Civil Engineering Materials & Const. Practices

CONSTRUCTION PRACTICES I

Construction Practices I

(Quality Control, Safety Issues & Project Management)

Quality Control

GENERAL PRINCIPLES OF INSPECTION OF CIVIL ENGINEERING WORKS

The aim of supervision is three fold :

- Provide sound and stable structures within allotted time.
- Achieve maximum economy of men, material and money.
- Achieve a high standard of work in accordance with modern engineering practice.

Supervision in a deeper sense includes the following broad aspects:

- The adherence to the standards of materials and craftsmanship specified in the drawing and specification.
- The discovery of elements or errors overlooked in the contract drawings/specifications and their early correction.
- Inadequacy of the design or specifications.
- Prevention of errors, which might result in unnecessary and costly maintenance cost.
- The checking of building processes/techniques and the evaluation of the materials to ensure conformity to the specifications.
- Elimination of unacceptable substitutes by the contractors.
- Avoidance of extra construction cost beyond accepted contract amounts.
- Skilled coordination of works of various trades.
- Prevention of unfair practices and procedures or attempts at avoidance of contractual obligations.

Essential Requisites

For 'Supervision' to be effective, it is essential to have a sound, well-considered plan for tackling the work. This implies that sound technical planning has preceded the execution, especially in respect of the following :

- Proper choice of specification/design.
- Feasible phasing of works.
- Selection of suitable agency of execution.
- Use of suitable machinery/equipment.

- Efficient site organisation.

Supervision During Construction

The responsibility of supervision lies mainly with the site Engineer. He should :

- Study the drawings, specifications, contract agreement in details to bring out the 'snags'. These should be settled in consultation with GE or referred to higher authorities at the earliest possible stage. To achieve this, an advance set of document is sent to GE/Engineer-in-Charge for comments.
- Fix the responsibilities of subordinates in writing.
- Check arrangements for site organisation.
- Insist on all records being kept up-to-date by periodical check.
- Check important stages of construction personally and get certain stages checked by Engineer in charge. Visit site of work frequently and settle difficulties on spot.
- Report all difficulties/contractual snags to engineer in charge.
- Work order book must be widely used. Important orders must be issued from files.
- Works diary should be maintained correctly, daily according to existing orders.
- Watch that the orders and instructions are noted by supervisory staff of the contractor and faults remedied. Ensure the same with your staff also. Your staff should give directions and advice and check faults rather than merely stand by while the work proceeds.
- Advise, correct and instruct all the time rather than criticise but reject all bad work and make subordinates understand their responsibility.
- See that all supervisory staff possesses proper tool bags and use them freely.
- Condemn any scaffolding that is dangerous and have it set right without delay and further use.
- See that rejected materials are removed from site without delay.
- Always watch progress and keep time and progress chart and other registers/charts up-to-date. See that everything goes on smoothly.
- Do not interfere unless you have a definite proposal for making improvement.
- Warn contractor and your staff that bad work on their part will mean your forfeiting confidence and entail dismantling.
- Do not generally punish staff if faults can be corrected by other measures. If you have to, punish drastically after warnings have been given in writing.
- Encourage good work of subordinates. It helps much in raising the standard of work.
- Ensure co-operation between B/R and E/M staff.

- Remember that surrender of funds due to non-completion of a work is better than carrying it out to lower standard.
- Any change in design/specification is necessary due to engineering reasons, issue a DO after the approval of the accepting authority before the work is actually carried out.
- Measurements are the basis of payment, hence every item of the work must be measured, when necessary, as soon as it is finished, especially so, when it is going to be hidden.

The Engineer in charge is overall incharge of the works in his division. He should ensure that:

- Site-engineer associated with the job at as early a stage as possible preferably from the beginning of technical planning.
- Site engineer is kept in full picture about all matters connected with the work, e.g. administrative arrangements, proposed deviations/amendments, notices on contractor, stores provisioning.
- Important stages of work are passed by Site engineer as per the works passing register.
- Periodic inspections are carried out at different times of the day.
- Relations with the contractor are maintained on a responsible and impartial basis; dealings with contractors are correct, tactful and firm.

Supervision after Completion

A thorough inspection of the work must be carried out by Site Engineer/Engineer incharge after completion of the work. If supervision during construction has been effective, no difficulty need be experienced. The underlying aim of this inspection is to ensure that the work is :

- Complete in all respect,
- Upto specifications as per contract
- Clearly and neatly finished, and
- Completed in time period specified in the contract.
- Points which often create trouble are the following :
- Internal fittings and fixtures.
- Doors, windows and built-in-furniture.
- Overall finish including site clearance.

If any rectifications are found necessary, the same should be immediately carried out/ordered on to the contractor.

Raising the Standard of Work

(a) Engineer must maintain sample rooms where samples of materials, fittings, fixtures and furniture are maintained. Samples rooms are kept 'alive' by frequent use and additions.

(b) The contractors must be ordered in writing to produce samples in respect of important materials/fittings, etc. for approval first before incorporating in the works.

(c) Contractors are asked to produce samples of workmanship for prior approval.

(d) All workmanship not conforming to specifications is rejected and ordered for demolition. Principles of SQC (Statistical Quality Control) and sampling techniques be applied wherever possible and provided for in contracts.

(e) Special note is kept about the maintenance periods of each contract, the works are thoroughly inspected and rectifications ordered in this period.

(f) Junior officers/subordinates are attached to experienced colleagues for training.

(g) Technical literature relating to construction materials/techniques is obtained and circulated among the staff. Similarly, various pamphlets issued by E-in-C regarding supervision of works should be circulated to supervisory staff.

(h) All problems where satisfactory results have not been obtained are referred to research institutions and their advice obtained, which should then be tried/decimated among the staff.

(i) Whenever specialist advice/service is employed, attachment of MES staff for gaining experience should be a condition of the contract. Only suitable hands are sent on such attachments.

AIM OF QUALITY CONTROL

The aim of quality control is to ensure the production of items for their intended use with defects and variations from their prescribed standards within limits prescribed. Quality also aims to avoid wastage of time, materials and money by high lighting the point at which a production process is becoming defective. In construction works following works need quality control:

- Concrete
- Steel
- Form works
- Masonry
- Water proofing
- Services etc

Concrete

In fact, concrete is a very important construction material, having a very high compressive strength. Its strength is influenced by several factors such as *(i)* quality of its constituent materials, *i.e.,* quality of cement, quality and grade of coarse aggregate, fine aggregate, proportion of cement and combined aggregate, proportion of fin_ and coarse aggregate in concrete. Water-cement ratio, aggregate grading, age of concrete, time of mixing, sequence of placing of materials in the mixer, time of compaction, type of' compaction, curing, testing procedure and position of placing test, specimens in machine, rate of loading etc. Hence to obtain a concrete of uniform quality, a constant supervision on its different activities of production is essential. The supervisor should be well versed with the properties of concrete. Hence, engineer incharge should be present throughout different operations of preparing, placing, compaction and finishing the concrete work.

Steel

It is a costly item and constitute a major item of expenditure in most of the works. In R.C.C. works it is used as reinforcement to take up tensile stresses. Hence before use as reinforcement, its tensile stresses should be checked, its proper bending, binding and placing should be checked carefully. The reinforcing: bars should be free from rust, scales, oils and other harmful coatings. Care should be taken that reinforcement does not get displaced during pouring of concrete.

Form work

The shape and finished surface of concrete' depends upon the form work. Hence form work must have smooth surface, so that the finished concrete may need minimum amount of rendering. In case the finished surface is not required to be plastered, the pattern left by the form work, should be such that it gives It pleasing look. The form work should be strong enough to withstand the weight of the green concrete. While removing the form work, care should be taken that concrete is not damaged while striking the form work.

Masonry work

The bricks to be used in masonry, should be of specified quality and grade having requisite strength and water absorption capacity should be within permissible limit. The bond in masonry should be properly maintained. Verticality .and dimensions of masonry work are very important and care 'Should be taken to maintain them.

Water proofing. Damp proof courses at plinth level and damp proofing of roofs etc. are very important. Hence proper attention should be paid to have them properly water proof.

Joinery and timber work

In this item, timber of specified quality should be used. Workmanship of the timber work should be properly checked and maintained as per specifications. These both items are very Important from the quality control point of view.

Services

Electric fittings, water supply, sanitary and air conditioning fittings are classified under this head. Proper control should be exercised on their execution as there, are very important items from the point of view of the customer's comforts. Hence they need special attention of quality control.

QUALITY CONTROL OF CONCRETE

Following are some of the factors, which affect the quality of concrete :

- Storage of cement,
- Measurement of ingredients of concrete,
- Batching operation,
- Admixtures,
- Mixing of concrete,
- Compaction of concrete,
- Placing of concrete,
- Curing of concrete,
- Formwork,
- Finishing of concrete, and
- Joining or repairs of concrete members.

Stages of Quality Control

There are three stages of Quality Control in concrete making, which are as follows :

Quality Control Prior to Construction

In this stage, properties and testing of constituent materials of concrete are done. Mainly cement and aggregates are tested for required physical and chemical properties and their suitability of a particular concrete is ascertained. Properties of aggregates like size, shape, texture, strength, specific gravity, bulk density, water absorption, soundness, bulking of sand and durability are found and tested in laboratory. Physical properties of cement and chemical composition of cement are found out and cements suitability is decided after matching these properties with standard specifications. Effect of aggregate properties on strength of concrete is also studied.

Quality Control During Construction

In this stage, water-cement ratio and its effect on concrete workability for different conditions and concrete mix design are studied. Also how best the ingredients of concrete can be stored, batched and mixed is decided. Method of curing and duration of curing are decided and method of finishing of concrete is also decided.

Quality Control After Construction

As such quality of concrete cannot be controlled after construction but certain tests definitely can be carried out to check whether quality control in concrete making has been ensured or not. There are different tests, which can be done on hardened concrete to check the strength of concrete, which will give the indication of the beginning of Quality Control.

Tests to Check Quality of Concrete in Various Stages

First Stage Test

- Fineness of cement
- Consistency of cement
- Initial and final setting time of cement
- Adulteration in cement
- Fineness modulus and grading of aggregates
- Bulking of sand
- Specific gravity of sand
- Impact value of aggregate
- Abrasion value of aggregate
- Soundness of cement
- Crushing value of aggregate

Second Stage Tests

- Water-cement ratio
- Slump test
- Compressive strength test
- Tensile strength test

Functions of Quality Control System

Following are the functions of a Quality Control System :

- Ensure that the equipment and testing instruments are calibrated and properly maintained.
- Define the activities affecting quality through instructions and procedures.
- Carry out unannounced spot checks on the quality of materials.
- Identify the problems and take the action to get the solution.
- Verify the implementation of solutions and corrections.
- Report regularly on the effectiveness of the system.

Guidelines of Quality Control

Following are the guidelines of quality control :

- The quality control department must be under the control of the top man, i.e. Highest authority.

- The highest authority in the organisation must believe in quality control.
- Every person in organisation must be aware of quality control system and inspection procedures.
- Quality must always be given preference over economy and speed.
- Timely inspection and remedial measures are essential.
- Good quality construction can only be done by using good quality material and good workmanship.
- Detected mistakes should not be repeated.
- Quality Control inspector should be honest, alert and of high integrity.
- Carelessness and ignorance should be avoided.
- No compromise should be done at any cost. Unacceptable material or work must be rejected.
- Required material testing and concrete testing must be carried out at site only.

Safety Issues

Following are area where safety issues become very important.

- Excavation;
- Scaffolding, ladders and form work;
- Hot bitumen work;
- Demolition works; and
- Drilling and blasting.

SAFETY MEASURES IN EXCAVATION WORKS

In the construction of buildings and other structures such as dams, bridges etc. excavation work is one of the important activities. If during excavation operations proper safety measures are not taken, it may become a major hazard and cause serious accidents. Some basic principles of safety measures are discussed below:

- Before starting excavation work, complete information of underground structure such as water pipe lines, sewers, gas lines, electric cables etc. is essential and all precautions should be taken ;to ensure safety to workers and public.
- The work should be entrusted to a experienced and competent supervisor. He should be made responsible for strict observance of safety precautions.
- The excavated trenches should be given proper protection against slides and caving in during and after heavy rains and storms etc.
- Workers should be asked to wear helmets where there is danger of falling stones etc.

- New workers must be kept under constant supervision while engaged on jobs involving hazards.
- Depending upon the. size of the project and nature of excavation, the excavation machinery should be selected properly.
- For operating the machinery, only qualified persons should be appointed; unqualified or un-authorized persons should never be allowed to handle the machinery as they are bound to have accident.
- Persons working on the machinery should be mentally and physically fit.
- Faulty machines should not be pressed in operation *i.e.* faulty machines should not be used.
- Dangerous parts of the machines such as belts, chain drive etc. should be provided with proper cover.
- While engine is running, replacement of oil, lubrication or repair work should not be done.
- After stopping a movable machinery, its driving wheels should be braked,
- While working in night, proper lighting arrangements should ensured.
- Work should not be done partially by machines and partially by manual labour as it is likely to meet with accident.
- In medium soils, trenches more than 1'5 m deep should be securely shored and timbered. In case of hard soils, timbering is necessary if the depth of cutting exceeds ,more than 2.0 m. Sheathing is placed against the sides of the trench, with planks held vertically. In loose soils the sheathings is firmly embedded into the bottom of the trench.
- The loose boulders, lumps of earth etc, should be removed, so that they may not roll down in trench and injure the workers,
- The excavated material should be away back from the edge of the trench at least more than 1 m. Actually the excavated material should be removed to a distant place. If this is not practicable, then boards should be provided to prevent the rolling down of the soil into the trench. Tools etc. used in construction should also be kept away from the edge of the trench for similar reasons.
- Vehicles should not be allowed to be driven close to the edges of the trench. While loading the excavated soil in the trucks, etc., care should be taken that loose soil does not roll down into the trench.
- The path ways and gangways should be non-slippery and should be of sufficient width.

- If traffic passes near the trenches, strong fences should be provided to prevent animals or public from falling into the trenches. To ensure safety of vehicles and pedestrians, the public walk sides should be sufficiently lighted. Red lights should be provided at both ends *of* the area under excavation and warning signals also be placed.
- Persons required to work under deep trenches or at high altitudes safety ropes should be tied to their safety belts, so that they could be helped at the time of need. A single worker should not be allowed to work in a trench alone.
- It should be ensured that harmful gases 'are not present in trenches, if they are present; then sufficient mechanical ventilation should be provided to protect the life of the workers.

SAFETY MEASURES IN SCAFFOLDING

- It is required for all types of structures constructed above ground level and for maintenance of same works. The type of scaffolding to be used depends upon the nature of the work and its situation.
- The vertical standards should be embedded into the ground sufficiently deep so that they may withstand the loads coming on them. On streets and pucca floors these standards may be placed into the empty tar drums and packed with bricks or stones etc.
- Various stages of construction may be effected at convenient heights.
- While connecting ledgers to standards and put logs to ledgers, lashing should be done securely. The rope used should be thick and stout.
- The sizes of different members should be properly designed according to the load they are supposed to carry.
- To safeguard against over turning, inclined rakers are provided and lashed at the junctions of standards and ledgers at appropriate height and embedded in the ground at the bottom,
- The boarding over which the mason sits, should be of sufficient width and strength to take up the load of workers and building material needed for immediate use. Proper guard rails should be provided so that mason and workers may not fall down.
- To avoid the risk of its sliding the putlong should be inserted sufficiently deep in the wall.
- No body should be allowed to stand below the scaffolding, as brick or stone may fall down from the scaffolding and injure the person below.
- As the scaffoldings are not designed to carry huge quantity of building materials, only small quantity of materials or load should be put on the scaffolding
- When the work is over, the scaffolding should be dismantled step by step from upper side. Its members should be stacked on the hard ground. They should not be stacked

against wall. This will avoid sagging and warping of the members. To avoid crack development, they should not be exposed to direct sun rays.

- Before using members of scaffolding second time and subsequently, they should be tested for their strength. Wooden. members should be free from dry and wet rot
- Workers should not be allowed to lit fire near the scaffolding.

SAFETY MEASURES IN FORM WORK

- Form work may be either of timber or steel. In case of timber form work, the timber used should be of coarse grained, so that nails may be driven without difficulty and without causing .damage to the timber. The timber should be free from knots and other defects.
- The sections of timber should be such as to be capable of bearing the pressure of green concrete at the rate of 2400 kg/m^3.
- The timber form work should be provided with C.1. sheet lining 01," sheathing to be water tight, So that "there is no loss of cement mortar. It also provides smooth surface to the concrete.
- The construction of form work should be such that it can be dismantled or removed easily, without causing any harm to the concrete or form work itself as it has to be used a number of times on future works.
- To provide smooth surface to concrete and avoid damage to concrete as well as to form work, the interior surface of the form work should be given a coating either of grease oil or such other material.
- Partially seasoned timber should be used for form work. In case, dry timber is used for form work, allowance for bulging and shrinkage should be made while preparing the surface.
- The reinforcement cage should not be laid in position with a jerk, but placed gently.
- Concrete should not be thrown in the form work from a height more than I m as it will displace the reinforcement from its position, damage form work and segregation of concrete may also occur.
- Before reuse of the form work, its members should be tested carefully. Damaged members should not be reused. The from work should be free from dry rot or wet rot.
- Steel form work is more economical as it can be used for more number of times and it is more safe and gives better concrete surface.
- At the time of removing form work, except workers on the work, nobody should be allowed near the work as any falling member may cause injury.
- The form work should be removed without any jerk or vibration as it may cause damage to the reinforced concrete. Before re moving the bottom form work of the

beam or slab, it should be ensured that its bottom surface has sufficiently hardened. Actually form work should be removed as per conditions laid down by I.S.I.

SAFETY MEASURES IN HOT BITUMEN WORKS

- The tar boilers should be equipped with suitable, temperature recording device. The tar or bitumen should not be allowed to be over heated. By over heating, the binding properties of tar are destroyed and with further heating it may catch fire. To keep constant temperature bitumen should be constantly stirred.
- Only trained and experienced workers should be deputed for bitumen work.
- The work should be so planned that workers are given rest at suitable intervals.
- The workers must be equipped with protective wear. It should be ensured that every worker is wearing tarring outfit for his safety.
- Workers must wear Goggles to avoid damage to eyes from fumes of hot bitumen.
- To safeguard against fire hazards, work should be suspended during stormy weather.
- When the wind/is blowing fast, bitumen spraying should be done carefully. It should not be done against the direction of the wind.
- Warning signals such as sirens must be kept ready at the site of work and must be sounded promptly in case of fire hazard.
- Fire fighting equipment also should be kept ready at the site of work.
- There must be a first-aid box at the site of work and some persons must be trained in first-aid work.
- At both end of the road under construction, sign boards indicating "bitumen work is in progress" must be displayed.
- To check the entry of road user in the portion under construction, it should be protected from all sides by keeping empty drums and proper diversion should be arranged.

SAFETY MEASURES IN DEMOLITION WORKS

Demolishing of structures is a very hazardous work. Thus the demolition work should be properly planned and executed in different stages. In this way the injuries to workers and accidents can be reduced to a minimum. To ensure safety, cooperation between management, supervisors and workers is extremely important. Before starting the demolishing work the way in which the various parts of the building are supported and to what extent the adjoining structures will be affected by the step by step demolishing work, should be studied carefully. After careful study, plans should be prepared for systematic demolition work and it should be followed strictly while doing the demolition work. Foreman should guide the workers at each stage. The demolition operations should not endanger the adjoining buildings.

CONSTRUCTION SAFETY RULES

- Keep your mind on your work at all times. No horseplay on the job. Injury or termination or both can be the result.
- Personal safety equipment must be worn as prescribed for each job, such as: safety glasses for eye protection, hard hats at all times within the confines of the construction area where there is a potential for falling materials or tools, gloves when handling materials, and safety shoes are necessary for protection against foot injuries.
- Precautions are necessary to prevent sunburn and to protect against burns from hot materials.
- If any part of your body should come in contact with an acid or caustic substance, rush to the nearest water available and flush the affected part. Secure medical aid immediately.
- Watch where you are walking. Don't run.
- The use of illegal drugs or alcohol or being under the influence of the same on the project shall be cause for termination. Inform your supervisor if taking strong prescription drugs that warn against driving or using machinery.
- Do not distract the attention of fellow workers. Do no engage in any act which would endanger another employee.
- Sanitation facilities have been or will be provided for your use. Defacing or damaging these facilities is forbidden.
- A good job is a clean job, and a clean job is the start of a safe job. So keep your working area free from rubbish and debris.
- Do not use a compressor to blow dust or dirt from your clothes, hair, or hands.
- Never work aloft if you are afraid to do so, if you are subject to dizzy spells, or if you are apt to be nervous or sick.
- Never move an injured person unless it is absolutely necessary. Further injury may result. Keep the injured as comfortable as possible and utilize job site first-aid equipment until an ambulance arrives.
- Know where firefighting equipment is located and be trained on how to use it.
- Lift correctly - with legs, not the back. If the load is too heavy GET HELP. Stay fit. Control your weight. Do stretching exercises. Approximately twenty percent of all construction related injuries result from lifting materials.
- Nobody but operator shall be allowed to ride on equipment unless proper seating is provided.
- Do not use power tools and equipment until you have been properly instructed in the safe work methods and become authorized to use them.

- Be sure that all guards are in place. Do not remove, displace, damage, or destroy any safety device or safeguard furnished or provided for use on the job, nor interfere with the use thereof.
- Do not enter an area which has been barricaded.
- If you must work around power shovels, trucks, and dozers, make sure operators can always see you. Barricades are required for cranes.
- Never oil, lubricate, or fuel equipment while it is running or in motion.
- Before servicing, repairing, or adjusting any powered tool or piece of equipment, disconnect it, lock out the source of power, and tag it out.
- Barricade danger areas. Guard rails or perimeter cables may be required.
- Trenches over five feet deep must be shored or sloped as required. Keep out of trenches or cuts that have not been properly shored or sloped. Excavated or other material shall not be stored nearer than two feet from the edge of the excavation. Excavations less than 5 ft may also require cave in protection in some instances.
- Use the "four and one" rule when using a ladder. One foot of base for every four feet of height.
- Portable ladders in use shall be equipped with safety feet unless ladder is tied, blocked or otherwise secured. Step ladders shall not be used as a straight ladder.
- Ladders must extend three feet above landing on roof for proper use.
- Defective ladders must be properly tagged and removed from service.
- Keep ladder bases free of debris, hoses, wires, materials, etc.

HAZARDS FOR WORKERS

Potential hazards for workers in construction include:

- Falls (from heights);
- Trench collapse;
- Scaffold collapse;
- Electric shock and arc flash/arc blast;
- Failure to use proper personal protective equipment; and
- Repetitive motion injuries.

PERSONAL PROTECTIVE EQUIPMENT

Hard hats and steel-toe boots are perhaps the most common personal protective equipment worn by construction workers around the world. A risk assessment may deem that other protective equipment is appropriate, such as gloves, goggles, or high-visibility clothing.

Project Management

PERT & CPM

Question

Explain clearly the difference between an activity and an event.

Answer

Activity - Activity stands for the time consuming part of a project. It represents a job. Activities are denoted by arrows.

Event - The event (also called node) is either the beginning or end of a job. Events are denoted by circles. Event does not consume time.

When all activities and events in a project are connected logically and sequentially, they form a network.

Question

In what ways does a CPM network differ from Pert network ?

Answer

- PERT (Programme Evaluation & Review Technique) is *event* oriented whereas CPM (Critical Path Method) is *activity* oriented.
- In CPM based network analysis no allowance is made for the uncertainties in the duration of time involved.
- In CPM, times are related to costs.
- PERT is a probabilistic tool. CPM is a deterministic tool.
- PERT is basically a tool for planning and control of time. CPM also allows and explicit estimate of costs in addition to time, therefore CPM can control both time and cost.
- PERT is more suitable for R&D related projects where the project is performed the first time and the estimate of duration are uncertain. CPM is best suited for routine and those projects where time and cost estimates can be accurately calculated.

Question

Give an example to distinguish between an activity and an event.

Answer

Foundation digging started	Event
Foundation is being dug	Activity
Foundation digging completed	Event

PERT NETWORK

Question

Define, (i) predecessor event (ii) successor event

Answer

Event or events that immediately come before another event are called predecessor events to that event. Event or events that immediately follow another event are called successor events to that event.

Question

Draw a PERT network of opening a new office. Assume that following events take place in some sequence.

Event 1: Location of site started

Event 2: Location of site completed

Event 3: Building for office selected

Event 4: Cleaning of the office building started

Event 5: Interior decorator starts work

Event 6: Interior decorator finishes work

Event 7: Opening of new office advertised or announced

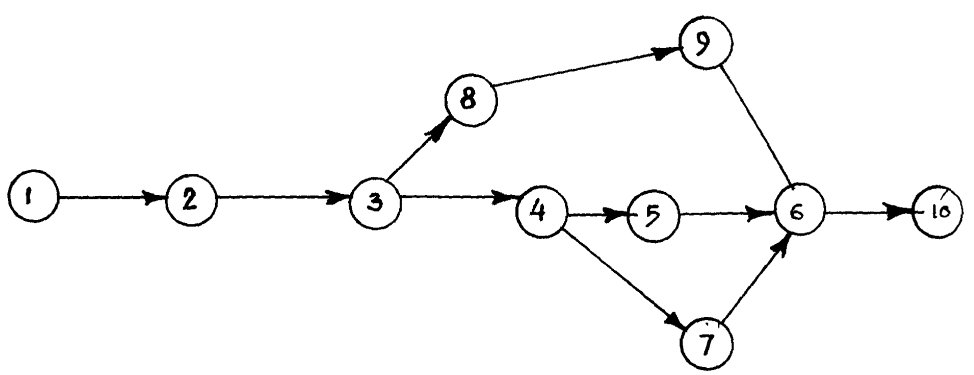
Event 8: List of invitees for the opening day prepared

Event 9: Invitations sent

Event 10: Office opened

Answer

See figure



Question

What do you understand by "dummy activity"? Explain it wit the aid of an example.

Answer

In constructing network very often a situation arises where a certain event j can not occur until another event i has taken place. In such a case, the activity joining i and j is called dummy activity. A dummy activity consumes no time. Consider example of a car taken to garage for cleaning. Inside as well as outside of the garage. The events can be putdown as follows:

Event 1: Start car from house

Event 2: Park car in garage

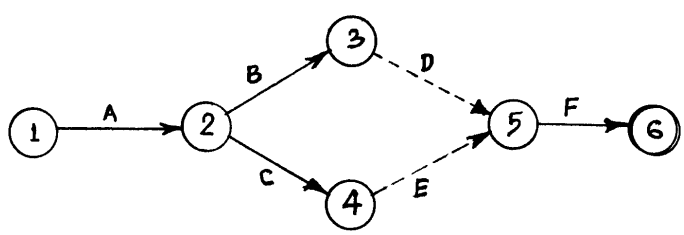
Event 3: Complete outside cleaning

Event 4: Complete inside cleaning

Event 5: Take car from garage

Event 6: Park car in house

Consider the network in the figure for this project. Time consumption for activity D and E are zero but they express the condition that events 3 and 4 must occur before event 5 can take place. Activities D and E are called the dummy activities and are usually indicated by dotted lines to distinguish them from real time consuming activities.



Question

Define

(i) *Optimistic Time Estimate (t_o)*

(ii) *Pessimistic Time Estimate (t_P)*

(iii) *Most likely Time Estimate (t_L)*

(iv) *Expected Time (t_E)*

Answer

Optimistic Time Estimate - This is the estimate of the shortest possible time in which an activity can be completed under ideal conditions.

Pessimistic Time Estimate - This is the maximum possible time it could take to accomplish the job. If everything went wrong then this would be the time estimate for the activity.

Most likely Time Estimate - this is the time estimate which lies between the optimistic and the pessimistic time estimates. It assumes that thing go in the normal way, with a few setbacks.

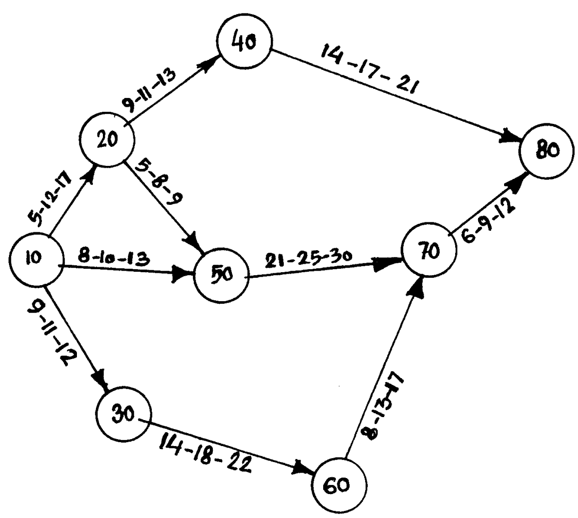
Expected Time - It is sum of one-sixth of optimistic, two thirds of most likely, and one-sixth of the pessimistic time estimates. That is

$$t_E = \frac{1}{6}t_O + \frac{2}{3}t_L + \frac{1}{6}t_P = \frac{t_O + 4t_L + t_P}{6}$$

Expected time indicates that there is a fifty-fifty chance of getting the job done within that time. Calculation of t_e is based on beta distribution of time estimates.

Question

For the network shown in figure, the optimistic, the most likely and the pessimistic time estimates are given on the arrows representing the activities. Find variance and expected time for each activity.



Answer

We know that

$$\text{expected time} \quad t_E = \frac{t_O + 4t_L + t_P}{6}$$

and variance

$$\sigma^2 = \left[\frac{t_P - t_O}{6}\right]$$

The values of the variance σ^2 and the expected time t_E are entered in their respective columns in table, and their calculations are straightforward.

Predecessor event	Successor event	t_O	t_L	t_P	σ^2	t_E
10	20	5	12	17	4.0	11.67
10	30	9	11	12	0.25	10.83
10	50	8	10	13	0.69	10.17
20	40	9	11	13	0.44	11.00
20	50	5	8	9	0.44	7.67
30	60	14	18	22	1.78	18.00
40	80	14	17	21	1.36	17.17
50	70	21	25	30	2.25	25-18
60	70	8	13	17	2.25	12-83
70	80	6	9	12	1.00	9.00

Question

Explain.

(i) Earliest Expected Time (T_E)

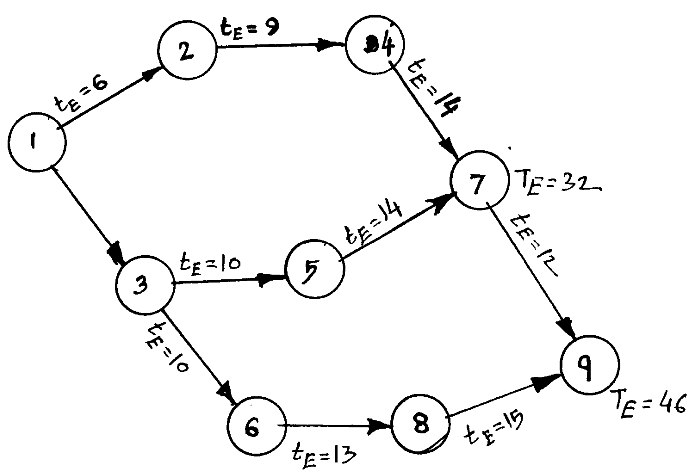
(ii) Latest Allowable Occurrence Time (T_L)

(iii) Slack and critical path

Answer

Earliest Expected Time (T_E)

It refers to the time when and event can be expected to be completed. It is computed by adding the expected time (t_Es) of the activity path leading to that event, let us consider the network shown in fig. The (t_E) for each activity is shown along the arrows.

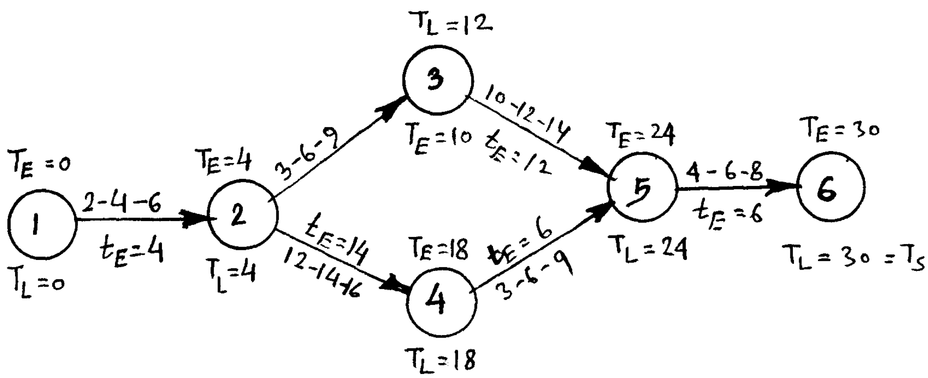


Here, event 7 is connected by two activity paths, these being 1 - 2, 2 - 4, 4 - 7 and 1 - 3, 3 - 5, 5 - 7. In the first path 1 - 2 - 4 - 7, T_E for event 7 is 6 + 9 + 14 = 29. In the second path, 1 - 3 - 5 - 7, T_E for the same event is 8 + 10 + 14 = 32. It is clear that event 7 cannot be considered completed until activities 1 - 3, 3 - 5, 5 - 7 have all been completed. Hence the earliest expected time T_E for event 7 is 32.

Now consider event 9. It can not occur until event 7 has occurred. There are now two paths leading to event 9 for its calculation of T_E, one through event 7 and other along 1 - 3, 3 - 6, 6 - 8, 8 - 9. The T_E for event 7 is 32 which gives for event 9 a T_E of 32 + 12 = 44. However along the activity path 1 - 3 - 6 - 8 - 9, the value of T_E for event 9 is 8 + 10 + 13 + 15 = 46. Hence, the earliest expected time for event 9 is 46, the larger of the two value obtained.

Latest Allowable Occurrence Time (T_L)

The latest time by which an event must occur to keep he project ion schedule is known as the latest allowable occurrence time (T_L). To explain this let us assume that it has been agreed to complete the project within a certain allotted time (say T_S). This time refers to the occurrence of the end event. Consider the network shown in figure below. Let T_S for the project is 30 weeks. The latest allowable occurrence time for event 5 is 30 - 6 = 24. Similarly for events 3 and 4, T_L = 24 -12 = 12, and 24 - 6 = 18, respectively. In event 2 we get two values, one by consideration activity 2 - 4. Thus for activity 2 - 3. T_L for event 2 is 12 - 6 = 6 and for activity 2 -4, T_L 18 - 14 = 4. Here smaller of the two will be selected. Hence T_L for event 2 is 4.



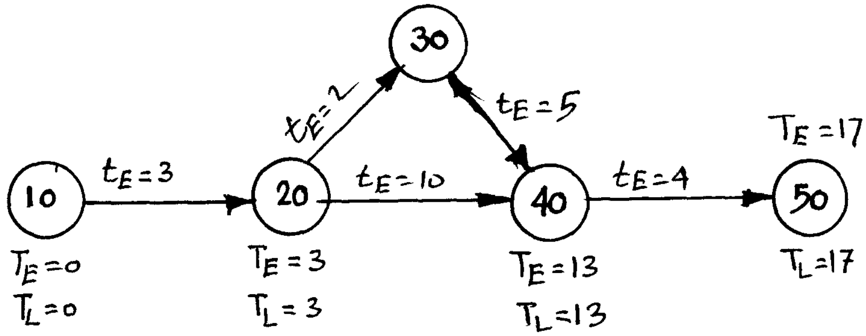
Slack

Slack is the difference between the latest allowable time and the earliest expected time, i.e.

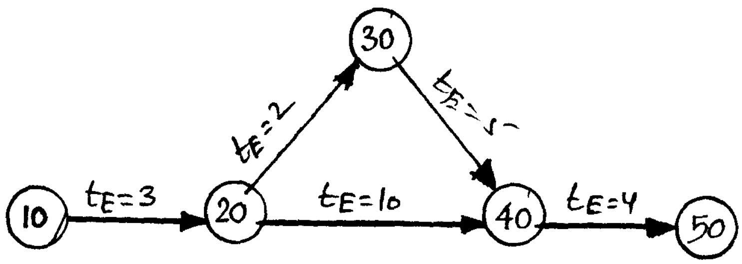
The term slack refers to an event since both T_L and T_E refer to events.

Critical Path

Referring to figure (a) below, we observe that path 10 - 20 - 40 - 50 connecting the initial and end events, consists of events all having zero or minimum slack times. This path is called the critical path. The network given by fig 16 - 6 is redrawn with the critical path indicated in heavy lines figure (b). This is the longest path time wise connecting the start and the end events



(a)



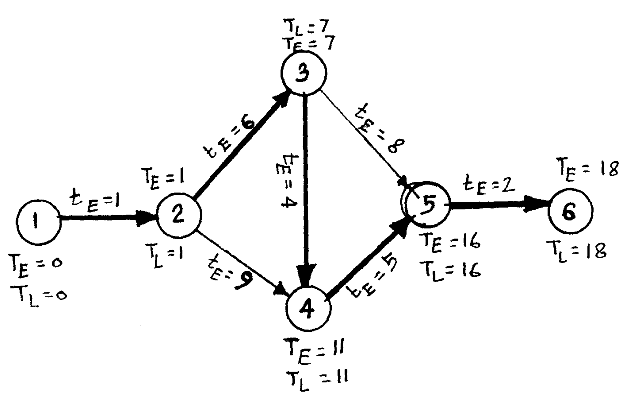
(b)

Question

The values of T_E are marked along the arrows for the network shown in figure given below. Values of T_E and T_L are also given. Draw critical path.

Answer

Critical path is shown in the same Fig. by heavy lines. Critical path connect events 6, 5, 4, 3, 2, and 1 i.e. the path is 1 - 2 - 3 - 4 - 5 - 6. This path takes longest time. Slack time for each event is zero.



Question

A small project is composed of seven activities as given below:

Activity		*Estimated duration (week)*		
i	*j*	***Optimistic***	***Most likely***	***Pessimistic***
1	*2*	*1*	*1*	*7*
1	*3*	*1*	*4*	*7*
1	*4*	*2*	*2*	*8*
2	*5*	*1*	*1*	*1*
3	*5*	*2*	*5*	*14*
4	*6*	*2*	*5*	*8*
5	*6*	*3*	*6*	*15*

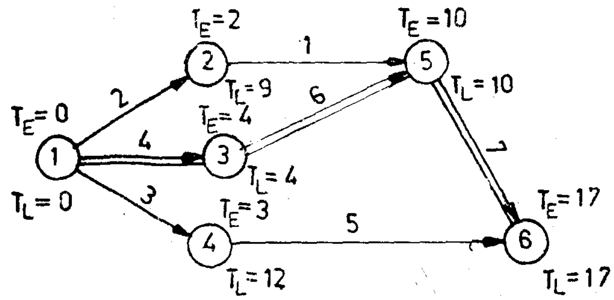
1. *Draw project network.*
2. *Find the expected duration and variance of all activities.*
3. *What is expected project length?*
4. *Calculate total slack of each activity.*
5. *Calculate the variance of project duration.*
6. *What is the probability that project will be completed at least 3 weeks earlier than expected?*

Answer

From the given data we can calculate the value of expected time (t_e) required and variance (σ^2) of each activity as shown in table below:

Activity		**t_0**	**t_L**	**t_P**	$t_e = \frac{t_0 + 4t_L + t_P}{6}$	$\sigma^2 = \left(\frac{t_p - t_0}{6}\right)^2$
i	j					
1	2	1	1	7	2	1
1	3	1	4	7	4	1
1	4	2	2	8	3	1
2	5	1	1	1	1	0
3	5	2	5	14	6	4
4	6	2	5	8	5	1
5	6	3	6	15	7	4

Now by using the values of expected time (t_e), we can draw the network as below and indicate the T_E and T_L for each event.



By knowing the values of T_E and T_L we see that critical path is 1-3-5-6, i.e. the path having minimum slack, and the expected project length is 17 weeks, slacks on all the activities are given below:

Activity	Slack	Activity	Slack
1-2	7	2-5	7
1-3	0	3-5	0
1-4	9	4-6	9
		5-6	0

To calculate probability, we first calculate variance along critical path,

$\Sigma\sigma^2$ along critical path = 1 + 4 + 4 = 9

$\therefore$ Standard deviation, $\sigma = 3$

Normal deviation = (scheduled time - expected time)/σ = -3/3 = -1

Hence the probability that project will be completed 3 weeks earlier then expected is 15.9%. [As we know that probability at -1, normal deviate is 15.9%]

Question

Identify the events and the activities in the following:

(a) Drive the piles

(b) Foundation erected

(c) Temperature measured

(d) Heat-treat the component

(e) Cure the concrete

(f) Door frame fixed

Answer

(a) activity (time consuming)

(b) event

(c) event

(d) activity (time consuming)

(e) activity (time consuming)

(f) event

Question

Define

(i) *Predecessor activity*

(ii) *Successor activity*

Answer

The activity or activities that immediately come before another activity are called predecessor activities to that activity. Those that immediately follow another activity are called successor activities to that activity. The activities are represented by arrows.

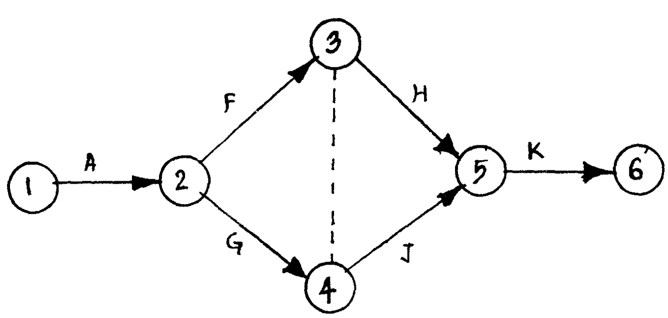
Question

Draw a CPM network. Following information is available.

1. A is the first operation of the project.
2. F and G can be done concurrently, but both must follow A
3. F must precede H
4. J cannot begin until both F and G are completed
5. K is dependent on the completion of both H and J
6. is the final operation in the project

Answer

The corresponding CPM network is shown in given figure. Since J cannot begin until both F and G are completed, we have to introduce a dummy activity shown by the dotted line. Dummy activity does not take any time.



Question

Explain

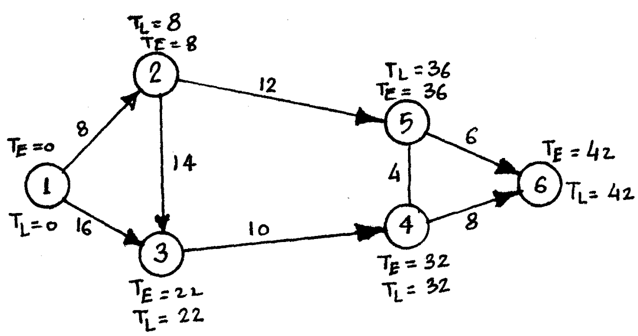
(i) Earliest Even Time (T_E)

(ii) Latest Allowable Occurrence Time (T_L)

Answer

(i) Already explained

(ii) **Latest Allowable Occurrence Time(T_L) -** Consider the network 16 - 10. Consider event 5. Job 5 - takes 6 weeks for completion. Since T_L for event 6 is 42 weeks, event 5 can occur as late as 42 - 6 = 36 weeks. Hence T_L for event 5 is 36 weeks. Now we come to event 4. Job 4 - 6 takes 8 weeks hence T_L for event 4 should be 42 - 8 = 34 weeks. But, job 4 - 5 - 6 takes 4 + 6 = 10 weeks hence T_L for event 4 should be 42 - 10 = 32 weeks. Smaller of the two T_L will be selected i.e. 32 weeks. Hence T_L for event 4 will be 32 weeks. In this manner, the T_L's for the remaining events have also been calculated and are shown in figure.



Question

For an activity i - j, define.

(i) *Earliest Start Time*

(ii) *Earliest Finish Time*

(iii) *Latest Start Time*

(iv) *Latest Finish Time*

Answer

(i) **Earliest Start Time -** This is the T_E for event i from which the activity arrow originates.

(ii) **Earliest Finish Time -** This is the T_E for event i form which the activity arrow originates plus the duration for the activity (i - j) .

(iii) **Latest Finish Time -** This is T_L for event J where activity arrow terminates.

Question

What do you understand by

(i) Total Float

(ii) Free Float

(iii) Independent Float

Answer

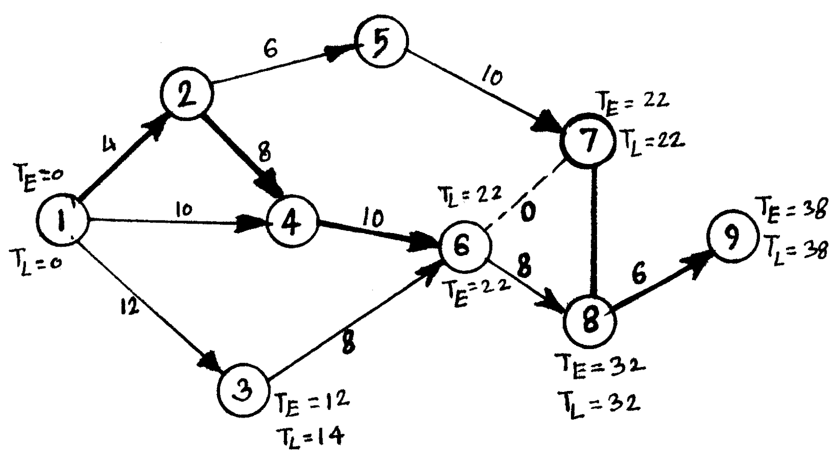
(i) **Total float -** It is the difference between latest start time for the activity minus its earliest start time.

(ii) **Free float -** The free float of an activity i - j is the difference between its earliest finish time and the T_E of event j.

(iii) **Independent -** Float for activity i - j = T_E of event j - T_L of event i - duration of activity i - j.

Question

From network given below, prepare a table giving earliest start time, earliest finish time, latest start time, latest finish time, total float, free float and independent float.



Answer

Event i	Event j	Duration	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Total Float	Free Float	Independent Float
1	2	4	0	4	0	4	0	0	0
1	3	12	0	12	2	14	2	0	0
1	4	10	0	10	2	12	2	2	2
2	4	8	4	12	4	12	0	0	0
2	5	6	4	10	6	12	2	0	0
3	6	8	12	20	14	22	2	2	0

4	6	10	12	22	12	22	0	0	0
5	7	10	10	20	12	22	2	2	0
6	7	0	22	22	22	22	0	0	0
6	8	8	22	30	24	32	2	2	2
7	8	10	22	32	22	32	0	0	0
8	9	6	32	38	32	38	0	0	0

Explanation of row 2

Earliest start time = T_E of event 1 = 0

Earliest finish time = T_E of event 1 + duration of activity 1 - 3 = 0 + 12 = 12

Latest start time = T_L for event 3-duration of 1 - 3 = 14 - 12 = 2

Latest finish time = T_L for event 3 = 14

Total float = latest start time - earliest start time = 2 - 0 = 2

Free float = earliest finish time - T_E of event 3 = 12 - 12 = 0

Independent float = T_E of event 3 - T_L of event 1 - duration of i - j = 12 - 0 - 12 = 0

Similarly data for other rows can be obtained.

Question

Given the following for a project

i	*j*	***Duration (days)***
1	*2*	*5*
3	*5*	*4*
4	*5*	*4*
2	*6*	*6*
5	*6*	*7*
5	*7*	*8*
6	*8*	*10*
7	*8*	*3*
7	*9*	*5*
8	*10*	*7*
9	*10*	*6*

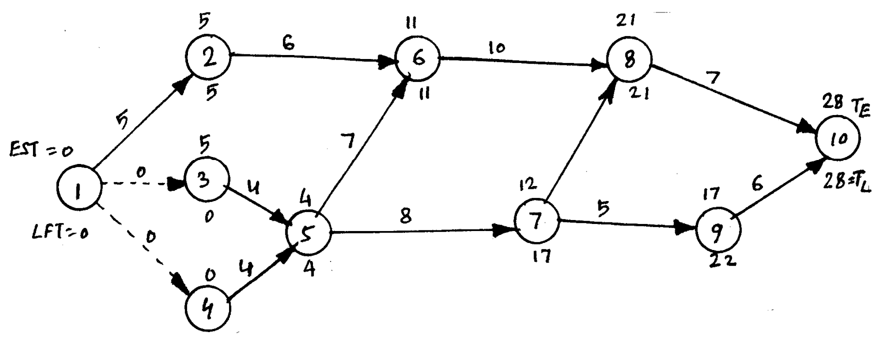
(i) *Draw a CPM diagram*

(ii) *Find out critical Path*

(iii) *compute the float*

Answer

(i) See figure. Here 1 - 3 and 1 - 4 are dummy activities taking zero time.



(ii)

Event	1	2	3	4	5	6	7	8	9	10
Slack (T_L - T_E)	0	0	0	0	0	0	5	0	5	0

A critical path must pass through zero nor minimum slack and also it must take longest time.

Hence following will be critical paths

(i) 1 - 2 - 6 - 8 10

(ii) 1 - 3 - 5 - 6 - 8 - 10

(iii) 1 - 4 - 5 - 6 - 8 - 10

(iii)

Event		Duration	Earliest Start	Latest Start	Total Float
i	j	(Days)	Time	Time	
1	2	5	0	0	0
1	3	0	0	0	0
1	4	0	0	0	0
2	6	6	5	5	0
3	5	4	0	0	0
4	5	4	0	0	0
5	6	7	4	4	0
5	7	8	4	9	5
6	8	10	11	11	0
7	8	3	12	18	6
8	10	7	21	21	0
9	10	6	17	22	5
7	9	5	12	17	5

Question

In the context of network planning methods, define the following terms:

(i) Early Start

(ii) Stack

(iii) Critical Path

(iv) Activity

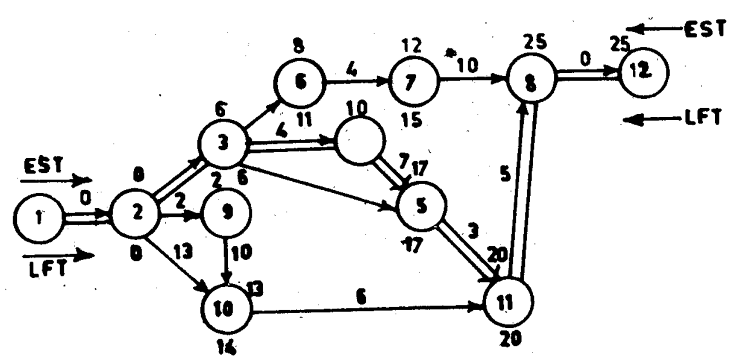
The following activates are involved in a project sequence of activities

Nodes		Expected Time
i	j	
1	2	0 Start
2	3	6
2	9	2
2	10	13
3	6	2
3	4	4
3	5	7
6	7	4
7	8	10
9	10	10
10	11	6
5	11	3
11	8	5
8	12	0

(i) Draw the network.

(ii) Find out the critical path to monitor the project. (6 + 14).

Answer



Question

A project comprises of eight activities. The precedence relationship and estimated duration of the eight activities are given as:

Activity Immediately	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
Preceded by	*None*	*None*	*None*	*A*	*A*	*A*	*(B, D)*	*(C, D)*
Duration (Days)	*3*	*2*	*5*	*5*	*4*	*7*	*10*	*10*

(i) Draw the project network and label the same.

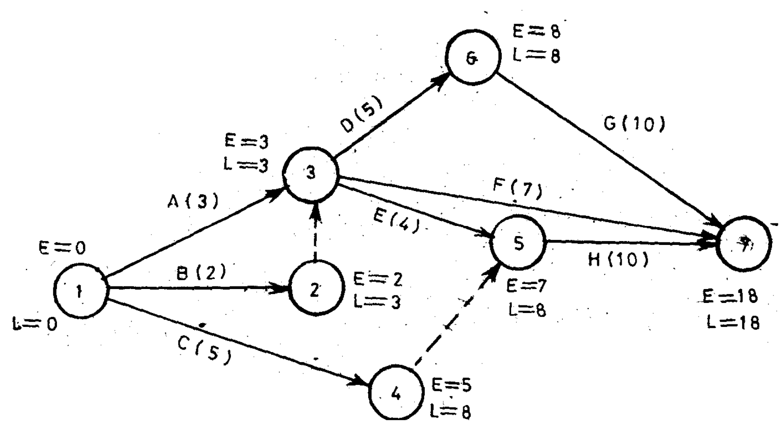
(ii) Estimate the project duration.

(iii) Identify the critical activities and the critical path.

(iv) Re estimate the project duration if the activity A gets delayed by 10 days.

Answer

(i)



(ii) 18 days

(iii) See Figure

(iv) 28 days

Question

(a) Illustrate with examples the essential difference between PERT and CPM technique.

(b) The table shown below indicate the relevant information regarding a project. With the help of information supplied complete the following:

(i) Draw the network and number the nodes.

(ii) find out the earliest and latest event times.

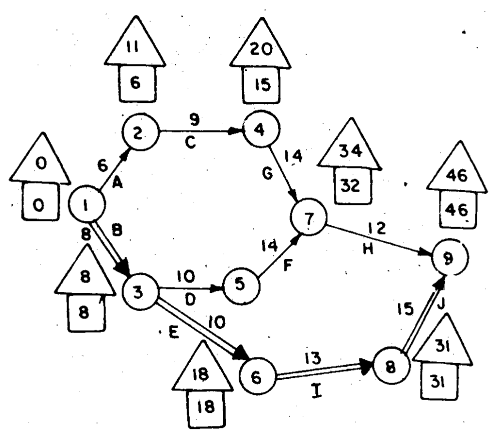
(iii) Identify the critical activities and critical path.

(iv) Estimate the project completion time.

Activity	*Predecessor Activities*	*Time (Days)*
A	-	*6*
B	-	*8*
C	*A*	*9*
D	*B*	*10*
E	*B*	*10*
F	*D*	*14*
G	*C*	*14*
H	*F, G*	*12*
I	*E*	*13*
J	*I*	*15*

Answer

(b)



Question (AMIE Summer 97)

State the basic difference between the CPM and PERT models? Relying on such differences indicated one specific example of possible application of each of the models.

A project comprises of the following activities and relevant information pertaining to such activities are given below:

Activity	*Description*	*Immediate Predecessors Activity*	*Estimated Time (Weeks)*
A	*Survey*	-	*12*
B	*Detailed Estimate 2 sanction*	*A*	*4*
C	*Preparation of tree cutting schedules*	*A*	*20*
D	*Procurement of tower stubs and tower parts*	*B*	*20*

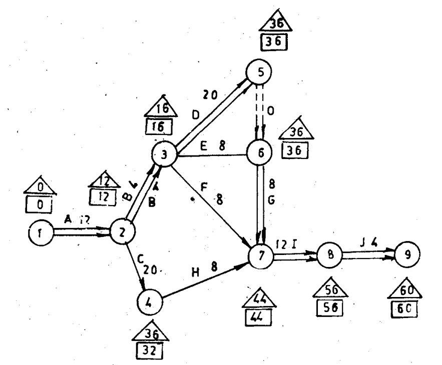
E	*Award contract for stub setting*	*B*	*8*
F	*Award contract for tower erection*	*B*	*8*
G	*Stub setting for towers*	*D, E*	*8*
H	*Tree cutting*	*C*	*8*
I	*Tower erecting and stringing*	*F, G, H*	*12*
J	*Energizing*	*I*	*4*

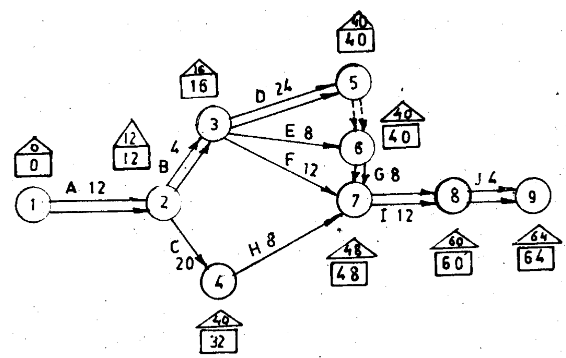
(i) Determine the estimated time for completing the project along with the associated probability.

(ii) Calculate total float of each activity and identify critical activities and critical path

(iii) If the activities D and F get delayed by 4 weeks each what will the effect of these delays on the project duration.

Answer

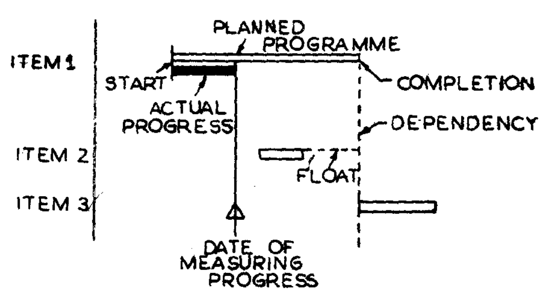




BAR CHART

Bar chart is an graphical representation of completion of various. activities of a project. This technique was developed by Henry Gantt 1919.

In the bar chart technique various activities involved in a. work are listed and their period of time, during which each activity is planned to take place is shown in the form of a horizontal bar plotted to a suitable time scale against each activity. The degree or details of the activities and the scale of time depends upon the intended use of the chart.

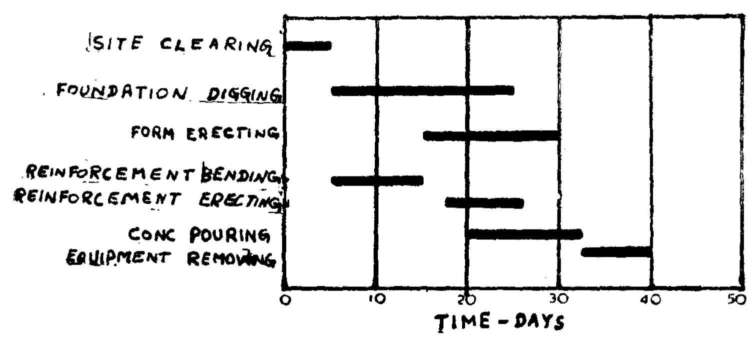


In a bar chart the planned programme is shown by a thick line and the actual progress obtained by hatchet line as shown in figure. The planned start and finish is shown by small vertical line. The float is shown by dotted horizontal line. The float indicates that though the item is scheduled to be completed by a certain target date, yet the subsequent items are not likely to be held up in, case or delay upto the period represented by dotted line. The dependency or one work on another is shown by vertical doted line. Connecting the start of the item with the completion of the item on which it depends. Above figure shows planned programme, float, dependency etc.

In all projects some activities may be started at the same time, while others can only be started after completion of previous activities. The activities which start simultaneously are shown starting from the same point and running parallel on the bar chart, while the activities to be completed in series start one after the other. In this case the starting point of one activity start sat the end point of the previous activity. This is illustrated by the following example. Let the following time is taken in the completion of different .activities of a work.

Item of work	Time required in weeks
Clearing of site	5
Excavation of foundations	20
Erection of form work	15
Preparing reinforcement	10
Placing reinforcement in position	5
Pouring of concrete and finishing	12

The bar chart programme of these activities is shown in figure.



If some activities are not started simultaneously then the work will take 67 weeks to complete, but to prolong work to such a large period will entail more expenditure and the resulting work will be uneconomical. Therefore, after the clearing of the site, the activities of foundation excavation and preparation of reinforcement can be started simultaneously as they have no co-relation between them i.e., they are independent activities. Thus they can be started simultaneously independent of each other. After excavation of half foundation putting form work may be started and after few weeks of starting of work, reinforcement may be placed in position. Let placing or reinforcement is started after 3 weeks and pouring concrete after 2 weeks of placing of reinforcement. The programme of this work is shown in figure above.

Advantages of bar charts

To construct and understand bar charts is easy. They can further be improved by colour coding of various activities. It is the most widely used form of representing planned programmes. Bar charts are useful for calculating the resource requirements of a project. Even on projects where net work techniques are used for planning, the final schedules are generally presented in the form of bar charts, Bar chart technique is useful for small projects only, for big and complicated projects bar chart has not proved useful for scheduling its different activities,

Limitations of bar charts

Though bar chart is simple to construct, easy to understand and widely used method of scheduling, yet it has a number of limitations as follows:

- It is difficult to depict complicated interdepencies or various items of work.
- It gives the impression that the rate of progress of any' activity is uniform and thus it is not possible to know the' peak or maximum rate - of progress necessary to its timely completion.
- Bar charts do not indicate the actual progress as they only represent the time which has passed or elapsed.
- Delays in the work are not detected till the allotted time is over and the work remains incomplete.
- Bar charts do not indicate, which activities are critical if and need careful supervision.
- In case of variation from planned programme, it is difficult to find out the alternative course of action to be adopted to complete the work in time.
- Bar chart is only a static representation of the planned programme and it does not indicate the dynamic happenings on the construction site of a complex project.

ASSIGNMENT

QUALITY CONTROL

Q.1. (AMIE W11, 10 marks): What is the concept of quality? State any three stages of quality control. Explain any three basic elements of quality.

Q.2. (AMIE S12, 6 marks): Explain the concept of quality control of concrete at site. How can it be achieved?

Q.3. (AMIE W13, 5 marks): What are general principles of inspection of civil engineering works and what are the main items requiring quality control?

Q.4. (AMIE W12, 6 marks): How can best workmanship be achieved during concrete construction?

Q.5. (AMIE W13, 5 marks): Why is there need of standards to be fixed for civil engineering works? Discuss in brief about the Indian Standard code for concrete.

SAFETY ISSUES

Q.6. (AMIE S11, 6 marks): What are the safety measures taken during construction of major civil engineering projects?

Q.7. (AMIE S13, 8 marks): Describe briefly the general safety programme for construction. What are the protective equipment provided to workers for safety during construction.

Q.8. (AMIE W12, 8 marks): Describe the methods of safety measures taken during construction of a multistoried building in a congested place.

PROJECT MANAGEMENT

Q.9. (AMIE W11, 5 marks): With the help of a sketch, explain Gantt bar chart. What are shortcomings of a Gantt bar chart ?

Q.10. (AMIE S12, 10 marks): What are the shortcomings of bar charts? How can these be removed ? Explain in detail. Support your answer with simple and neat sketches.

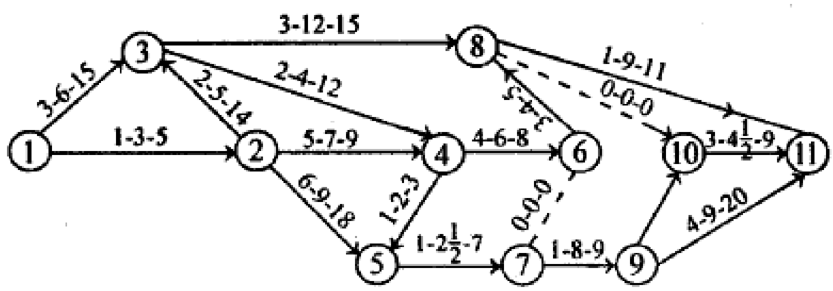
Q.11. (AMIE S11, 10 marks): Describe how to apply the techniques (i) CPM, (ii) bar charts, and (iii) pie diagram for managing the construction schedule of a civil engineering project

Q.12. (AMIE W11, 5 marks): Define the following: (i) Optimum time estimation (ii) Most likely time estimation (iii) Pessimistic time estimation (iv) Expected time estimation (v) Critical path.

Q.13. (AMIE W13, 5 marks): What are different methods of time scheduling in civil engineering construction activities? What were the limitations of bar charts that led to development of critical path method and network methods ?

Q.14. (AMIE S13, 4 marks): What are the advantages of network diagram ?

Q.15. (AMIE S13, 8 marks): A construction company has to submit a bid for construction of a building. From specification, PERT network along with three time estimates (in weeks) were made and shown in figure Determine the critical path and its standard variation.



Q.16. (AMIE W12, 20 marks): During construction of a multistoried building, duration of various activities for each floor is given below :

(A) Building planning and design	7 days
(B) Layout	2 days
(C) Construction of foundation	20 days
(D) Superstructure (walls and columns) up to roof level	30 days
(E) Door/window frame fixing	7 days
(F) Roof construction	40 days
(G) Electrical conduit	7 days
(H) Laying drainage pipes	7 days
(I) Laying water pipes	7 days
(J) Plastering work	15 days
(K) Paris work	10 days
(L) Laying electrical wiring/fittings	10 days
(M) Fixing sanitary/water fittings	7 days
(N) Finishing/colour washing/roof treatment/flooring	16 days

Choose the activities in a proper sequence and prepare the CPM network and then determine the total project duration for a six-storeyed building.