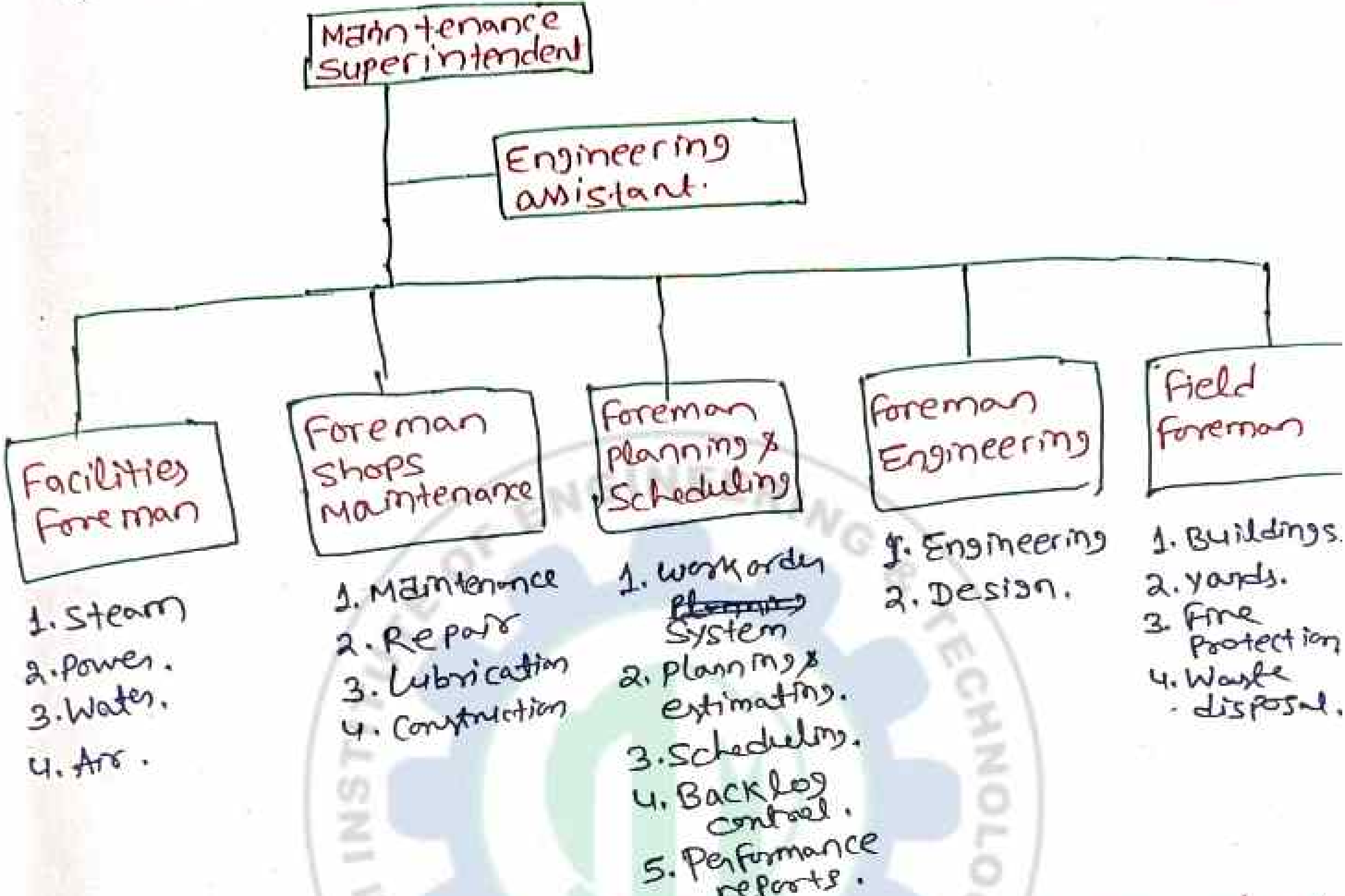
(M) Establishing & maintaining a suitable store of maintenance materials.

(N) House keeping:-

Good housekeeping involves upkeep & cleaning of equipments, building, toilets, washrooms, etc.

(O) Pollution & noise abatement

Organisation of Maintenance Department.



(Figure: Organization Structure of maintenance dept.)

(1) The buildings, Plant and services are called by the accountant fixed assets & in many companies they form at least 50%. of the money invested.
In any company, Small or big, it is therefore essential that Some part of the main organization Should be responsible for maintaining these important assets.

(2) The section which preserves & looks after the upkeep of equipments, building etc. is called maintenance department.

(3) To work satisfactorily, the maintenance dept. has no organization structure.

~~(4) A few basic concepts of good organisations that Should be kept as short as possible. In other words, a level which simply transmits information up & instructions down should be eliminated.~~

(4) A few basic concepts of good organisations that should be kept in mind in developing an organisation are:

(a) A resonably clear division of authority with little or no overlap.

(b) Verticle lines of authority & responsibility should be kept as short as possible. In other words, a level which simply transmits information up & instructions down should be eliminated.

(c) Keep optimum number of persons (3 to 6 is the average value) reporting to an individual.

(d) Fit the organisation to the personalities involved. This means that the organisation structure should be flexible & it may be revised periodically to fit changing personnel & conditions.

(5) The basic organisation structure of maintenance department depends upon:

(a) Types of maintenance activities to be looked after

The wider the maintenance field to be covered, the bigger is the organisation.

(b) Continuity of operations

The size of the maintenance force & therefore the structure of maintenance organisation depends upon:

- wheather it is a four, five or six working days week and
- wheather the plant run in one, two or three shifts

(c) Size of the plant.

The organisation structure of the maintenance department varies with the size of Plant. The larger the plant the more the number of persons in the maintenance force.

(d) Compact or dispersed plant.

A plant spread in a wider area (Like ECIL Hyderabad) needs decentralization & may require several parallel maintenance organisations. A compact plant may need only one such organisation.

(e) Nature of industry i.e wheather it is Primarily an electrical, electronics, chemical or a mechanical industry.

(f) State of training & reliability of work force.

(6) In establishing a maintenance organisation, It is essential to recognise that:

(a) the plant to be maintained at a level consistent with low cost & high productivity,

(b) Supervisors should be appointed according to the duties & responsibility involved; &

(c) Modern age indicates greater need of newer engineering techniques & skills.

TYPES OF MAINTENANCE

Maintenance may be classified into following catogories (a) corrective or breakdown maintenance.

(b) Scheduled maintenance.

(c) Preventive maintenance.

(d) Predictive maintenance.

1.7.2 Corrective or Breakdown Maintenance.

→ It implies that repairs are made after the equipment is out of order & it cannot perform its normal function any longer, e.g an electric motor will not start, a belt is broken etc.

→ Under such conditions, Production department calls on the maintenance department to rectify the defect. The maintenance department checks into the difficulty & makes the necessary repairs.

→ After removing the fault, maintenance engineers do not attend the equipment again until another failure or break down occurs.

→ This type of maintenance may be quite Justified in small factories which:

(i) are different to the benefits of scheduling.

(ii) do not feel a financial Justification for scheduling techniques; and.

(iii) get seldom (temporary & permanent) demand in excess of normal operating capacity.

→ In many factories make-and-mend is the rule rather than expection.

→ Breakdown maintenance practice is economical for those (non-critical) equipments whose down-time & repair costs are less this way than with any other type of maintenance.

→ Breakdown type of maintenance involves little administrative work, few records & a comparative small staff.

Typical causes of Equipment Breakdown :-

(i) Failure to replace worn out parts.
(ii) Lack of lubrication.
(iii) Neglected cooling system.
(iv) Indifference towards minor faults.
(v) External factors (such as too low or too high line voltage, wrong fuel, etc.)
(vi) Indifference towards :- equipment vibrations, unusual sounds coming out of the rotating machinery, equipment getting too much heated up, etc.

Disadvantages of Breakdown Maintenance.

(i) Breakdowns generally occur at inopportunate times. This leads to poor, hurried maintenance & excessive delay in production.
(ii) Reduction of output.
(iii) Faster plant deterioration.
(iv) Increased chances of accidents & less safety to both workers & machines.
(v) More spoilt material.
(vi) Direct loss of profit.
(vii) Breakdown maintenance practice cannot be employed for those plant items which are regulated by statutory provisions, for example cranes, lifts, hoists & pressure vessels.

1.7.3 Scheduled Maintenance :-

→ Scheduled Maintenance is a stich-in-time procedure aimed at avoiding breakdowns.

→ Breakdowns can be dangerous to life and as far as possible should be minimized.

→ Scheduled maintenance practice incorportates (in M), inspection, lubrication, repair & overhaul of certain equipments which is neglected can result in breakdown.

Inspection, B

→ Scheduled maintenance practice is generally followed for overhauling of machines, cleaning of water & other tanks, white-washing of buildings etc.

Advantage

→ The equipment down time is decrease.

→ The no. of measure repairs are reduced.

→ The life expectancy of assets increased.

Disadvantage:-

→ The maintenance cost is more.

1.7.4 Preventive Maintenance

(a) The preventive maintenance involves periodic inspection of equipment & machinery to uncover conditions that lead to production breakdown & harmful depreciation.

(b) Up keep of plant equipment to correct such conditions while they are still in a minor stage.

→ Preventive maintenance is practised to some extent in about 75% of all manufacturing companies, but every preventive maintenance programme is tailored as per the requirement of each company.

→ The key to all good preventive maintenance programmes, however, is inspection.

→ Help can be taken of suitable statistical techniques in order to find how often to inspect.

Objectives of preventive maintenance:-

(i) To minimize the possibility of unanticipated production interruption or major breakdown by locating or uncovering any condition which may lead to it.

(ii) To make plant equipment & machinery always available & ready for use.

(iii) To maintain the value of equipment & machinery by periodic inspections, repairs, overhauls, etc.

(iv) To maintain the optimum productive efficiency of the plant equipment & machinery.

(v) To maintain the operational accuracy of the plant equipment.

(vi) To reduce the work content of maintenance jobs.

(vii) To achieve maximum production at minimum repair cost.

(viii) To ensure safety of life & limbs of the workmen

Advantages

→ It reduces the breakdown.
→ Less repair is required.
→ Greater safety for the worker.
→ Low maintenance & repair cost.
→ It increases equipment life.
→ Lower cost of manufacturing.

Disadvantages.

→ It cost more when initially it is started.

1.7.5 Predictive Maintenance :-

→ It is the new maintenance technique.

→ Some sensitive instrument like, audio gauges, vibration analyzers, Amplitute meters, pressure, temperature & resistance strain gauge etc. to predict troubles before the equipment fails.

→ Unusual Sounds coming out of a rotating equipment predict a trouble; an electric cable excessively hot at one point predicts a trouble.

→ In predictive maintenance, equipment conditions are measured periodically, or on a contineous basis & this enables maintenance men to take a timely action such as equipment adjustment, repair or overhaul.

→ predictive maintenance extends the service life of an equipment without fear to failure.

Advantages :-

→ It reduces the equipment cost as repair is made report before the replacement of parts.

→ Minimum labour is needed.

Disadvantages :-

→ The cost of equipment need for the condition of machined is high.

2. OPERATIONS RESEARCH

2.1 Operations Research.

→ Operations Research signifies research on operations. However, it takes into consideration a particular view of operations & a particular kind of research. Operations research is the organised application of modern science, mathematics & computer techniques to complex military, government, business or industrial problems arising in the direction & management of large systems of men, materials, money & machines.

→ The purpose is to provide the management with explicit quantitative understanding & assessment of complex situations; to have sounder basis for arriving at best decisions.

→ Operations research seeks the optimum state in all spheres & thus provides optimum solution to organisational problems. It is of considerable value in production management.

Applications.

(a) Locating factories & warehouses to minimize transportation cost.

(b) Work allocation to machines for minimizing production time & costs.

(c) Inventory problems.

(d) Material handling

(e) Dealing with waiting times.

(f) Equipment replacement.

(g) Dividing advertising budget.

(h) Establishing equitable bonus systems.

(i) Routing of tankers.

(J) Traffic control.
(K) Petrochemical mixes.
(L) Municipal & hospital administration, &
(m) Marketing. etc.

Methodology of operation Research:-

Various steps involved are as follows.

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

(2) Formulate a mathematical model:

→ A model is of great help in facilitating the investigations of operations & operation research expresses a problem by a model: The model covers the relationship of the variables. Generally two types of model employed.

* An analogue model is in the form of an electronic circuitry or (it may be) a mechanical system.
* A other called symbolic model is in the form of a matrix, a graph or an equation.

(3) Develop a mathematical solution.

→ Data is supplied to the model. Information is computed, & results are analysed to find the Mathematical Solution for alternative policies.

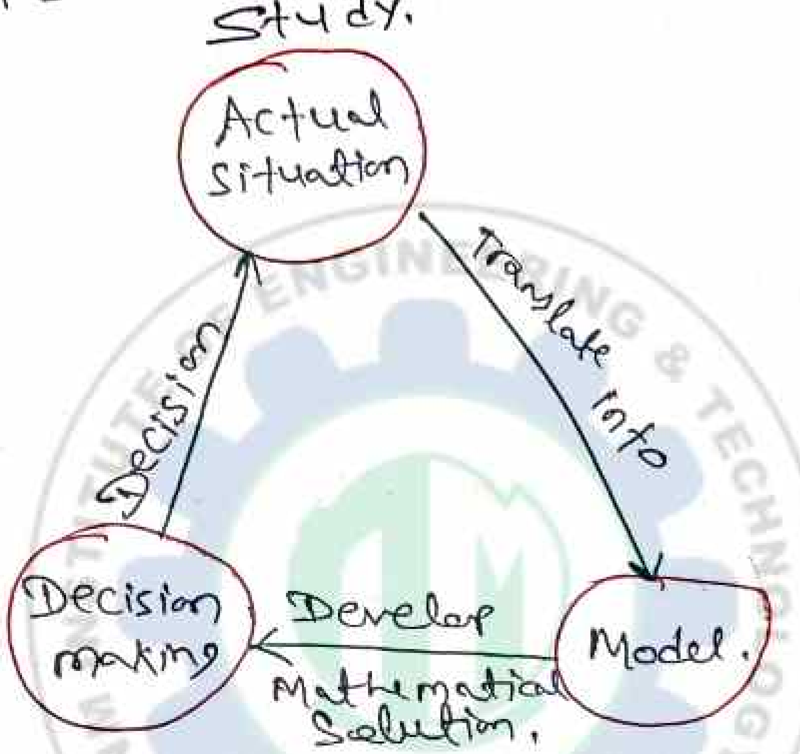
(4) Interpret the Solution & prepare the information in such a form that is meaningful, intelligible & quantitative. Translate it into a decision.

(5) Implement the decision to the real situation.

(6) Verify the results.

→ After applying the Solution to real

situation, the actual results produced by the model must be tested statistically & verified to explore any significant deviation from the expected results. If found so, the model can be modified & again the cycle is repeated.



(Figure: Operations Research Procedure)

Methods of Operation 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.

2.2 Define Linear Programming Problem:

→ 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 aggricultural works like blending fertilizers, selecting the right crop to be planted; in finance, personnel & 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 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.

The linear Programming model may look as under

Maximise $Z = c_1x_1 + c_2x_2 + c_3x_3 + \ldots + c_nx_n$

Subject to the conditions

$$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + \ldots\ldots a_{1n}x_n \leq b_1$$

$$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + \ldots\ldots a_{2n}x_n \leq b_2$$

$$\vdots \qquad \vdots \qquad \vdots \qquad \vdots$$

$$a_{m1}x_1 + a_{m2}x_2 + a_{m3}x_3 + \ldots\ldots a_{mn}x_n \leq b_m$$

$$b_i \geq 0, \; i = 1, 2, 3 \ldots\ldots m$$

$$x_j \geq 0, \; j = 1, 2, 3 \ldots\ldots n$$

The methods, which are commonly used to solve linear programming problems are discussed below.

2.3 Solution of L.P.P by graphical method -

Q) A furniture manufacturer makes two products X_1 & X_2 namely tables & chairs. Each tables contributes a profit of RS. 100 & each chair that of RS. 40. Tables & chairs from raw material to finished product, are processed in three sections S_1, S_2, S_3. In Section S_1 each table (X_1) requires five hours & each chair (X_2) requires two hours of processing. In section S_2 each table requires three hours & each chair two hours & in section S_3, the times are 1 & 2 hours respectively. The manufacturer wants to optimize his profits if sections S_1, S_2 & S_3 can be availed for not more than 1000, 900 & 500 hours respectively.

Solution → The first step is to formulate the linear programming model i.e mathematical model from the given above. The model is as under:

Maximize $Z = 100x_1 + 40x_2$ (Z)

Subject to, $5x_1 + 2x_2 \leq 1000$ (C_1)

$3x_1 + 2x_2 \leq 900$ (C_2)

$x_1 + 2x_2 \leq 500$ (C_3)

$x_1, x_2 \geq 0$ (C_4)

C_1 is constraint No. 1 & so on.

→ The second step is to convert the constraint inequalities temporarily, into equation, i.e

$5x_1 + 2x_2 \leq 1000$ (C_1) —— (i)

$3x_1 + 2x_2 \leq 900$ (C_2) —— (ii)

$x_1 + 2x_2 \leq 500$ (C_3) —— (iii)

1st method

* divide eqⁿ (1) by 1000

$$\frac{5x_1}{1000} + \frac{2x_2}{1000} = \frac{1000}{1000}$$

$$\Rightarrow \frac{x_1}{200} + \frac{x_2}{500} = 1$$

* divide eqⁿ (2) by 900

$$\frac{3x_1}{900} + \frac{2x_2}{900} = \frac{900}{900}$$

$$\Rightarrow \frac{x_1}{300} + \frac{x_2}{450} = 1$$

* Divide eqⁿ (3) by 500

$$\frac{x_1}{500} + \frac{2x_2}{500} = \frac{500}{500}$$

$$\Rightarrow \frac{x_1}{500} + \frac{x_2}{250} = 1$$

→ In third step axis are marked on the graph paper & are labelled with variables X_1 & X_2.

→ In fourth step is to draw straight lines on the graph paper using the constraint equations, & to mark the feasibility solution on the graph paper. For example, taking first constraint equation.

2nd method.

In eqn (1)

$5x_1 + 2x_2 = 1000.$

If $x_1 = 0$, $x_2 = \frac{1000}{2} = 500$

If $x_2 = 0$, $x_1 = \frac{1000}{5} = 200$

In eqn-2

$3x_1 + 2x_2 = 900$

If $x_1 = 0$, $x_2 = \frac{900}{2} = 450$

If $x_2 = 0$ $x_1 = \frac{900}{3} = 300.$

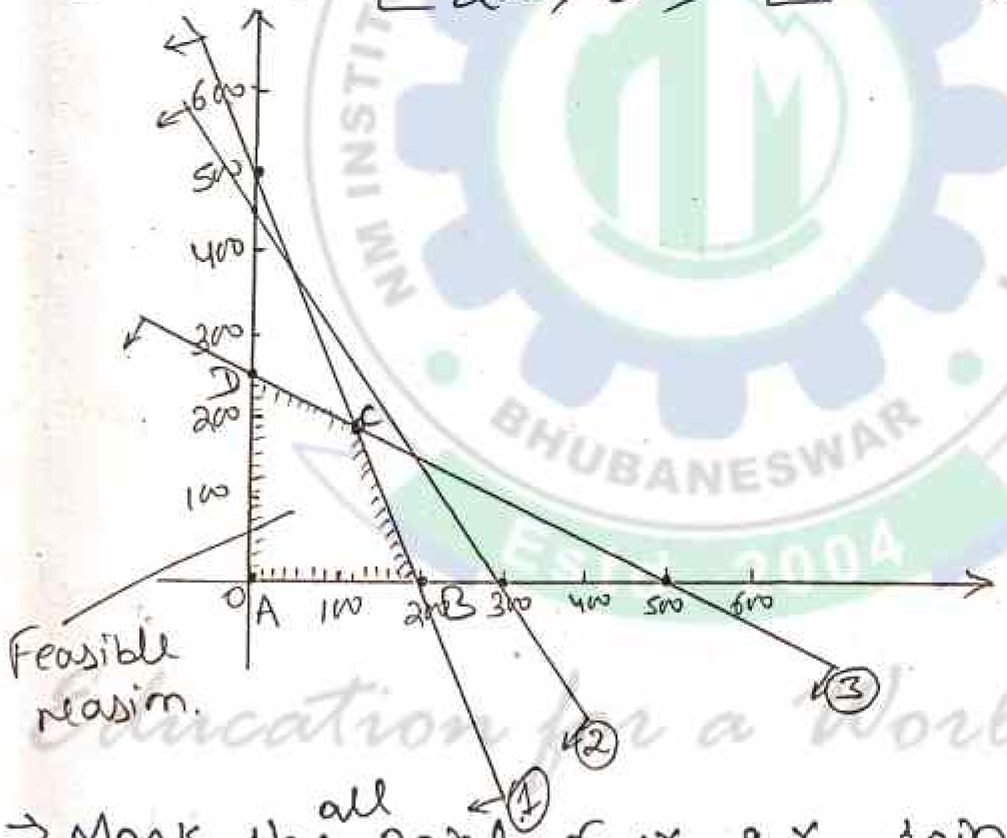
In eqn-3

$x_1 + 2x_2 = 500$

If $x_1 = 0$, $x_2 = \frac{500}{2} = 250$

If $x_2 = 0$ $x_1 = 500.$

In eqn 1 $\begin{bmatrix} x_1 & x_2 \\ 0, & 500 \\ 200, & 0 \end{bmatrix}$ eqn-2 $\begin{bmatrix} x_1 & x_2 \\ 0 & 450 \\ 300 & 0 \end{bmatrix}$ eqn-3 $\begin{bmatrix} x_1 & x_2 \\ 0 & 250 \\ 500 & 0 \end{bmatrix}$



→ Mark the all point of x_1 & x_2 join them. This straight line represents C_1, C_2 & C_3.

Point A (0,0)

Point B (200, 0)

Point C (125, 187.5)

Point D (0, 250)

→ The fathest point of the region of feasible solution. i.e point C at the intersection of C_1 & C_3.

→ The co-ordinate point C can be found by solving eqn C_1 & C_3.

$$5x_1 + 2x_2 \leq 1000 \quad — \quad C_1$$

Substract. $$x_1 + 2x_2 \leq 500 \quad — \quad C_3$$

(−) (−) (−)

$$\Rightarrow 4x_1 = 500, \quad x_1 = \frac{500}{4} = 125$$

x_1 value puts in eqn-(1)

$$5.(125) + 2x_2 \leq 1000$$

$$\Rightarrow 625 + 2x_2 = 1000$$

$$2x_2 = 1000 - 625$$

$$x_2 = 375/2 = 187.5$$

point C (125, 187.5)

point A (0, 0)

$$\text{Max } Z = 100x_1 + 40x_2 \Rightarrow 0$$

point B (200, 0)

$$\text{Max } Z = 100.(200) + 0 \Rightarrow 20,000 \text{ (max)}$$

point C (125, 187.5)

$$Z = 100.(125) + 40(187.5) \Rightarrow 20,000 \text{ (max)}$$

point D = (0, 250)

$$Z = 100(0) + 40(250) = 10,000$$

∴ The maximum value of Z occurs at two verties B & C.

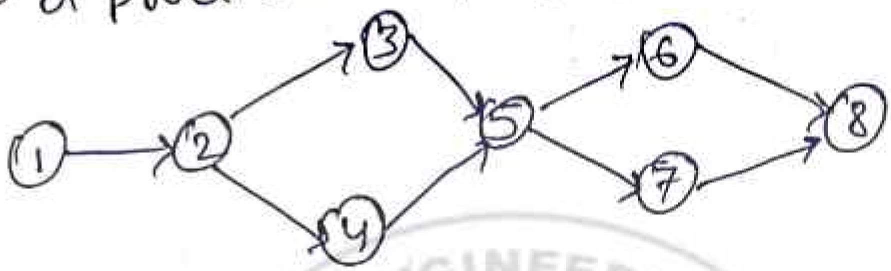
~~Thus in Since the Joining~~.

Since the infinite no. of points on the line joining B & C, it gives the same max value of Z.

∴ Thus infinite no. of optimal solution for LPP.

2.4 Evaluation of Project completion time by critical Path method & PERT

① **Network Diagram:-** It is Pictorial representation of the various events & activities relating to a particular project.



(1) → (2) Activity.

(1), (2) → events.

② **Event:-** An event refers to the starting or finishing point of an activity & it requires no time. Events may be simple, node, head event or tail events.

③ **Activity:-** An activity refers to some action, the performance of which requires some time & resources. Activities may be preceding activities, succeeding activities, concurrent activities &/ or dummy activities.

Critical Path Method (CPM)

→ It is a graphical technique which involves the preparation of the network diagram & its analysis to indicate the critical path, non-critical paths, critical activities, non-critical activities, slacks, & different floats of various activities. It has the potential scheduling of a project in minimum possible time & cost in the light of the given constraints.

* **Path:**
→ A connected sequence of activities leading from the starting event to the ending event.

(1) → (2) → (3) – (4) – (5) → (6)

* **Critical path:**
→ A longest path (time) determines the project duration.

* **Critical Activity:**
→ All of activities that make up the critical path.

(1) → (2), (2) → (4), (4) → (5), (5) → (7)

Computation of Slack & Floats.

* **LT:** It is the latest possible time at which an event can occur. The LT of the starting event of a project is zero.

* **ET:** It is the earliest possible time at which an event can occur. The ET of the starting event of a project is zero, but the ET of all other events is equal to the greatest of the EFTs of its preceding activities.

* **Slack:** In realation to an event a slack is the difference between its LT & ET.

Head slack $= LT_H - ET_H$

Tail slack $= LT_T - ET_T$

A slack can be positive, Negative or zero.

* **Float:** The term Float refers to the slack of an activity.

* **Total Float:** It is the time by which one activity other than the critical activity can

be manipulted without delaying the overall time of the project.

$$TF = (L_{st} - E_{st}) \text{ or } (L_{ft} - E_{ft})$$

It can give either positive or negative value.

→ There will be no float for a critical activity as it can't be delayed.

* <u>Free Float</u>:- It is that portion of total float within which an activity can be manipulated without affecting the float of subsequent activities.

FF = Total float - Head slack.

It may either be positive or negative.

* <u>Independent</u> <u>Float</u>:- It is that part of the total float within which an activity can be delayed for its starting without affecting the floats of its preceding activities.

IF = FF - Tail slack.

→ It is always positive. If it is found negative, then the same should be made upto zero.

→ positive float (TF, FF & IF) implies that there are idle time & resources available for the activities which could be utilised.

→ Negative float (TF & FF) indicates that the activities concerned are short of time & resources.

→ Both positive & negative floats are undesirable. The knowledge of float helps the management in determining the flexibility of the schedule & the extent to which the resources will be utilised on different activities. This helps in diverting the resources from the non-critical activities to the critical activities which can result in shortening the project period & in the saving of costs.

Program Evaluation & Review Technique (PERT)

→ It is used as a formidable instrument by the project planner & controllers in the determination of the expected total time a project is likely to take for its completion & for analysing & administering large complex projects to be performed in some sequence.

The determination of the most expected activity time (t_e) rests on the following time estimates.

1. The most optimistic time (t_o) :-

→ It is the shortest possible time within which an activity can be performed when everything goes perfectly without any disturbance. It is the most ideal time which rarely occurs in practise.

2. The most pessimistic time (t_p) :-

→ It is the longest possible time which is likely to take place to complete an activity when all sorts of complicacies & unusual delays take place. This is also rarely occurs in practice.

3. The most likely time (t_m):

→ It refers to that time which is most likely to take place to complete a particular activity or a project. This is the best possible estimate of time which normally occurs in the completion of an activity.

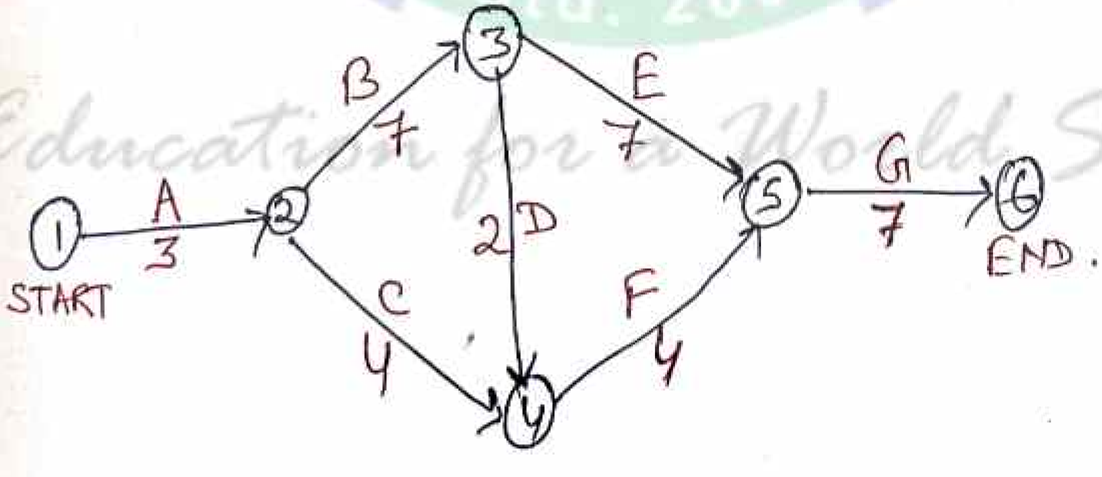
→ Now, on the basis of these time estimates the expected activity times is estimated by the formula:

$$t_e = \frac{t_o + 4t_m + t_p}{6} \quad (t_e = \text{mean})$$

$$\sigma_t = \left(\frac{t_p - t_o}{6}\right)^2 \quad (\sigma_t = \text{Variance})$$

Example-1

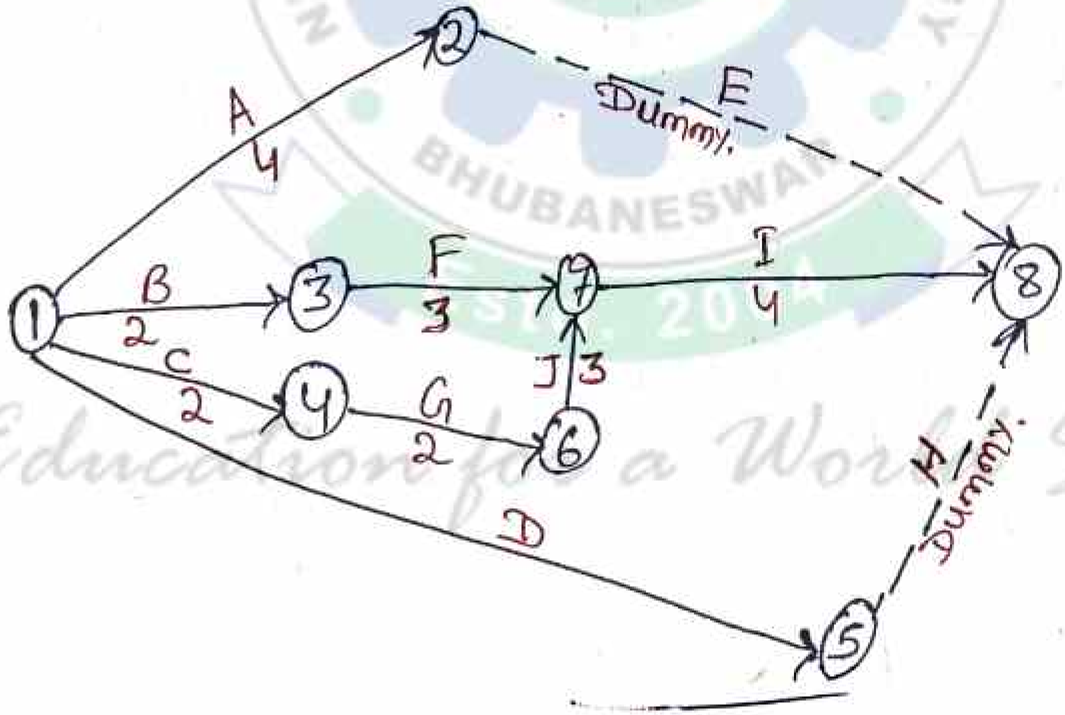
Draw a network diagram from the following information. B & C follow A, E follows B, F follows D & C, & G follows E & F. where A, B, C, D, E, F & G are the activities requiring 3, 7, 4, 2, 7, 4 & 7 days respectively.



Example-2

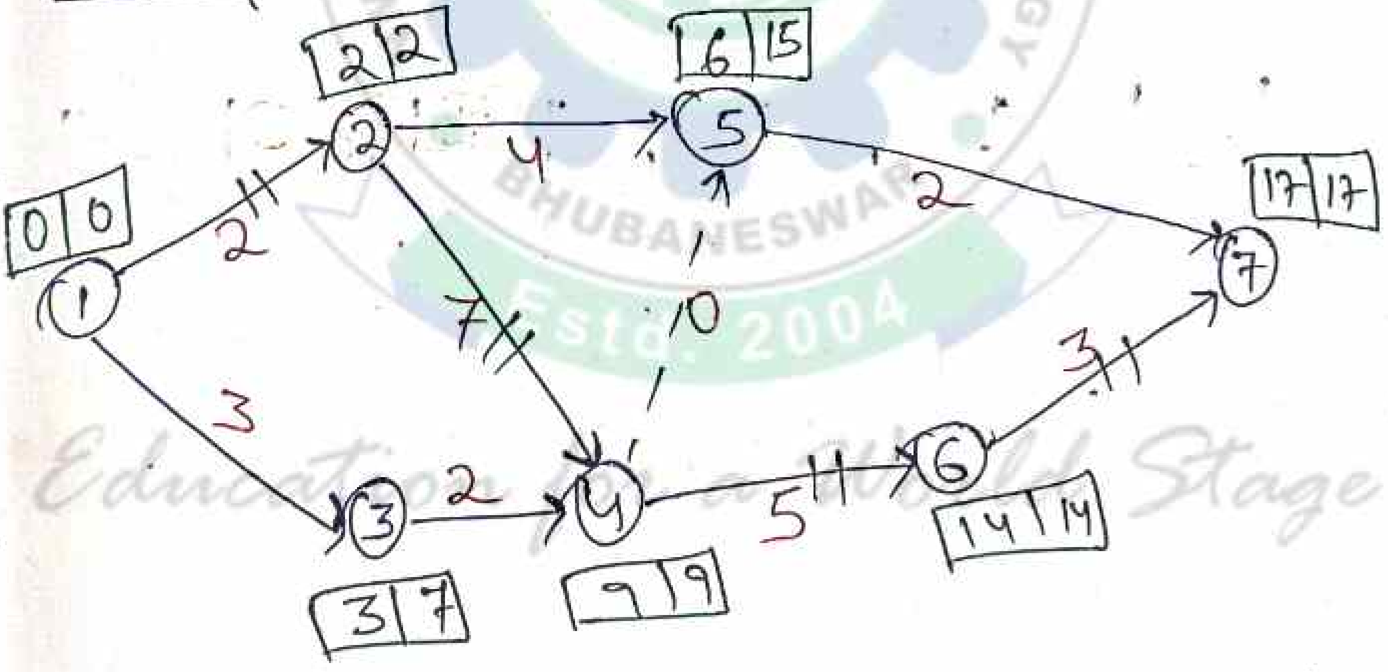
Draw a Network diagram from the following.

Activity		Name of the Activity	Pre-requisite Activity	Estimated Time
Event	Event			
1	2	A	None	4
1	3	B	None	2
1	4	C	None	2
1	5	D	None	2
2	8	E	A	-
3	7	F	B	3
4	6	G	C	2
5	8	H	D	-
7	8	I	F&J	4
6	7	J	G	3



Example-3

Predecessor (P) ①	Successor (S) ②	Expected time (tE) ③	Earliest Start ④	Earliest Finish ⑤	Latest Start ⑥	Latest Finish ⑦	Slack ⑦-⑤/⑥-④ EFinish-LFinish
1	2	2	0	2	0	2	0 → CA
1	3	3	0	3	4	7	4
2	4	7	2	9	2	9	0 → CA
2	5	4	2	6	11	15	9
3	4	2	3	5	7	9	4
4	5	0	9	9	15	15	6
4	6	5	9	14	9	14	0 → CA
5	7	2	9	11	15	17	6
6	7	3	14	17	14	17	0 → CA

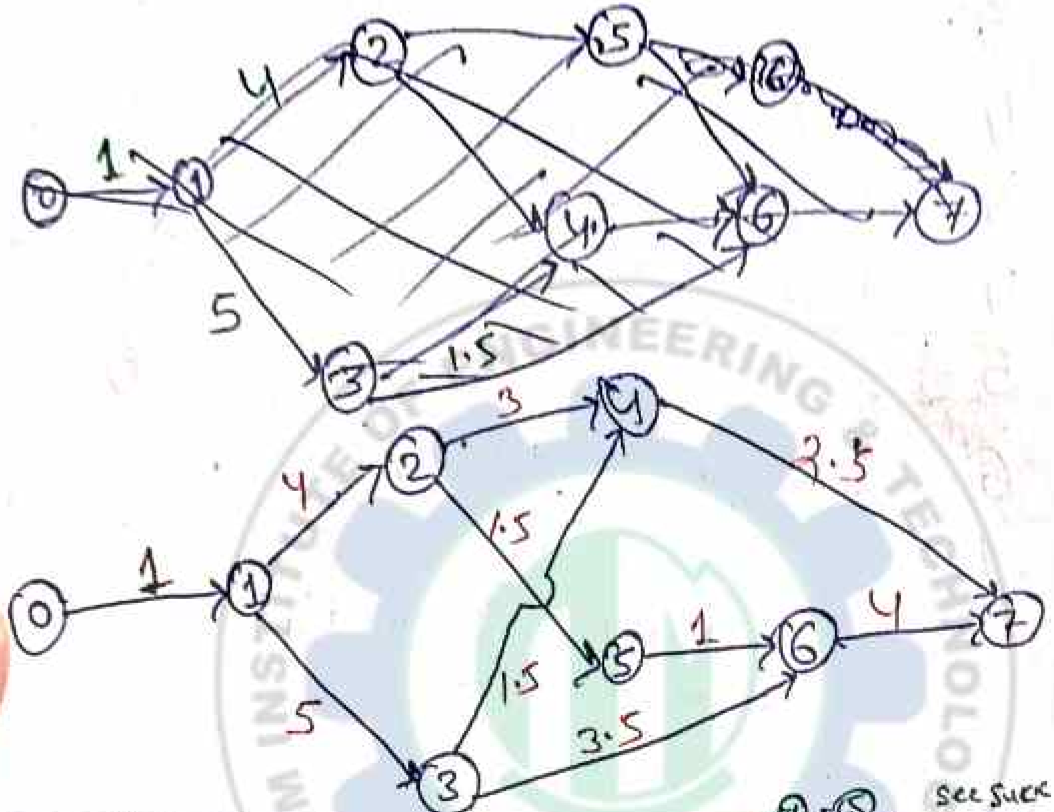


∴ ① → ② → ④ → ⑥ → ⑦ (critical path)

The above path is longest time duration.

Example-4

Q) Draw the critical path of the below CPM Network & findout the total float, free float & Independent float of the Network diagram.



Prec ①	Succ ②	Activity time ③	Earliest S ④	Earliest F ⑤	Latest S ⑥	Latest F ⑦	Total Float ⑧ (⑥-④ / ⑦-⑤)	Free Float ⑨ ⑧-(⑦-⑤) (see succ)	Independent float ⑨-(⑥-④) (see prec)
0	1	1	0	1	0	1	0	0	0
1	2	4	1	5	3	7	2	0	0
1	3	5	1	6	1	6	0	0	0
2	4	3	5	8	8	11	3	0	-2
2	5	1.5	5	6.5	7	8.5	2	0	-2
3	4	1.5	6	7.5	9.5	11	3.5	0.5	0.5
3	6	3.5	6	9.5	6	9.5	0	0	0
4	7	2.5	8	10.5	11	13.5	3	3	0
5	6	1	6.5	7.5	8.5	9.5	2	2	0
6	7	4	9.5	13.5	9.5	13.5	0	0	0

Example-5

Consider the following data of a project.

Activity	predecessor	Duration a	b	c
a	-Nil-	1	2	3
b	-Nil-	2	2	8
c	a	6	7	8
d	b	1	2	3
e	a	1	4	7
f	c, d	1	5	9
g	c, d, e	1	2	3
h	f	1	2	9

findout the expected time, standard deviation & variance.

Activity	predecessor	$t_E = \frac{t_o + 4t_m + t_p}{6}$ (t_o min, t_p max)	Variance $(\sigma^2) = \left(\frac{t_p - t_o}{6}\right)^2$	std. deviation = $\sqrt{\text{variance}}$
a	Nil	2	1/9	1/3
b	Nil	3	1	1
c	a	7	1/9	1/3
d	b	2	1/9	1/3
e	a	4	1	1
f	c, d	5	16/9	4/3
g	c, d, e	2	1/9	1/3
h	f	3	16/9	4/3.

CPM	
(1) It is a deterministic model under which result is ascertained in a manner of certainty.	(1) It is a probabilistic model under which result is estimated in a manner of probability.
(2) It deals with the activities of precise well known time.	(2) It deals with the activities of uncertain time.
(3) It is used for repetitive jobs like residental construction.	(3) It is known for non-repetitive jobs like planning & scheduling of research programme.
(4) It is activity oriented in as much as its result are calculated on the basis of the activities.	(4) It is event oriented in as much as its results are calculated on the basis of events.
(5) It does not make use of Dummy activities.	(5) It makes use of Dummy activities to represent the proper sequencing of the activities.
(6) It deals with cost of a project schedules & their minimization.	(6) It has nothing to do with cost of a project.
(7) It deals with the concept of crashing.	(7) It does not deal with concept of crashing.
(8) Its calculation is based on the type of time estimation that is precisely known.	(8) It finds out expected time of each activity on the basis of three types of estimates; viz, optimistic time, pessimistic time & most likely time.
(9) It does not make use of the statistical device in the determination of the time estimates.	(9) It makes use of the statistical devices, viz. standard deviation, variance, probability(z), & normal distribution table in the determination of probabilities of completing or not completing a project or a path with in a given time.

3. INVENTORY CONTROL

3.1 classification of Inventory.

(i) Fluctuation inventories have to be carried for the reason that sales & production times for the product can not be always predicted with accuracy. There are variations in demand & lead times required to manufacture items. Thus there is a need for reserve stock to account for the flutions in demand & lead time.

(ii) Anticipation inventories are built up in advance for big selling season, promotion programme or anticipation of likely change in demand suddenly & in case of plant shutdown period. It is the inventory for the future need.

(iii) Lot size inventory refers to producing & storing at the rate higher than the current consumption rate. The production in lots is going to help the advantage of price discounts for quantities purchased in bulk & fewer set ups & hence the lower set-up cost.

(iv) The transportation inventories exist because materials must be moved from one place to another. When transportation requires a long time, the items in transport represent the inventory. Thus transportation inventory is a result of extended or longer transportation time.

3.2 Objectives of Inventory Control.

(i) To ensure adequate supply of products to customers & avoid shortages as far as possible.

(ii) To make sure that the financial investment in inventories is minimum. (i.e, to see that the working capital is blocked to the minimum possible extent)

(iii) Efficient purchasing, storing, consumption & accounting for materials is an important objective.

(iv) To maintain timely record of inventories of all the items & to maintain the stock within the desired limits.

(v) To ensure timely action for replenishment.

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

(vii) To provide a scientific base for both short term & long term planning of materials.

3.3 Function of inventory.

(i) Separate different operations from one another & make them independent, so that each operation (starting from raw material to finished product) can be performed economically. For e.g. Ordering of raw material can be carried out independently of the finished goods distributing finished goods in one big lot, than in small batch sizes. Besides economy, the men & machinery also can be better utilized if the operations are separated & carried out in various departments than if coupled & tied at one place.

(ii) Maintain smooth & efficient production flow.
(iii) Purchase in desired quantities & thus nullify the effects of changes in prices or supply.
(iv) Keep a process continually operating.
(v) Create motivational effect. A person may be tempted to purchase more if inventories are displayed in bulk.

3.4 Benefits of inventory control :-

It is an established fact that through the practice of scientific inventory control, the stocks can be reduced anywhere between 10% to 40%. The benefit's of Inventory control are :

(i) Improvement in customers. relationship because of the timely delivery of goods & services.
(ii) Smooth & uninterrupted production, & hence no stock out.
(iii) Efficient utilisation of working capital.
(iv) Helps in minimising loss due to deterioration obsolescence damage & preliferage.
(v) Economy in purchasing.
(vi) Eliminates the possibility of duplicate ordering.

3.5 Cost associated with inventory.

(i) Purchase (or production) cost :- The value of an item is its unit purchasing (production) cost. This cost becomes significant when availing the price discounts. This cost is expressed as Rs/unit.

(ii) Capital cost :- The amount invested in an item, (capital cost) is an amount of capital not available for other purchases. If the money were invested some where else, a return on the investment is expected. A charge to inventory expenses is made to account for this unreceived return. The amount of the charge reflects the percentage return expected from other investment.

(iii) Ordering cost :- It is also known by the name procurement cost or replenishment or acquisition cost. Cost of ordering cost is the amount of money expended to get an item into inventory. This takes in to account all the costs incurred from calling the quotations to the point at which the items are taken to stock.

There are two types of costs - Fixed costs & Variable cost.

Fixed costs do not depend on the number of orders where as variable costs change with respect to the number of orders placed.

The salaries & wages of permanent employees involved in purchase function & control of inventory purchasing incoming inspection, accounting for purchase orders constitute the major part of the fixed costs.

The cost of placing an order varies from one organisation to another. They are generally classified under the following heads:

(i) **Purchasing:-** The clerical & administrative cost associated with the purchasing, the cost of requisitioning material, placing the order, follow up, receiving & evaluating quotations.

(ii) **Inspection:-** The cost of checking material after they are received by the supplier for quantity & quality & maintaining records of the receipts.

(iii) **Accounting:-** The cost of checking supply against each order, making payments & maintaining records of purchases.

(iv) **Transportation costs.**

(iv) **Inventory carrying costs (Holding costs):**

→ These are the costs associated with holding a given level of inventory on hand & this cost vary in direct proportion to the amount of holding & period of holding the stock in stores. The holding costs include,

(i) Storage costs (rent, heating, lighting etc.)

(ii) Handling costs: Costs associated with moving the items. such as cost of labour, equipment for handling.

(iii) Depreciation, Taxes & insurance.

(iv) Costs on record keeping.

(v) Product deterioration & obsolenseence.

(vi) Spoilage, breakage, pilferage & loss due to perishable nature.

(v) Shortage cost ÷ When there is a demand for the product & the item needed is not in stock, then we incur a shortage cost or cost associated with stock out. The shortage costs include:

(i) Backorder costs.
(ii) Loss of future sales.
(iii) Loss of customer good will.
(iv) Extra cost associated with urgent, small quantity ordering costs,
(v) Loss of profit contribution by lost sales revenue.

The unsatisfied demand can be satisfied at a later stage (by means of back orders) or unfulfilled demand is lost completely (no-back ordering, the shortage costs become proportional to only the shortage quantity.)

3.6 Terminology in Inventory control:

(i) Demand: It is the number of items (Products) required per unit of time. The demand may be either deterministic or Probabilistic in nature.

(ii) Order cycle ÷ The time period between two successive orders is called order cycle.

(iii) Lead time ÷ The length of time between placing an order & receipt of items is called lead time.

(iv) Safety Stock :- It is also called Buffer stock or Minimum stock. It is the stock or inventory needed to account for delay in material supply & to account for sudden increase in demand due to rush orders.

(v) Inventory turnover :- If the Company maintains inventories equal to 3 months consumption. It means that inventory turnover is 4 times a year. i.e the entire inventory is used up & replaced 4 times a year.

(vi) Re-order-Level(ROL) :- It is the point at which the replenishment action is initiated. when the stock level reaches R.O.L, the order is placed for the item.

(vii) Re-order quantity :- This is the quantity of material (item) to be ordered at the re-order level.

Normally this quantity equals the economic order quantity.

3.7 ~~Economic~~ Economic order quantity

→ A problem which always remains is that how much material may be ordered at a time. An industry making bolts will definitely like to know the length of steel bars to be purchased at any one time. This length of steel bars is called "Economic order Quantity" & an economic order quantity is one which permits lowest cost per unit & is most advantageous.

→ Before calculating economic order quantity it is necessary to become familiar with terms like maximum inventory, minimum inventory, standard & reorder point, which are known as Quantity standards.

→ Starting from an instant when inventory 'OA' is in stores, it (inventory) consumes gradually in quantity from A along 'AD' at a uniform rate. It is pre known that it takes 'L' Number of days between initiating order & receiving the needed inventory.

→ Therefore as the quantity reaches point 'B', purchase requisition is initiated which takes from 'B' to 'C', that is time R. From 'C' to 'D' is the inventory procurement time 'P'. At the point 'D' when only reserve stock is left, the ordered material is supposed to arrive & again the total quantity shoots to its maximum value, i.e the point A' (A = A')

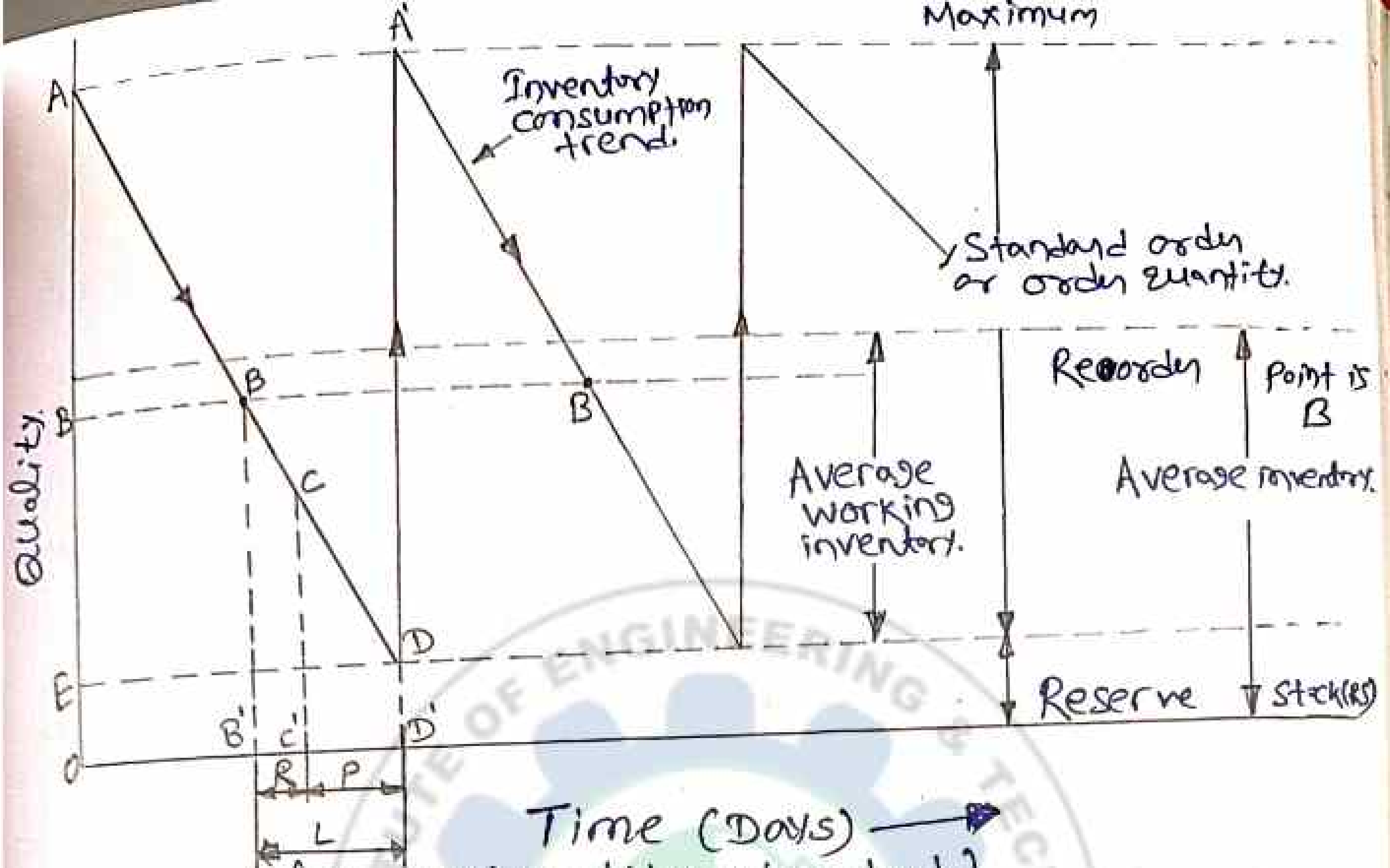
→ Maximum Quantity 'OA' is the upper or maximum limit to which the inventory can be kept in the stores at any time.

→ Minimum Quantity 'OE' is the Lower or minimum limit of the inventory which must be kept in the stores at any time.

* The purpose should be to hold enough & not excessive stock of material. Stock holding:

(i) Avoid running out of stock.

(ii) Helps creating a buffer stock which may be used if the materials fall below the minimum level.



(Fig 1: Quantity standard.)

(iii) Makes sure the predecided delivery dates.

(iv) Provides quick availability of materials.

(v) Takes care of price fluctuations & shortage of inventory in the market.

(vi) Advises regarding, obsolete & slow running items.

(vii) Helps in standardization & thus reducing the variety of items to be handled.

→ Standard order (A'D) is the difference between maximum & minimum quantity & it is known as economical purchase inventory size.

→ Reorder Point (B) indicates that it is high time to initiate a purchase order & if not done so the inventory may exhaust, & even reserve stock utilized before the new material arrives.

From B' to D' it is as lead time (L) & it may be determined on the basis of past experience it involves:

(i) Time to prepare purchase requisition & placing the order;

(ii) Time taken to deliver purchase order to the seller.

(iii) Time for seller (vendor) to get or prepare inventory &

(iv) Time for the inventory to be dispached from the vendor's end & to reach the customer.

Time, (i) above is known as requistion time (R) & (ii) + (iii) + (iv) is the procurement time (P). The economic lot size for an order or the economic order quantity depends upon two types of costs.

(i) <u>Inventory procurement costs</u>, which consists of expenditure with

→ receiving quatations.

→ Making purchase requistion.

→ Following up & expediting purchase order.

→ Receiving materials & then inspecting it &

→ processing seller's (vendor's) invoice.

Procurements cost decrease as the order quantity increases (Fig: 2)

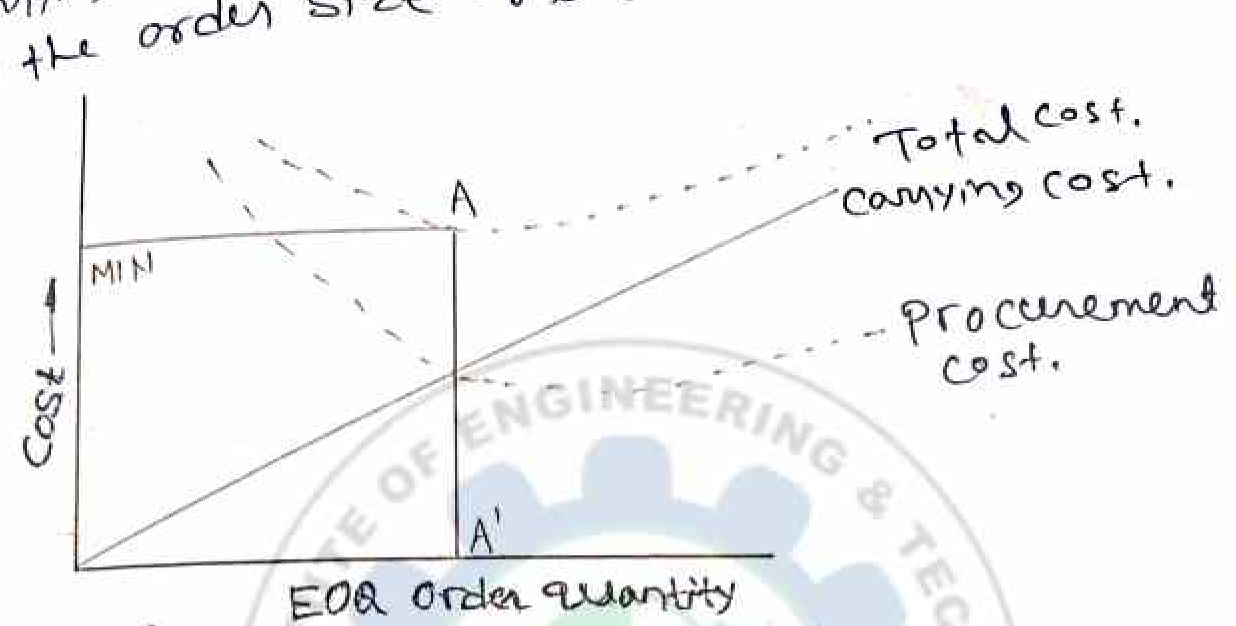
(ii) <u>Carrying costs</u>, which vary with quantity ordered, base on average inventory & consists of.

→ Interest on capital investment.

→ Cost of storage facility, up-keep of materials record keeping etc.

→ Cost including deterioration & obsolescence i.e
→ Cost of insurance, property tax, etc.

Carrying costs are almost directly proportional to the order size or lot size or order quantity.



(Fig-2: Relationship between cost & quantity)

→ In figure 2 the procurement cost & inventory carrying costs have been plotted with respect to quantity in lot. Total cost is calculated by adding procurement cost & carrying cost. Total cost is minimum at the point & thus A' represents the economic order quantity or economic lot size.

EOQ in mathematically.

Now we describe the assumptions, variable definations, cost formulas & EOQ formula as follows: ASSUMPTIONS:

(i) Annual demand, carrying cost & ordering cost for a material can be calculated with precision, i.e are known with certainty & is constant over time.

(ii) Average inventory level for a material is order quantity divided by two. This implicitly assumes that no safety stock is utilized, orders are received all at once, materials are used at a uniform rate, & materials are entirely used up when the next order arrives.

(iii) Volume discounts do not exist (i.e purchase costs do not vary with quantity ordered)

(iv) There are no stockout costs, i.e inventory is replenished immediately as the stock level is almost zero.

(v) Lead time is known as well as fixed & is equal to or greater than zero.

Variable Definations.

D = Annual demand for a material (units per year)

Q = Quantity of material order at each order point (units per order)

C_h = Cost of carrying (or holding) one unit in inventory for one year (₹ per unit per year)

C_0 = Average cost of completing an order for material (₹, per order)

TIC = Total annual stocking cost for a material (₹ per year)

Cost Formula

Annual carrying (or holding) cost

= Average inventory level × carrying cost per unit per year. $= \left(\frac{Q}{2}\right)C_h$

Annual ordering cost

= No. of orders placed per year × ordering cost per order

$\left(\frac{\text{Annual demand}}{\text{No. of units in each order}}\right)$ (ordering cost per order) $= \left(\frac{D}{Q}\right)C_0$

Total annual cost = Annual carrying cost + Annual ordering cost.

$$= \left(\frac{Q}{2}\right)C_h + \left(\frac{D}{Q}\right)C_0$$

Economic order Quantity Formula.

The optimal order quantity is obtained when the annual ordering costs for a material are exactly equal to the annual carrying costs:

① Set the annual carrying costs equal to annual ordering costs:

$$\left(\frac{Q}{2}\right) C_h = \left(\frac{D}{Q}\right) C_o$$

② Multiply both sides of equation by Q:

$$Q^2 \left(\frac{C_h}{2}\right) = D\, C_o$$

③ Divide both sides of equation by $\left(\frac{C_h}{2}\right)$:

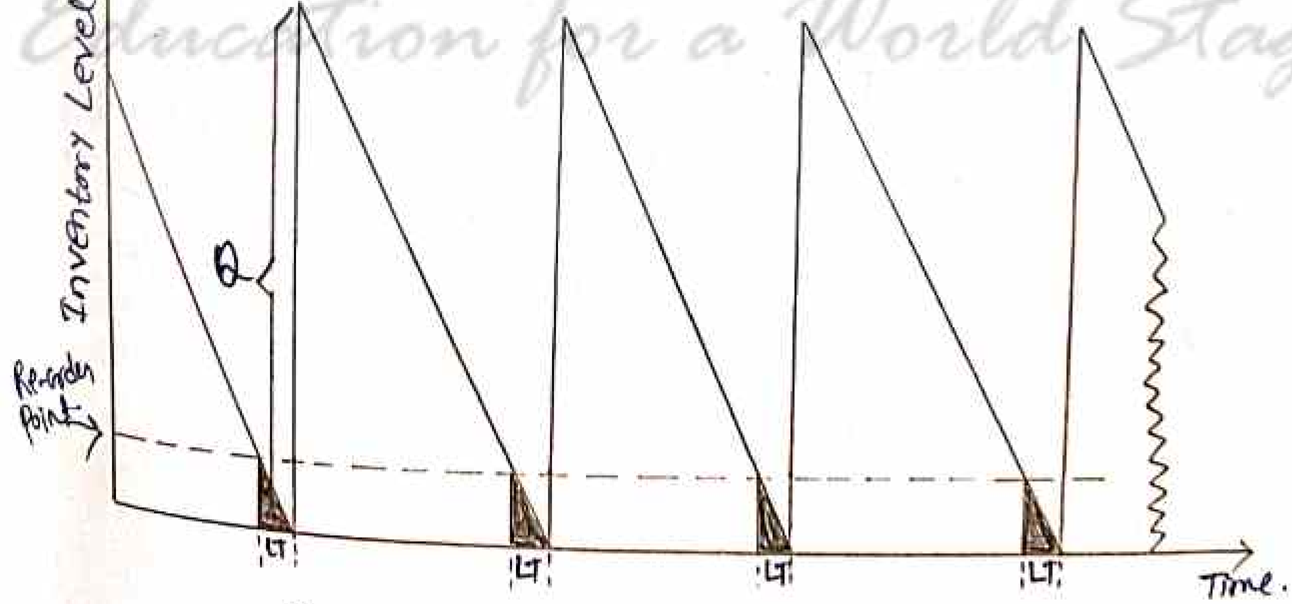
$$Q^2 = \frac{2 D C_o}{C_h}$$

④ Take the square root of both sides of equation:

$$Q = \sqrt{\frac{2DC_o}{C_h}}$$

⑤ The EOQ is therefore: $Q^* = Q^* = \sqrt{\frac{2DC_o}{C_h}}$

This Economic lot size formula is due to R.M. Wilson.



(Fig-3)

Average Inventory Level

$$= \frac{\text{Maximum Inventory} + \text{Minimum Inventory}}{2}$$

$$= \frac{Q+0}{2} = \frac{Q}{2}$$

→ As demonstrated in Figure-3 an average inventory of $Q/2$ implies no safety stock, orders are received all at once, materials are used at a uniform rate, & materials are entirely used up when the next order comes. The presence of all these characteristics however is rare in practice; but in spite of minor deviations, $Q/2$ may still be a resonable estimate of average inventory levels for some materials. A quick check of the stock records of a material will either confirm or deny the validity of $Q/2$ as an estimate of average inventory levels. If another measure of average inventory levels is observed to be a more precise estimate, this new value could be substituted for $Q/2$ in the cost formulas, thus resulting in a slightly different EOQ formula.

I. Other Important Formula :- The optimal number of orders or manufacturing runs per year (N^*) & the optimal time between two successive order (T^*) can be determined as follows:

$$N^* = \frac{\text{Demand}}{\text{optimal order quantity}} = \frac{D}{Q^*} = \sqrt{\frac{DC_h}{2C_o}}$$

II. $T^* = \dfrac{\text{Number of working day in a year.}}{N^*}$, ($T^*$ is also called the inventory cycle time)

III. Minimum total yearly inventory variable cost is given by:

$$TC(Q^*) = \frac{D}{Q^*}C_0 + \frac{Q^*}{2}C_h$$

$$= \left\{ DC_0 / \sqrt{\frac{2DC_0}{C_h}} \right\} + \left\{ C_h \sqrt{\frac{2DC_0}{4C_h}} \right\}$$

$$= \sqrt{2DC_0C_h}$$

Remarks:

(i) Inventory having cost in many circumstances are often expressed as an annual percentage of the unit cost or price. In these cases, there is another variable in the equation. Let 'I' be the annual inventory carrying charge as a percent of price. The cost of storing one unit of inventory for the year, C_h is given by $C_h = IC$, where C is the unit price of an inventory item. In this case, Q^* can be expressed as

$$Q^* = \sqrt{2DC_0(IC)}.$$

(ii) Calculus Approach. As mentioned earlier, the total inventory cost is the sum of the ordering & holding costs. In terms of the variables in the model, the total variables cost (TC) can be derived as:

$$TC = (D/Q)C_0 + (Q/2)C_h \quad \text{------ (i)}$$

Differentiating the expression (i) w.r.t Q.

$$\frac{d}{dQ}(TC) = \frac{-D}{Q^2}C_0 + \frac{C_h}{2}$$

The first derivative is set equal to zero in order to obtain the optimal value of Q,

i.e $\frac{-D}{Q^2} C_0 + \frac{C_h}{2} = 0$

$$Q^2 = \frac{2DC_0}{C_h} \therefore Q = \sqrt{\frac{2DC_0}{C_h}} \quad \text{--- (ii)}$$

The above approach results the same formula as the algebric method but we cannot conclude wheather the total costs are at a minimum or maximum with respect to the economic order quantity. However, the use of second derivative, viz.,

$\frac{d^2(TC)}{dQ^2} = + \frac{2DC_0}{Q^3}$ which is positive, indicates that a minimum total cost will be attained with respect to this economic order quantity.

Example-1:

Q) Data relevant to component R used by Engineering India Limited in 20 different assemblies includes: Purchases price: ₹15 per 100, annual usuage: 1,00,000 units, Cost of buying office: Fixed ₹15,575 per annum; Variable ₹12 per order; rent of components ₹3,000 per annum, heating: ₹700 per annum interest: 25% per annum; Insurance 0.05% per annum based on total purchases, depreciation as 1% per annum of all items purchased, (a)

(i) Calculate EOQ for Component R.

(ii) Calculate the percentage changes in total annual variable costs relating to component R if the annual usuage was (a) 125,000 units & (b) 75,000 units

Solution.

In usual notations, we are given:

$D = 1,50,000$ units, $C_0 = 12$

$C_h = (15/100) \times (0.25 + 0.0005 + 0.01) = 0.039075$.

Demand/year.	Economic order Quantity $Q^* = \sqrt{\frac{2DC_0}{C_h}}$	Ordering cost $= \frac{D}{Q^*} \times C_0$	Holding cost $= \frac{Q^*}{2} \times C_h$	Total Annual cost.
1,00,000	$\sqrt{\frac{2 \times 12 \times 1,00,000}{0.039075}}$ $= 7,837$	$\frac{1,00,000}{7,837} \times 12$ $= 153.12$	$\frac{7837}{2} \times 0.039075$ $= 153.12$	306.24
1,25,000	$\sqrt{\frac{2 \times 12 \times 1,25,000}{0.039075}}$ $= 8,762$	$\frac{1,25,000}{8,762} \times 12$ $= 171.12$	$\frac{8762}{2} \times 0.039075$ $= 171.17$	342.31
75,000	$\sqrt{\frac{2 \times 12 \times 75,000}{0.039075}}$ $= 6787$	$\frac{75,000}{6787} \times 12$ $= 132.6$	$\frac{6787}{2} \times 0.039075$ $= 132.6$	265.20

∴ Thus when the annual usage was 1,25,000 units, the total annual variable cost has increased by about 12%. whereas it has decreased by 13%. when the annual usage was 75,000 units.

Example-2

A manufacture has to supply his customers 800 units of his product per year. Shortages are not allowed & the inventory carrying cost amount to ₹ 0.70 per unit year The set up cost per run is ₹ 70. Find:

(i) The Economic Order Quantity.

(ii) The minimal Average yearly cost.

(iii) The optimal number of orders per year.

(iv) The optimal period of supply per optimal order.

Solution

In the usual notations, we are given:

D, total number of units supplied per unit time period = 800 units.

C_o, set up cost per run = ₹ 70

C_h, inventory carrying cost per unit per year = ₹ 0.70

(i) Economic order quantity is given by:

$$Q^* = \sqrt{\frac{2DC_o}{C_h}} = \sqrt{\frac{2 \times 800 \times 70}{0.70}} = 400 \text{ units.}$$

(ii) Minimum average yearly cost is given by:

$$TC(Q^*) = \frac{D}{Q^*} C_o + \frac{Q^*}{2} C_h$$

$$= \frac{800 \times 70}{400} + \frac{400 \times 0.70}{2}$$

$$= ₹\ 280$$

Alter $TC(Q^*) = \sqrt{2DC_oC_h} = \sqrt{2 \times 800 \times 70 \times 0.70}$

$$= ₹\ 280$$

(iii) The optimal number of order per year.

$$N^* = \frac{D}{Q^*} = \frac{800}{400} = 2$$

(iv) The optimal period of supply per optimal order is: $T^* = \frac{1}{N^*} = \frac{1}{2}$

3.8 ABC Analysis :-

→ The inventory of an industrial organisation generally consists of thousands of items with varying prices, usuage rate lead time. It is neither desirable nor possible to pay equal attention to all the items. For example, A T.V. set has about 5% of its parts contribute to 80% of the total costs. This is true of majority of the items like car, refrigerator etc.

→ ABC Analysis is a basic analytical tool which enables management to concentrate its efforts where efforts will be greater.

→ The pare to principle (20/80) of cause & effect is a useful concept in business where it can be used to solve majority of production, quality & inventory problems.

→ The concept applied to inventory control is called as ABC analysis.

→ Statistics reveal that just a few items account for bulk of the annual consumption of the materials. These few items are called 'A' class items which hold the key to business. The other items known as 'B' & 'C' which are numerous in number but their contribution is less significant. ABC analysis thus tends to segregate the items into three categories A, B & C on the basic of their annual usuage. The categorisation is made to pay right alternation & control demanded by items.

* **'A' Class Items** :- These items hardly constitute 5-10% of the total items & account for 70-75% of the total money spend on inventories. These items require rigid & strict control &

need to be stocked in smaller quantities.

These items are to be ~~stocked in smaller quantities~~. Procured frequently & each time less quantity is procured. The inventory of 'A' class items is kept at minimum.

<u>'B' class items</u> :- These items are generally 10-15% of total items & represent 10-15% of the total expenditure on materials. These are intermediate items. The control on these items should be intermediate between A & C items.

<u>'C' class items</u> :- These are about 70-80% numbers & constitute only 5-10% total expenditure on materials.

These items being less expensive doesn't require strict control. These are ordered in bulk as against infrequent ordering of A class items.

4. INSPECTION AND QUALITY CONTROL

Defination & concept.

→ An Item or Component or Product which is manufactured is required to perform certain functions. The act of checking wheather a component actually does so or not is called Inspection.

→ In other word, Inspection means checking the acceptability of the manufactured Product.

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

OBJECTIVES

(i) Inspection seperates defective components from non-defective ones & thus ensures the adequate quality of products.

(ii) Inspection locates defects in raw materials & Flaws in processes which otherwise cause problems at the final stage. for example, detecting the parts not having proper tolerances during processing itself, will minimize the troubles arising at the time of assembly.

(iii) Inspection prevents further work being done on semifinished products already detected as spoiled.

(iv) Inspection make sure that the product works & it works without hurting anybody i.e its operation is safe.

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

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

* Kinds of Inspection.

(a) Roving Inspection.

→ The Inspector walks round on the shop floor, from machine to machine & checks samples of the work of various machine operators or workers.

Floor Inspection:-

(i) Helps catching errors during process itself i.e before the final production is ready, &

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

(b) Fixed Inspection:-

→ The work is brought at intervals for inspectors to check

→ Fixed inspection discovers defects after the job has been completed.

→ Fixed inspection is used when inspection equipment & tools cannot be brought on the shop floor.

→ It is a sort of centralized inspection, the worker & the inspector do not come in contact with each other; thus it eliminates any chances of passing a doubtful product.

(c) Key point inspection :-

→ Every product (more or less) has a Key point in process of manufacture.

A Keypoint is a stage beyond which either the product requires an expensive operation or it may not be capable of rework.

→ Inspection at a Keypoint segregates & thus avoids unnecessary further expenditure on poor & substandard parts, which are likely to be rejected finally.

(d) Final inspection :-

→ The final inspection of the product may check its appearance & performance.

→ Many destructive & non-destructive inspection & test methods such as tensile, fatigue, impact testing etc. & ultrasonic inspection, X-ray radiography, etc. respectively, are available for final inspection of the products manufactured.

→ Final Inspection is a centralized inspection & it makes use of special equipments.

Defination of Quality.

→ Quality is the 'totality of features & characteristics both for the products & services that can satisfy both the explicit & implicit needs of the customers.

→ "Quality" of any product is regarded as the degree to which it fulfills the requirements of the customer.

* Defination of CONTROL

→ Control is a system for measuring & checking (inspecting) a phenomenon. It suggests when to inspect, how often to inspect & how much to inspect. In addition, it incorporates a feedback mechanism which explores the causes of poor quality & takes corrective action.

* Defination of Quality Control.

→ Quality control is a systematic control of various factors that effect the quality of the product. The various factors include material, tools, machines, type of labour, working conditions, measuring instruments, etc.

→ Quality control can be defined as the entire collection of activities which ensures that the operation will produce the optimum quality products at minimum cost.

* Factors affecting Quality

→ In addition to men, materials, machines & manufacturing conditions there are some other factors which affect the product quality. These are:

* Market Research i.e indepth into demands of purchaser.
* Money i.e capability to invest.
* Management i.e Management policies for quality level.
* Production methods & product design.

→ Modern

→ Modern quality control begins with an evaluation of the customer's requirements & has a part to play at every stage from goods manufactured right through sales to a customer, who remains satisfied.

Objectives of Quality Control.

→ To decide about the standard of quality of a product that is easily acceptable to the customer & at the same time this standard should be economical to maintain.

→ To take different measures to improve the standard of quality of product.

→ To take various steps to solve any kind of deviations in the quality of the product during manufacturing.

Functions of Quality Control Department

→ Only the products of uniform & standard quality are allowed to be sold.

→ To suggest method & ways to prevent the manufacturing difficulties.

→ To reject the defective goods so that the products of poor quality may not reach to the customers.

→ To find out the points where the control is breaking down & to investigate the cause of it.

→ To correct the rejected goods, if it is possible. This procedure is known as rehabilitation of defective goods.

Advantages of Quality Control.

→ Quality of product is improved which, in turn increases sales.

→ Scarp rejection & rework are minimized thus reducing wastage. So the cost of manufacturing reduces.

→ Good quality product improves reputation.

→ Inspection cost reduces to a great extent.

→ Uniformity in quality can be achieved.

→ Improvement in manufacturer & Consumer relations.

Disadvantages of Quality Control.

→ It does not prevent waste of resources when products are faulty.

→ The process of inspecting the goods or service costs money, e.g. the wages paid to the inspectors the cost of testing goods in the laboratory.

→ It does not encourage all workers to be responsible for quality.

Statistical Quality Control: Basic Fundamentals

→ A quality control system performs inspection, testing & analysis to conclude wheather the quality of each product is as per laid quality standards 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 & at the same time less costly. It

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→ Statistical quality control makes inspection more reliable & at the same time less costly. It controls the quality level of the outgoing products.

Statistical Quality Control - Defination & Concept

Statistis:- It means data, a good amount of data to obtain reliable results. The science of statistics handles this data in order to draw certain conclusions.. Statistical techniques find extensive applications in quality control, production planning & control, business charts, linear programming, etc.

Quality:- Quality is a relative term & is generally explained with reference to the end use of the product. For example, a gear used in a sugar cane juice extracting machine through not of the same material & without possessing good finish, tolerance & accuracy as that of a gear used in the head stock of a sophisticated lathe may be considered of good quality if it works ~~stds~~ satisfactorily in the juice extracting machine. Thus a component is said to be of good ~~standards~~ quality if it works well in the equipment for which it is meant. Quality is thus defined as fitness for purpose.

Control:- Control is a system for measuring & checking (inspecting) a phenomenon. It suggests when to inspect, how often to inspect & how much to inspect. In addition, it incorporates a feed back mechanism which explores the causes of poor quality & takes corrective action.

* Control differs from 'Inspection', as it ascertains quality characteristics of an item, compares the same with prescribed quality standards & separates defective items from non defective ones. Inspection, however, does not involve any mechanism to take corrective action.

* Advantages of Statistical Quality Control

→ **Reduction in cost** :- Since only a fractional output is inspected, hence cost of inspection is greatly reduced.

→ **Greater efficiency** :- It requires lesser time & boredom as compared to the 100 percent inspection & hence the efficiency increase.

→ **Easy to apply** :- Once the S.Q.C plan is established it is easy to apply even by man who does not have extensive specialized training.

→ **Accurate prediction** :- Specifications can easily be predicted for the future, which is not possible even with 100 percent inspection.

→ **Can be used where inspection is needs destruction of items** :- In cases where destruction of product is necessary for inspecting it, 100 percent inspection is not possible (which will spoil all the products), sampling inspection is resorted to.

→ **Early detection of faults** :- The moment a sample point falls outside the control limits, it is taken as a danger signal & necessary corrective measures are taken. Whereas in 100 percent inspection, unwanted variations in quality may be detected after large number of defective items have already been produced. Thus by using the control charts, we can known from graphic picture that how the production is proceeding & where corrective action is required & where it is not required.

Control chart

→ Since variation manufacturing process are unavoidable, the control chart tells when to leave a process alone and thus prevent unnecessary frequent adjustments. Control charts are graphical representation and are based on statistical sampling theory, according to which an adequate sized random sample is drawn from each lot.

→ Control charts detect variations in the processing & warn if there is any departure from the specified tolerance limits. These control charts immediately tell the undesired variations & help in detecting the cause & its removal.

→ In control charts, where both upper & lower values are specified for a quality characteristic, as soon as some products show variation outside the tolerances, a review of situation is taken & corrective step is immediately taken.

→ If analysis of the control chart indicates that the process is currently under control (i.e is stable, with variation only coming from sources common to the process) then data from the process can be used to predict the future performance of the process.

→ A control chart is a specific kind of run chart that allows significant changes to be differentiated from the natural variability of the process.

In other word, Control chart is:

* A device which specifies the state of stati- statistical control,
* A device for attaining statistical control,
* A device to judge wheather statistical control has been attained or not.

Types of control charts.

- Control charts
  - Variables or Measurement charts
    - X(bar) chart
    - R chart
  - Attribute charts
    - P chart
    - np chart
    - C chart.

→ Control charts can be used to measure any characteristic of a product, such as the number of chocklates in a box, or the volume of bottled water. The different characteristics that can be measured by control charts can be divided into two groups: Variables, & attributes.

→ A <u>control chart for variables</u> is used to monitor characteristics that can be measured & have a continuum of values, such as height, weight, or volume. A soft drink bottling operation is an example of a variable measure, since the amount of liquid in the bottles is measured & can take on a number of different values. Other example are the weight of a bag of sugar, the temperature of a baking oven, or the diameter of plastic tubing.

→ A <u>control chart for attributes</u> on the other hand, is used to monitor characteristics that have discrete values & can be counted. Often they can be evaluated with a simple yes or no decission. Examples include color, taste, or smell. The monitoring of attributes usually takes less time than that of variables because a variable needs to be measured. An attributes requires only a single decision, such as yes or no, good or bad, acceptable or unacceptable (e.g. the apple is good or rotten, the meat is good or stale, the shoes have a defect or do not have a defect, the light bulb works or it does not work) or counting the number of defects (e.g., the number of broken cookies in the box, the number of dents in the car, the no. of barnacles on the bottom of boat).

* Mean ($\bar{x}$-bar) charts.

→ A mean control chart is often referred to as an x bar chart. It is used to monitor changes in the mean of a process. To construct a mean chart we first need to construct the centre line of the chart.

→ To do this we take multiple samples & compute their means. Usually these samples are small, with about four or five observations. Each sample has its own mean. The centre line of chart is then computed as the mean of all sample means, where is the number of samples:

(i) It shows changes in process average & is affected by changes in process variability.

(ii) It is a chart for the measure of central tendency.

(iii) It shows erratic or cyclic shifts in the process.

(iv) It detects steady progress changes, like tool wear.

(v) It is the most commonly used variables chart.

(vi) when used along with R chart:

a) It tells when to leave the process alone & when to chase & go for the cause leading to variation;

b) It secures information in establishing or modifying process, specifications or inspection procedures;

c) It controls the quality of incoming material.

(vii) x-Bar & R charts when used together form a powerful instrument for diagnosing quality problems.

* Range (R) chart:-

→ These are another type of control chart for variables. Whereas x-bar charts measure shift in the central tendency of the process, range chart monitor the dispersion or variability of the process. The method for developing & using R-charts are the same as that for x-bar charts.

→ The centre line of the control chart is the average range, & the upper & lower control limits are computed. The R-chart is used to monitor process variability when sample sizes are small (n<10), or to simplify the calculations made by process operators. This chart is called the R chart because the statistic being plotted is the sample range.

(i) It controls general variability of the process & is affected by changes in process variability.

(ii) It is a chart for measure of spread.

(iii) It is generally used along with x-bar chart.

Plotting of '$\bar{x}$' & 'R' charts.

→ A number of samples of component coming out of the process are taken over period of time. Each sample must be taken at random & the size of sample is generally kept as 5 but 10 to 15 units can be taken for sensitive control charts.

→ For each example, the average value $\bar{x}$ of all the measurements & the range R are calculated. The grand average $\bar{\bar{x}}$ (equal to the average value of all the average $\bar{x}$) & $\bar{R}$ ($\bar{R}$ is equal to the average of all the ranges R) are found & from these we can calculate the control limits for the $\bar{x}$ & R charts. Therefore,

$$\bar{\bar{X}} = \frac{\bar{x}_1 + \bar{x}_2 + \cdots + \bar{x}_m}{m}$$ ∵ n = sample size

$$\bar{R} = \frac{R_1 + R_2 + \cdots + R_m}{m}$$

Variables. Data ($\bar{x}$ & R control charts)

$\bar{x}$ control chart

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

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

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

R control chart.

$UCL = \bar{R}D_4$

$LCL = \bar{R}D_3$

$CL = \bar{R}$

Here the factors A_2, D_4 & D_3 depend on the number of units per sample. Larger the number, the close the limits. The value of the factors A_2, D_4 & D_3 can be obtained from S.Q.C tables.

→ **'p'-charts.** are used to measure the proportion of items in a sample that are defective. Example are the proportion of broken cookies in a batch & the proportion of cars produced with a misaligned fender. P-charts are appropriate when both the number of defectives measured & the size of the total sample can be counted. A proportion can then be computed & used as the statistic of measurement.

(i) It can be a fraction defective chart.

(ii) Each item is classified as good (non-defective) or bad (defective).

(iii) This chart is used to control the general quality of the component parts & it checks if the fluctuations in product quality (level) are due to chance alone.

Plotting of 'p' charts: By calculating, first, the fraction defective & then the control limits. The process is said to be in control if fraction defective values fall within the control limits. In case the process is out of control an investigation to hunt for the cause becomes necessary.

The mean proportion defective $(\bar{P}) = \dfrac{\text{Total number of Defective}}{\text{Total number Inspected}}$

The standard deviation of P:

$$\sigma_{\bar{p}} = \sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

where n = sample size.

Control limits are:

$$UCL = \bar{p} + z * \sigma_{\bar{p}} \qquad LCL = \bar{p} - z * \sigma_{\bar{p}}$$

or

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

Usually the z value is equal to 3 (as was used in the X & R charts), since the variations within three standard deviations are considered as natural variations. However, the choice of the value of z depends on the environment in which the chart is being used, & on managerial judgment.

→ c-charts: count the actual number of defects. For example, we can count the number of complaints from customers in a month, the number of bacteria on a Petri dish, or the number of barnacles on the bottom of a boat. However, we cannot compute the proportion of complaints from customers, the proportion of bacteria on a petri dish, or the proportion of barnacles on the bottom of a boat.

'C' chart can be plotted by using the following formulas:

$$\bar{C} = \frac{\text{Total number of defects.}}{\text{Total number of Samples.}}$$

$$UCL = \bar{C} + 3\sqrt{\bar{C}}$$

$$LCL = \bar{C} - 3\sqrt{\bar{C}}$$

ISO 9000 Standard :-

→ Increases in international trade during the 1980s created a need for the development of universal standards of quality. Universal standards were seen as necessary in order for companies to be able to objectively document their quality practices around the world. Then in 1987 the international organization for standardization (ISO) published its first set of standards for quality management called ISO 9000.

→ International Organization for Standardization is an international organization whose purpose is to establish agreement on international quality standards. It currently has members from 91 countries, including the United State.

→ To develop & promote international quality Standards, ISO 9000 has been Created. ISO 9000 consists of a set of standards & a certification process for companies, By receiving ISO 9000 certification, companies demonstrate that they have met the standards specified by the ISO.

Total Quality Management (TQM)

→ At its core, Total quality Management (TQM) is a management approach to long-term success through customer satisfaction.

→ In a TQM effort, all members of an organization participate in improving processes, Products, services & the culture in which they work.

→ Total Quality management (TQM) is an approach that seeks to improve quality & performance which will meet or exceed customer expectations. This can be achieved by integrating all quality related functions & processes throughout the company.

→ TQM looks at the overall quality measures used by a company including managing quality design & development, quality control & maintenance, quality improvement, and quality assurance. TQM takes into account all quality measures taken at all levels & involving all company employees.

Principles of TQM :

A number of key principles can be identified in defining TQM, including:

→ Executive Management – Top management should act as the main driver for TQM & create an environment that ensure its success.

→ Training – Employees should receive regular training on the methods & concept of quality.

→ Customer Focus :- Improvements in quality should improve customer satisfication.

→ Decision Making :- Quality decisions should be made based on measurement.

→ Metrology and Tools :- Use of appropriate methodology & tools ensures that non-conformances are identified, measured & responded to consistently.

→ Contineous Improvement :- Companies should contineously work towards improving manufacturing & quality procedures.

→ Company Culture :- The culture of the company should aim at developing employees ability to work together to improve quality.

→ Employee Involvement :- Employees should be encouraged to be pro-active in identifying & adressing quality related problems.

The Seven tools of Quality Control :

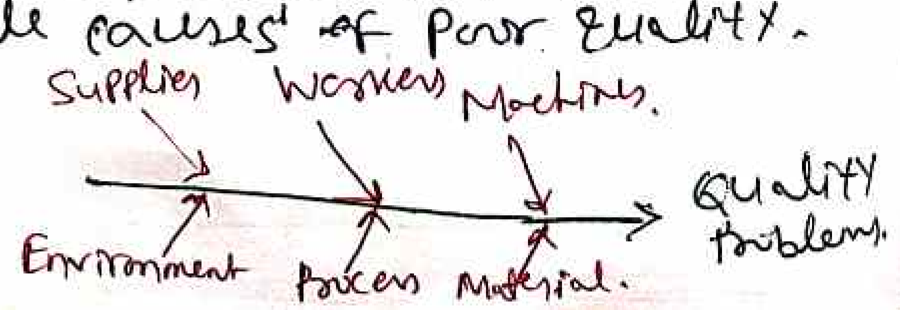
1) Cause & effect analysis :

→ This chart that identify potential causes for particular quality problems. They are often called fish bone diagram because they look like the bones of a fish. The head of the fish is the quality problem, such as damaged zippers on a garment or broken valves on a tyre. The diagram is drawn so that the "spine" of the fish connects the "head" to the possible cause of the problem.

→ These causes could be related to the machines, workers, measurement, suppliers, materials & many other aspects of the production process. Each of these possible causes can then have smaller 'bones' that address specific issues that relate to each cause. For e.g., a problem with machines could be related to lack of training, poor supervision, or fatigue.

→ Cause & effect diagrams are problem solving tool commonly used by quality control teams. Specific causes of problems can be explored through brainstorming.

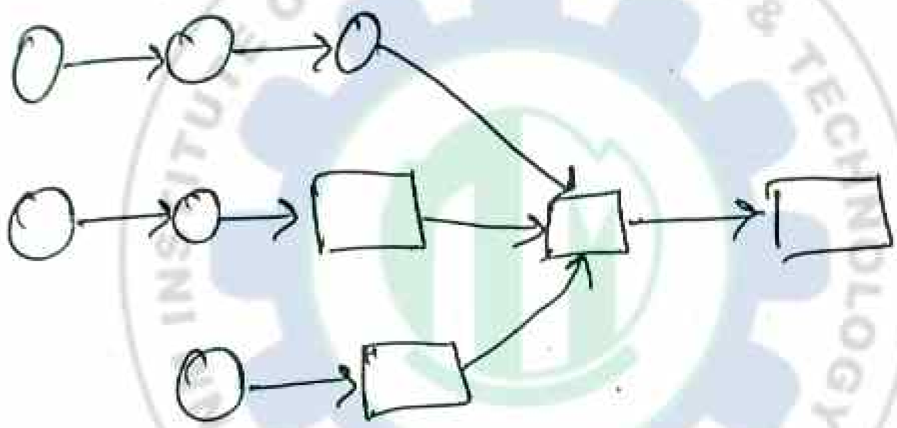
→ The development of a cause & effect diagram requires the team to think through all the possible causes of poor quality.



2) Flowchart:

→ A flow chart is a schematic diagram of the sequence of steps involved in an operation or process. It provides a visual tool that is easy to use & understand.

→ By seeing the steps involved in an operation or process, everyone develops a clear picture of how the operation works & where problems could arise.



3) Check list.

→ A checklist is a list of common defects & the number of observed occurrences of these defects. It is a simple yet effective fact-finding tool that allows the worker to collect specific information regarding the defects observed.

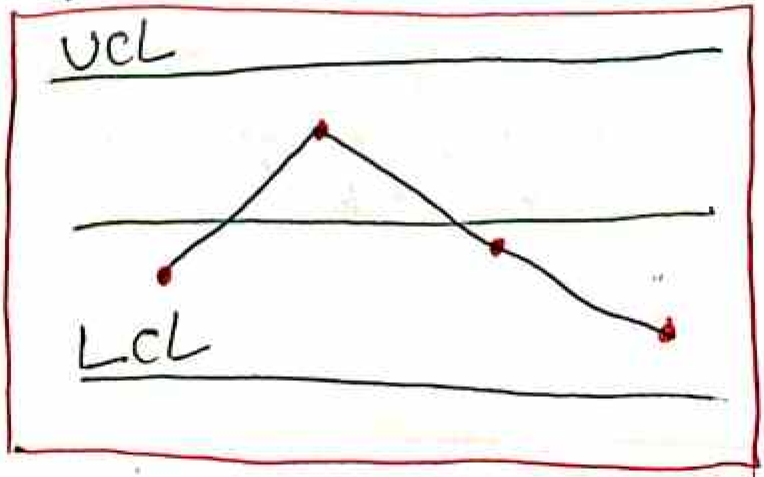
→ It is clear that the biggest problem is ripped material. This means that the plant needs to focus on this specific problem. A checklist can also be used to focus on other dimensions, such as location or time.

Defect type	No. of Defect	Total.
Broken zipper.	✓✓✓	3
Ripped material.	✓✓✓✓✓✓✓	7
Missing buttons.	✓✓✓	3
Faded Color.	✓✓	2

4) Control charts.

→ Control chart are a very important quality control tool. We will study the use of control chart at great length in the next chapter. These charts are used to evaluate wheather 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 is operating within expections, we say that it is 'in control'.

→ To evaluate whether or not a process is in control, we regularly measure the variable of interest & plot it on a control chart. The chart has a line down the centre representing the average value of the variable we are measuring. Above & below the center line are two lines, called the upper control limit (UCL) & the lower control limit (LCL). As long as the observed values fall within the upper & lower control limits, the process is in control & there is no problem with quality. When a measured observation falls outside of these limits, there is a problem.

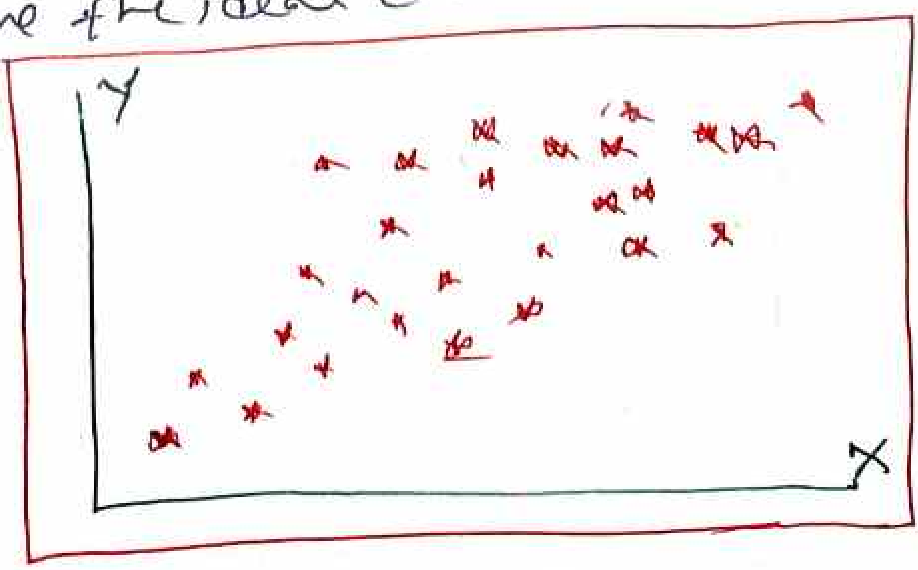


Scatter Diagrams:

→ Scatter diagrams are graphs that show two variables are related to one another. They are particularly useful in detecting the amount of correlation, or the degree of linear relationship, between two variables. For e.g. increased production speed & number of defects could be correlated positively; as production speed increases, so does the number of defects..

→ Two variables could also be correlated positively negatively; So that an increase in one of the variables is associated with a decrease in the number of defects observed.

→ The greater degree of correlation, the more linear are the observations in the scatter diagram. On the other hand, the more scattered the observations in the diagram, the less correlation exists between the variables. Of course, other types of relationships can also be observed on a scatter diagram, such as an inverted. This may be the case when one is observing the relationship between two variables such as oven temperature & number of defects, since temperatures below & above the ideal could lead to defects.

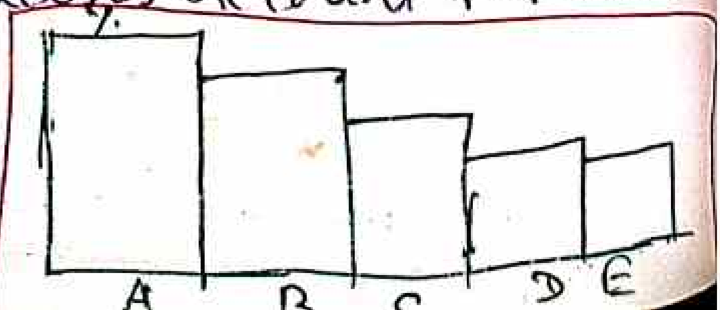


6) Pareto Analysis :-

→ Pareto analysis is a technique used to identify quality problems. based on their degree of importance. The logic behind pareto analysis is that only a few quality problems are important, whereas many others are not critical. The technique was named after Vilfredo Pareto, a nineteenth-century Italian economist who determined that only a small percentage of people controlled most of the wealth.

→ This concept has often been called the 80-20 rule. & has been extended to many areas. In quality management the logic behind pareto's principle is that most quality problems are a result of only a few causes. the trick is to identify these causes.

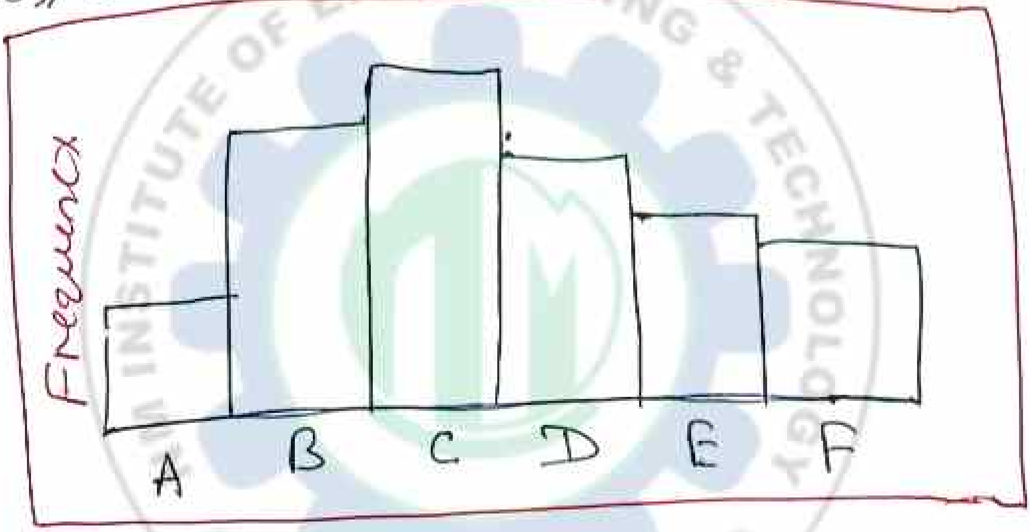
→ One way to use pareto analysis is to develop a chart that ranks the causes of poor quality in decreasing order based on the percentage of defects each has caused. For example, a tally can be made of the number of defects that result from different causes, such as operator error, defective parts, or inaccurate machine calibrations. percentages of defects can be computed from the tally & placed in a chart. ~~like the~~ we generally tends to find that a few causes account for most of the defects.



4) Histogram:

→ A histogram is a chart that shows the frequency distribution of observed valued. values of a variable. We can see from the plot what type of distribution a particular variable displays, such as weather it has a normal distribution & wheather the distribution is symmetrical.

e.g. Restuarants use quality control tools to evaluate & monitor the quality of delivered goods, such as meats, produce, or backed goods.



SIX SIGMA:

→ Six Sigma seeks to Improve the quality of process outputs by identifying & removing the causes of defects (errors) & minimizing variability in manufacturing & business processes. It uses a set of quality management methods, including statistical methods, and creates a special infrastructure of people with in the organization.

→ Each six sigma project carried out within an organization follows a defined sequence of steps & has quantified values targets. The six sigma term orginated from terminology associated with manufacturing, specially terms associated with statistical modeling of manufacturing process.

5> PRODUCTION PLANNING AND CONTROL

Introduction

→ Production planning & control is a tool available to the management to achieve the stated objectives. Thus, a production system is encompassed by the four factors i.e quantity, quality, cost & time.

→ Production planning starts with the analysis of the given data, i.e demand for products, delivery schedule etc. & on the basis of the information available, a scheme of utilisation of firm resources like machines, materials & men are worked out to obtain the target in the most economical way.

→ Once the plan is prepared, then execution of plan is performed in line with the details given in the plan. Production control comes into action if there is any deviation between the actual & planned. The corrective action is taken so as to achieve the targets set as per plan by using control techniques.

Objectives of PPC

(i) Systematic planning of production activities to achieve the highest efficiency in production of goods/services.

(ii) To organize the production facilities like machines, men etc. to achieve stated production objectives with respect to quantity & quality time & cost.

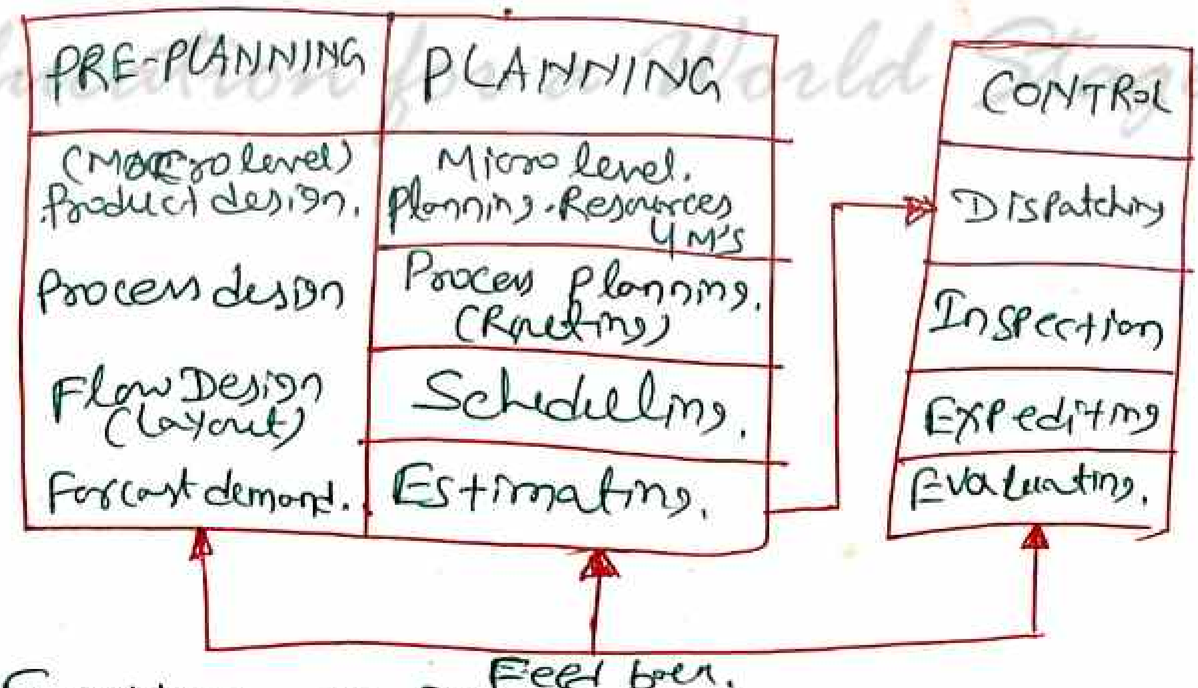
(iii) Optimum Scheduling of resources.
(iv) Coordinate with other departments relating to production to achieve regular balanced & uniterrupted production flow.
(v) To conform to delivery commitments.
(vi) Materials planning & control.
(vii) To be able to make adjustments due to changes in demand & rush orders.

Functions of PPC :-

Functions of production planning & controlling is classified into.
1) Pre planning function.
2) Planning function.
3) Control function.

1) Pre-Planning Function :-

→ Pre-planning is a macro level planning & deals with analysis of data & is an outline of the planning policy based upon the forcasting demand, market analysis & product design & development.



(Function of PPC)

→ This stage is concerned with process design (new process & developments, equipment policy & replacement and work flow (Plant layout). The pre-planning function of PPC is concerned with decision making with respect to methods, machines & work flow with respect to availability, scope & capacity.

2) Planning function :-

→ The Planning function start once the task to be accomplished is specified, with the analysis of Four M's i.e Machines, Methods, & Manpower. This is followed by process planning (routing). Both short-term (near future) & long-term planning are considered. Standardisation, simplification of products & processes are given due consideration.

3) Control Function :-

→ Control phase is effected by dispatching, inspection & expediting material control, analysis of work-in-process. Finally, evaluation makes the PPC cycle complete & corrective actions are taken through a feedback from analysis. A good communication & feedback system is essential to enhance & ensure effectiveness of PPC.

Types of Production systems :-

There are mainly three types of Production systems mentioned as below:

(i) Contineous /mass Production.
(ii) Job or unit Production.
(iii) Intermittent/Batch Production.

(i) Contineous/mass Production :-

→ It is used when we need to Produce standardized Products with a standard set of Process & operation sequence, in anticipation of demand. This ensures contineous production of output. It is also termed as mass production, flow production or assembly line production.

→ This system results in less work in process (WIP) inventory & high Product quality but involves high capital investment in machinery & equipment. This ensures very high rate of production as we need not to intervene once the Production has begun. The system is appropriate in plants where large volume of small variety of output is Produced. e.g. Oil refineries, cement Manufacturing & Sugar Factory etc.

Characteristics of Contineous/mass Production

a) As same product is manufactured for sufficiently long time, machines can be laid down in order of Processing sequence.
b) Standard methods & machines are used during part manufacture
c) Most of equipment's are semiautomatic or automatic in nature.

d) Material handling is also automatic (such as conveyors)

e) Semi skilled workers are normally employed as most of the facilities are automatic.

f) As product flows along a pre-defined line planning & control of the system is much easier.

g) Cost of production per unit is very low owing to the high rate of production.

h) In process inventories are low as production scheduling is simple & can be implemented with ease.

(ii) Job or unit production :

→ It involves production as per customer's specifications. This ensures the simultaneous production of large number of batches/orders. Each batch or order comprises of a small lot of identical products & is different from other batches. It requires comparatively smaller investment in machines & equipment.

→ It is flexible & can be adapted to changes in product design & order size without much inconvenience. This system is most suitable where hetrogeneous products are produced against specific orders.

→ In this system products are made to satisfy a specific order. However that order may be produced - only once or at irregular time intervals. such as & when new order arrives or at regular time intervals to satisfy a continuous demand.

Characteristics of Job or unit Production :-

a) Machines & Methods employed should be general purpose as product changes are quite frequent.

b) Man power should be skilled enough to deal with changing work conditions.

c) Schedules are actually non existent in this system as no definite data is available on the product. In process inventory will usually be high as accurate plans & schedules do not exist.

d) Product cost is normally high material & labor cost.

e) Grouping of machines is done on functional basis (i.e. as lathe section, milling section etc.) This system is very flexible as management has to manufacture varying product types. Material handling systems are also flexible to meet changing product requirements.

(iii) Intermittent / Batch Production:

→ This is concerned with the production of different types of products in small quantities usually termed as batches. A batch contains the similar products but in small quantity. This is used to meet a specific order or to meet a continuous demand. Batch can be manufactured either only once or Repeatedly at irregular time intervals as & when demand arise or repeatedly at regular time intervals to satisfy a continuous demand.

→ Under this system the goods may be produced partly for inventory & partly for customer's orders. For example, components are made for inventory but they are combined differently for different customers. e.g. Automobile plants, printing presses, electrical goods plant are examples of this type of manufacturing.

Characteristics of Intermittent / Batch Production.

a) As final product is somewhat standard & manufactured in batches, economy of scale can be availed to some extent.

b) Machines are grouped on functional basis similar to the Job shop manufacturing.

c) Semi-automatic, special purpose automatic machines are generally used to take advantage of the similarity among the products.

d) Labor should be skilled enough to work upon different product batches.

e) In process inventory is usually high owing to the type of layout & material handling policies adopted.

f) Semi-automatic material handling systems are most appropriate in conjuction with the semi-automatic machines.

→ Principles of Production & Process Planning

i) Customer Demand :-

→ Before you can plan to assign resources, you have to know how much to produce. Production planning focuses on the principle of meeting the targeted customer demand rate in the most efficient way possible while keeping open the capacity to respond to variations in demand.

ii) Materials :-

→ To fulfil your production targets the materials availability needed to produce should be ensured. The most efficient production planning keeps the minimum materials as standard inventory. Planners should evalute how much material the company needs, the lead times for order, the delivery times for suppliers & the reliability of the supply.

iii) Equipments :-

→ The production planners takes into account the capabilities of the equipment used to produce the output. Basic stability of equipment comprising of availability (A), performance & quality parameters can be determined by overall equipment Effectiveness.

iv) Man power :-

→ Man power planning requires accurately estimating the number of employees required to do the work. The capacity of the workforce has to match the capabilities of the equipment to plan for the highest efficiency.

v) Processes :

→ Effective production planning makes sure that the processes used for the output continue to operate efficiently & safely. Often the normal operation of a process requires occasional testing & adjustments.

vi) Controls :

→ A final production planning principle puts in place controls that detect problems as soon as they occur. Verification of inventory, use of qualified suppliers & personnel, standardization where possible. Where control are in place, it enables to take possible corrective actions to minimize the effects & return production to the required levels.

→ After the analysis of each aspect at the client place, the modular kitchen manufacturer, the overall plant capacity was ascertained.

→ The next step was to assist the client with a proper production plan. The Faber infinite team worked over best possible alternatives to provide the client with an user friendly. Simple yet powerful module which will cater to all the basic requirements & also keeping room for the surprise elements.

→ The solution module was developed encompassing order receipt process, capacity booking, production to dispatches & even installation at the client sites. Making it a comprehensive solution. It also consisted of provision to calculate the delivery performance by measuring on time in full ratio. and also. highlighting the reason for failure, if any.

Forcasting:-

→ Forcasting is essential for number of planning decisions & often provides a valuable input on which operations of the business. enterprises depend.

→ Forcasting is a process of estimating a future event by casting forward past data. The past data are systematically combined in a predetermined way to obtain the estimate of the future.

→ Prediction is a process of estimating a future event based on subjective considerations other than just past data, these subjective considerations need not be combined in a predetermined way.

Elements of Production Planning :-

(i) Planning
(ii) Routing.
(iii) Scheduling
(iv) Despatching
(v) Follow-up & Expediting
(vi) Inspection.

(i) Planning :-

→ It is the first element of PPC. Planning is given an important role in every business. A seperate department is setup for this work. Planning is deciding in advance what is to done in future.

→ Control devices are also decided in advance so that all activities are carried on properly. An organizational set up is created to prepare plans & policies.

→ Various chart, manuals & production budgets are also prepared. If production planning is defective then control will also be defective. Planning provides a sound base for control.

(ii) Routing :-

→ It is determining the exact path or routing which will be followed in production. The stages from which goods are to pass are decided after a proper thought. Routing may be compared to a tram journey for reaching a particular place. The route will be economical in time & money. The passenger will decide the route only after taking into consideration various factors affecting his journey.

→ Similar is the case with production routing. It is the selection of the path from where each unit has to pass before reaching the final stage. The path must have the best & cheapest sequence of operations.

Routing Procedure :-

i) Deciding what part to be made or purchased.
ii) Determining materials required.
iii) Determining manufacturing operations & sequences.
iv) Determining of lot sizes.
v) Determining of scrap factors.
vi) Analysis of cost of the product.
vii) Preparation of production control forms.

iii) Scheduling:

→ Scheduling is the determining of time & date when each operation is to be commenced & completed. It includes the scheduling of materials, machines & all other requisites of production.

Types of Schedules.

i) Master Scheduling.
ii) Operation Scheduling.
iii) Detail operation Scheduling.

iv) Despatching :-

→ The term dispatching refers to the process of actually ordering the work to be done. It involves putting the plan into effect by issuing orders. It is concerned with starting the process & operation on the basis of route sheets & schedule charts.

→ Dispatches put production in effect by releasing & guiding manufacturing order in the sequence previously determined by routesheet & schedule.

Procedure

i) Moving of materials from process to process.
ii) Assigning of work to machines.
iii) Issuing of tools to production department.
iv) Issuing of Job orders.
v) Recording of time taken.
vi) Ensuring necessary changes.
vii) Having proper liaison with routing.

Important Documents.

i) Material requisitions.
ii) Work order.
iii) Control sheet.
iv) Internal delivery note.
v) Tool & gause ticket.

IV) Follow up & Expditing:-

→ It is that branch of production control procedure which regulates the progress of materials & part through the production process.

Procedure:-

i) Progress should be checked.
ii) Causes of difference should be ascertained.
iii) Helping in removing the deviations.
iv) Report with departments supplying material.

vi) Inspection:-

→ Inspection is also an important function of control. The purpose of inspection is to see whether the products manufactured are of requisite quality or not. It is carried on at various levels of production process so that pre-determined standards of quality are achieved. Inspection is under-taken both of products & input.