

PROJECT PLANNING AND SCHEDULING

Engineering

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CONCEPT OF PROJECT

- Every product or services what we are acquiring today is the outcome of our necessity.
- For fulfilling the desire or necessity, an idea is generated in a human mind.
- To translate the idea into reality, a single person is not capable of doing it alone.
- A person utilizes the different resources including the human and non human resources for translating the idea into the physical form.
- The process of converting the idea into reality by utilizing the different resources is said to be a project.

DEFINITION OF PROJECT

- “A project can be defined as an **unique** task (however large or small) with **defined goal**, limited in **cost and time** and giving some **benefits** to the users after its **completion**”.
- “A project is defined as a **temporary** endeavor undertaken to create a **unique** products or services”.
- “A project is a collection of limited activities, carried out in an **organized manner** with a clearly **defined start and finish points**, to achieve some **specific results** that satisfy the needs of an organization as derived from the current business plans.”

RESOURCES OF A PROJECT

Generally Denoted by 5 ‘M’

- Money
- Manpower
- Material
- Machine
- Minute/ Management



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Management of the above listed 5 ‘M’s relies on core function of project management

A good project is that which is:

- Technically feasible
- Economically viable
- Socially acceptable
- Politically suitable &
- Environmentally friendly



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Because projects are
considered as cutting edge of
any development

CHARACTERISTICS OF A PROJECT

Any task or job or work can be said as a project if it meets the certain characteristics.

1. A Defined Goal/ Objective
2. Unique
3. Specific task not routinely performed
4. Temporary (Life Span)
5. Team Work
6. Resource being consumed
7. Risk and Uncertainties
8. Planning and Control
9. Constraints
10. Contracting and subcontracting
11. Progressive Elaboration
12. Life cycle
13. Defined Deliverables

CLASSIFICATION OF PROJECT

(Cont'd...)

According to Sponsorship
(Who Sponsors??)



Customer sponsorship

- Sponsorship by an individual or a party

Organization

- By firm, company

Contractor

- To sub contractor

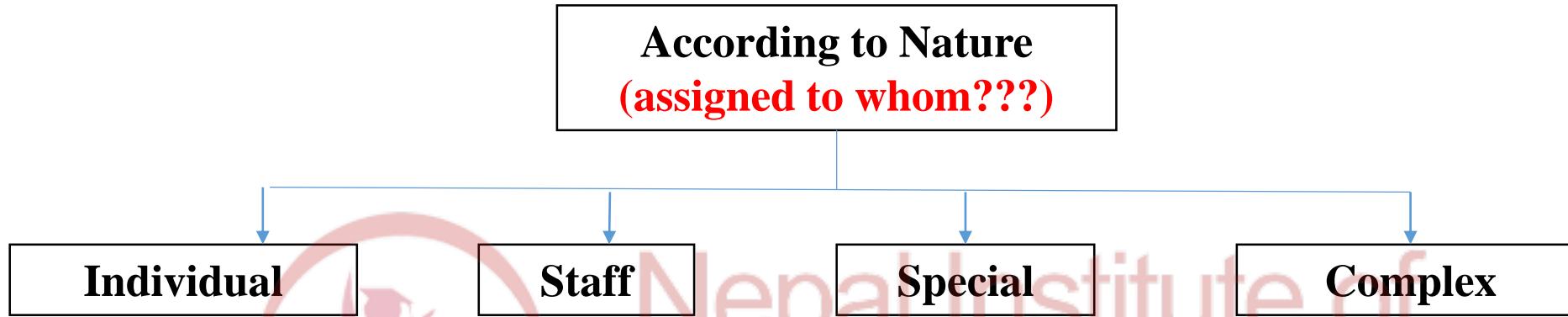
Government Organizations

- Department, office

International Non-Government organizations

- Non-governmental Organizations

CLASSIFICATION OF PROJECT (Cont'd...)



1. Individual

- This sub class of project is one in which **one individual** (may be from within the organization or an independent person) is assigned with the responsibilities to complete it. [2]

- An INGO may identify individual from its organizational setup or independent person.

CLASSIFICATION OF PROJECT

(Cont'd...)

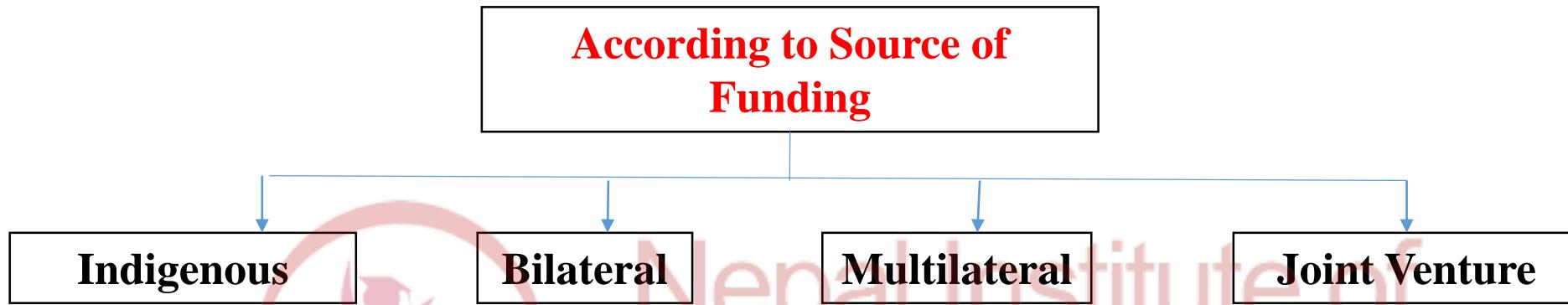
2. Staff

- This sub class of project refers to assigning the project activities to a particular department.
- The research and development or engineering department within a company may be assigned to develop a project on new product development.

3. Special

- This sub class is one in which an independent researcher is identified and entrusted with the responsibilities to conduct a research.
- This is similar to the individual project but will address a special issue. Example: national expert on security issue.

CLASSIFICATION OF PROJECT (Cont'd...)



1. Indigenous Project

- It is based on local thinking, technology, and environment and carried mostly by local people.
- It is mostly the blend of indigenous materials, technology and resources.
- It helps to preserve and protect tradition and culture and help to expand people friendly market for local products. [3]

CLASSIFICATION OF PROJECT (Cont'd...)

2. Bilateral Project

- All the projects which are carried on under the **agreement of two countries** are called bilateral projects.
- It involves both technology as well as capital. These projects are mostly funded through the financial resources of the donor. They could be in the form of grants. [4]
- These projects are governed by an agreement and memorandum of understanding between two governments.
[2]
- Example: JICA, USAID, GTZ, KOICA etc.

CLASSIFICATION OF PROJECT

(Cont'd...)

3. Multilateral Project

- All the projects which involves the funding of projects through the resources directed by the donors through multilateral agencies are called multilateral projects.[4]
- The financial resources are mobilized from the international financial institutions by way of credit or loans.
- Multilateral agencies might be European union (EU), World bank, Asian Development Bank (ADB), International Finance Corporation (IFC), World Bank etc.

CLASSIFICATION OF PROJECT

(Cont'd...)

4. Joint Venture Project

- Any project undertaken to produce goods and services through collaboration of foreign and local investors is joint venture project.
- The ownership is proportionally shared in an agreed ratio.
- It is associated with transfers of technology, capital, or managerial skills.
- Due to globalization and advancement in information technology, joint venture business is becoming very popular.
- Examples: Maruti-Suzuki in India,

CLASSIFICATION OF PROJECT (Cont'd...)



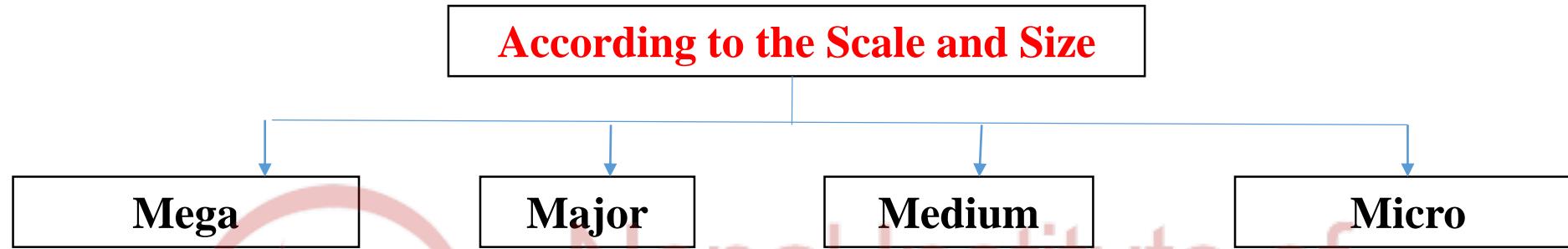
1. Product oriented

- The focus is on the technical content of the project. The outcome of the project is a product which fulfills consumer needs.
Examples – building, road, bridge etc.

2. Process oriented

- No consideration is given to technical context. Examples- person focused training, repair of cement plant etc.

CLASSIFICATION OF PROJECT (Cont'd...)



1. Mega Project

- It is a big size complex project for 10 to 20 years involving huge investment and high technology, includes multiple public and private stakeholders and impact millions of people.
- These projects required environmental screening like EIA (Environmental Impact Assessment).

CLASSIFICATION OF PROJECT

(Cont'd...)

2. Major Project

➤ It is smaller in size than mega project. The project requires relatively large amount of fund, large number of people and more activities to be performed is known as major project. [5]

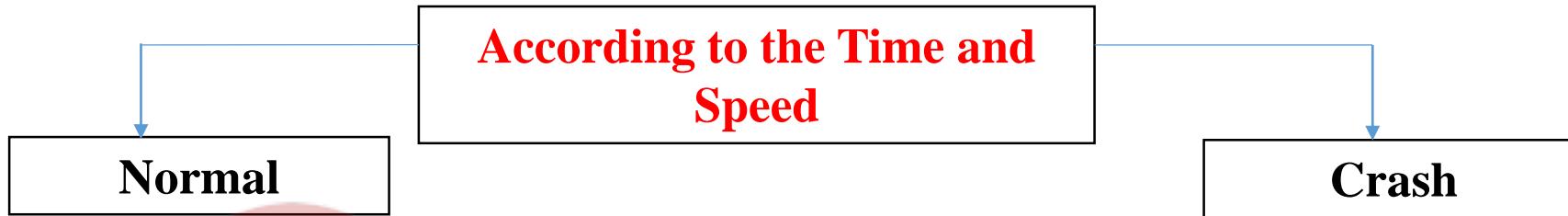
3. Medium Project

➤ It is small in size than major project. These project requires IEE (Initial Environment Examination).

4. Micro Project

➤ It refers to a very small project for short duration. The financial resources involved is also very small.

CLASSIFICATION OF PROJECT (Cont'd...)



1. Normal Project

- In this category of projects, adequate time is allowed for Implementation of the project.
- All the phases in a project are allowed to take the time they should normally take. This type of project will require minimum capital cost and no sacrifice in terms of quality. [6]



CLASSIFICATION OF PROJECT

(Cont'd...)

2. Crash Project

- Crashing is the process of **shortening the project duration**. When the project duration exceeds the normal completion time, crashing is encouraged.
- Saving in time is achieved by **spending extra resources** in terms of money, materials and manpower with compromising quality. Overlapping or shortening of project phases is encouraged.

PROJECT LIFE CYCLE AND PHASES

- Project is a temporary job. It cannot continue endlessly. The life span of the project is divided into phases.
- A project depending upon its nature, size and type, undergoes through different well defined phases right from its inception to successful completion.
- Collectively, the project phases are known as project life cycle phases. The breakdown and terminology of these phases differs depending upon the nature of the project or organization.

PROJECT LIFE CYCLE AND PHASES

(Cont'd...)

- Project life cycle defines **what technical work should be done** in each phase and **who should be involved** in each phase. [7]
- The project life cycle refers to a **logical sequence of activities** to accomplish the project goal or objective.
- A lucid understanding of these phases **permits project manager to better control the resources** in the achievement of desired goals. [3]

PROJECT LIFE CYCLE AND PHASES

(Cont'd...)

Generally for engineering project (infrastructure related project) , five basic phases contribute to develop an idea into reality.

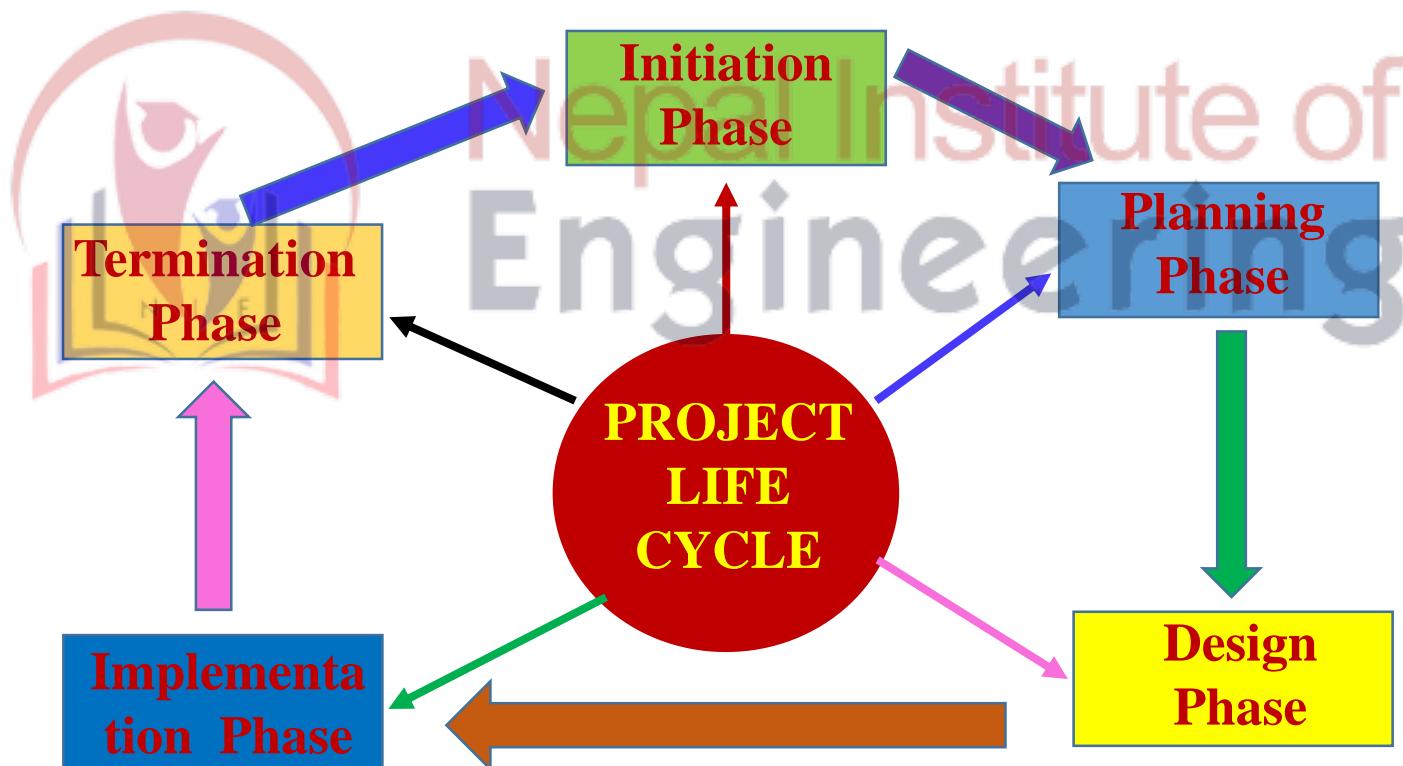


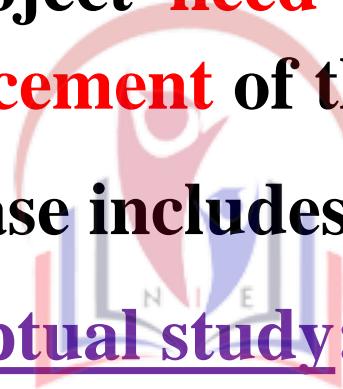
Fig: Project life cycle phases [11]

PROJECT LIFE CYCLE AND PHASES

(Cont'd...)

1. Initiation Phase

- The project **need** is identified in this phase and it **signals the commencement** of the project.
- This phase includes:
 - (a) Conceptual study:
 - Projects are born with creative ideas. It includes preliminary evaluation of ideas, such as **project identification** and **project formulation**.
 - Creation of the project charter.



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PROJECT LIFE CYCLE AND PHASES

(Cont'd...)

(b) Feasibility study:

- The objective of the feasibility study is to have **more detailed information** about the location, nature, dimensions, raw material needed, equipment, cost-benefit analysis, and the detail about the users who will be benefitted from the project.

(c) Market study:

- It includes the study of the marketing prospects and **demand of the product**, considering (a) potential size and composition of the market (b) present and projected demand of the product/services.

After the completion of this phase, a go/no-go decision is made.

PROJECT LIFE CYCLE AND PHASES

(Cont'd...)

2. Planning Phase

- Planning is deciding in advance the **future course of actions** which is the primary function of management. [8]
- Major activities carried out in this phase are:
 - (a) **Work breakdown structure:**
 - The project is broken down into small elements so that all the activities to be performed in the project are included.
 - Allocation of roles and responsibilities to the different stakeholders.

PROJECT LIFE CYCLE AND PHASES

(Cont'd...)

(b) Cost and Schedule Planning:

- After breaking down the project, the **time and cost of each activity is determined** and overall time and cost of the project is determined.

(c) Contract terms and condition:

- Procurement related works are also carried out in this phase which involves two major type of activities: [9]

(i) Contracting and sub contracting for services of general and speciality construction contractors.

(ii) Obtaining materials and equipment required to construct the project.

PROJECT LIFE CYCLE AND PHASES

(Cont'd...)

3. Engineering and Design Phase

➤ This Phase includes:

(a) Preliminary Engineering and Design:

- It stresses architectural concepts, evaluation of technological process alternatives, size and capacity decisions, and comparative economic studies. [9]
- For example: In designing dam, hydropower, irrigation channel preliminary design requires analysis of hydrological characteristics, geological condition, precise location of dam etc.

PROJECT LIFE CYCLE AND PHASES

(Cont'd...)

(b) Detailed Engineering and Design

- It involves the process of successively breaking down, analyzing and designing the structure and its elements.
- It gives the information to the constructors exactly how to build the structure in the field considering the standard of safety. [9]
- This detailed phase include architects, interior designers, landscape architects, and several engineering disciplines including chemical, civil, electrical, mechanical etc.

PROJECT LIFE CYCLE AND PHASES

(Cont'd...)

4. Implementation and Controlling Phase

- This phase is also known as the execution or construction phase. Relatively this is the **longest phase** in a project life cycle.
- This phase involves about **80% of the total project work and the resources** are also extensively used.
- It is the mark or signal that something starts growing in the project site and **stakeholders can see the project visibly.** [3]

PROJECT LIFE CYCLE AND PHASES

(Cont'd...)

This Phase includes :

- Application of the paper work physically in the real field.**
- Mobilization of human and non human resources in accomplishing the activities defined in earlier phases.**
- Manufacturing, installation of machines and testing and civil works.**
- Controlling is performed to check project performance at any point of time during implementation.**
- Risk management**
- Resolves issues if any**
- The facility is substantially completed at this phase.**

PROJECT LIFE CYCLE AND PHASES

(Cont'd...)

5. Divestment/ Phase out/ Termination

- This phase is the end of project and **project is brought to its completion.**
- The final testing and maintenance of the project is done and **handed over to the customer** and resources are released to other projects.
- The basic tasks in this phase are evaluation and handover of the project output to the beneficiaries.

PROJECT LIFE CYCLE AND PHASES (Cont'd...)

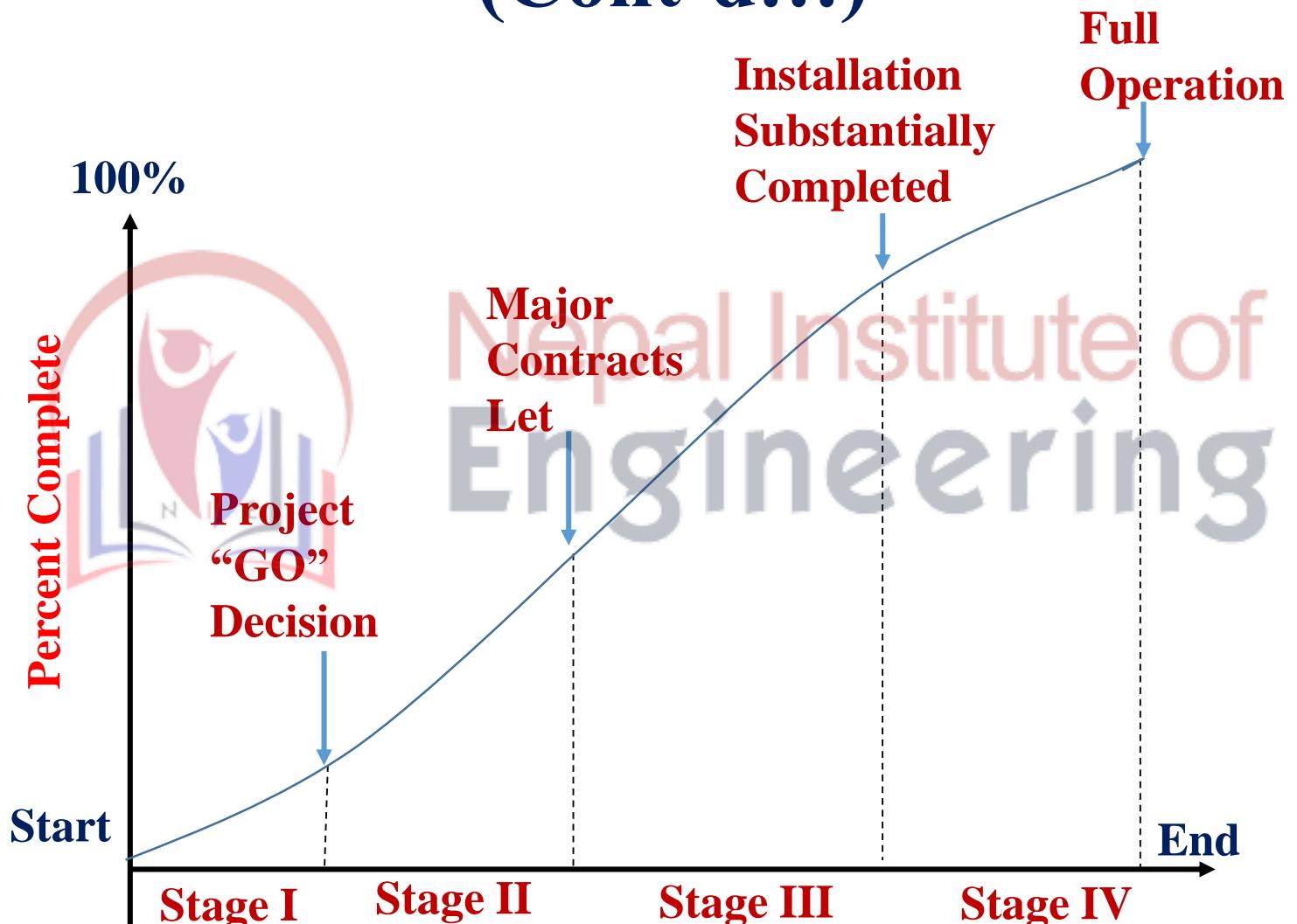
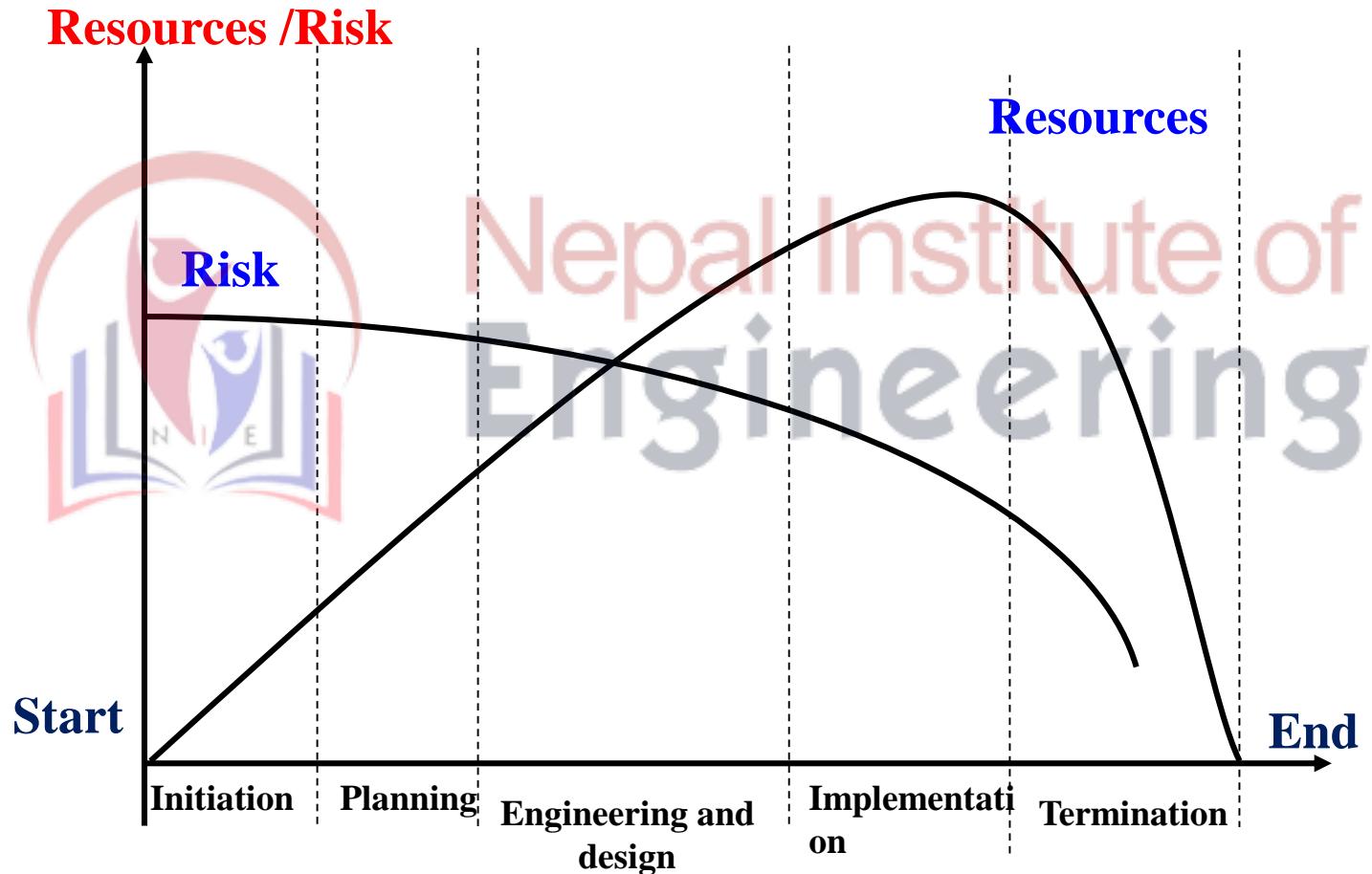


Fig: LIFE CYCLE STAGES [7]

Project life cycle in terms of resources/risk and time



PROJECT CASH FLOW (Cont'd...)

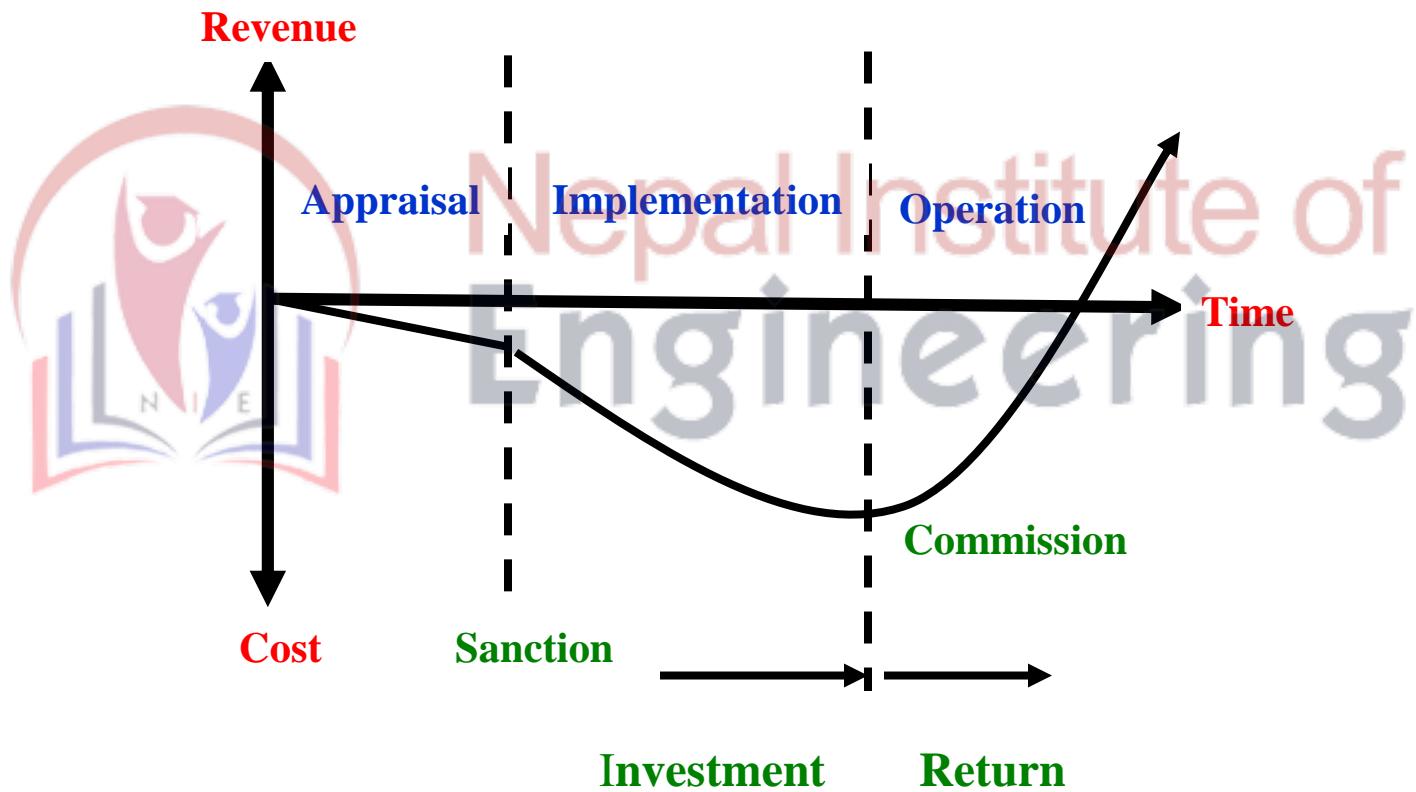


Fig: Project Cash Flow

CONCEPT OF PROJECT PLANNING

Meaning of General Planning

- In the simple sense, planning means thinking ahead of an operation to be performed.
- It is the function of selecting the enterprise objectives and establishing the policies, procedures, and programs necessary for achieving them. [7]
- Planning includes both assessment of future opportunities and challenges for an organization and developing strategies to achieve the organizational goals.
- Planning is the intellectual capability of manager who decides whether or not the act or take up to a particular event or not. [6]

CONCEPT OF PROJECT PLANNING

Meaning of Project Planning

- It is concerned with developing a project for investment.
- It identifies and addresses the tasks required for accomplishment of project objectives.
- It acts as a roadmap for managing the project. It determines how the project objectives will be accomplished.
- It involves detailed design, budgeting, scheduling and allocation of resources.
- It is the process of thinking through and making explicit the project's objectives, goals and strategies necessary to bring the project through its lifecycle to successful termination. [8]

Meaning of Project Planning (Cont'd...)

➤ Steps of project planning: [9]

1. **DEFINE** : The objective of the project in definite words.
2. **ESTABLISH** : Goals and stages intermediate to attain the final target.
3. **DEVELOP** : Forecast and means of achieving goal, i.e., activities.
4. **EVALUATE** : Organization's resources – financial, managerial, and operational to carry out activities and to determine what is feasible and what is not.
5. **DETERMINE** : Alternatives – individual courses of action that will allow to accomplish goal.

Meaning of Project Planning (Cont'd...)

6. **TEST** : For consistency with company's policy.
 7. **CHOOSE** : An alternative which is not only consistent with its goals and concept but also one that can be accomplished with the evaluated resources.
 8. **DECIDE** : on a plan
- Planning is important because it provides direction, unifying framework and performance standards.

FEATURES OF PROJECT PLANNING

1. *Process:* It is a systematic mental process of doing things and involves creative thinking and imagination.
2. *Future/goal oriented:* Planning is essentially thinking ahead and preparing for future. It provides direction to the organization.
3. *Intellectual Process:* Planning is a mental exercise involving creative thinking and imagination. A manager can prepare sound plans only when he has sound judgment, foresight and vision.

FEATURES OF PROJECT PLANNING

(Cont'd...)

4. ***Primary Function:*** Planning serves as basis for other functions of management. It precedes all other functions of management such as organizing, staffing, leading/directing and controlling.
5. ***Aims at efficiency:*** Sound planning leads to accomplishment of desired objectives at minimum possible cost. It helps in optimization of resources.
6. ***Continuous:*** Planning is an ongoing process. Plans are prepared for specific time period. At the end of each plan period new plans are period.

FUNCTIONS OF PROJECT PLANNING

- 1. Stating the objectives of the project to be undertaken.**
- 2. Definition of work requirement.**
- 3. Definition of resource needed such as funds, materials, machines, human resources, facilities etc.**
- 4. Determining the time frame of the overall project and also scheduling its various stages.**
- 5. To eliminate or minimize the risk and uncertainty.**
- 6. It provides a basis for organizing the work on the project and allocating responsibilities to individuals.**

IMPORTANCE OF PROJECT PLANNING

- 1. Making Objective clear.**
- 2. Helps in coordination.**
- 3. Economy and efficiency in operation of resources.**
- 4. Reduce risk and uncertainty.**
- 5. Provide the basis of control.**
- 6. Facilitates decision making.**
- 7. Helps the organization at right path.**

PROJECT SCHEDULING

- Projects are growing increasingly complex and costly; therefore attention must be paid to the control of both time and cost.
- Improved management and scheduling of projects are imperative to the success of any project, particularly large scales ones.
- Therefore it is necessary to schedule a project by using proper techniques.
- A schedule is defined as “**time phased**” plan for performing the work necessary to complete the project.



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PROJECT SCHEDULING (Cont'd..)

- A schedule is **graphical representation** which shows the **starting and completion dates** of each activity and the **sequential relationship** among the various activities.
- Project scheduling refers to the process of **laying out all the actual activities** of the project in the time order in which they are to be performed. [2]
- The schedule development process must often be inter-related along with cost estimating prior to determination of the project schedule. [4]

PROJECT SCHEDULING (Cont'd...)

Scheduling is done in the following steps [7]

1. **CALCULATE** : Detailed control information
2. **ASSIGN** : Timings to events and activities.
3. **GIVE**: Consideration to the resources. The manager is generally concerned with those resources whose availability is limited and may impose a constraint on the project.
4. **ALLOCATE**: The resources

Therefore scheduling also can be said as allocation of resources needed at each stages of production, along with the expected completion time of each activity.

WHY PROJECT SCHEDULE?

- To predict project completion time and activity completion time.
- To control financing and payment.
- To serve as a record.
- To support delay claim.
- To manage changes and uncertainties



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METHODS OF PROJECT SCHEDULING

1. Bar chart / Gantt chart

- Linked Bar Chart
- Milestone Chart

2. Network Analysis

- Critical Path Method (CPM)
- Program Evaluation Review Technique (PERT)
- Precedence Diagramming Method (PDM)

3. Line of Balance Technique.



BAR CHART/GANTT CHART

- The oldest formal planning tool is the bar chart.
- It is developed as a production control tool in 1917 by Henry L. Gantt, an American mechanical engineer, hence also called **Gantt chart** in his respect.
- It is a **graphical or pictorial representation** showing the various activities involved in a project.
- The job/ activities are **listed vertically as per their sequence** and each of them is **allotted a horizontal strip**, denoting the **estimated time to complete that particular activity** as per calendar days/months. [6]
- Used as scheduling tool for **small and medium size project**.

BAR CHART/GANTT CHART (Cont'd....)

Steps in Preparing Bar Chart

- Breakdown the whole project into various activities or into sub activities.
- Develop a logical sequence of the activities and also find out the activities that can be executed concurrently.
- Decide the time duration for each activity for its completion.
- Finally by using a number of bars, as required, the different activity to be performed are indicated on a chart.

BAR CHART/GANTT CHART (Cont'd....)

S.N.	Job/ Activity	Calendar month					
		Jan	Feb	Mar	Apr	May	June
1	Foundation work	■					
2	R.C.C. work		■	■			
3	Door and windows work			■			
4	Interior Finish				■	■	
5	Sanitary works			■			
6	Electrical works		■				
7	Exterior finish					■	

Fig: Bar Chart for a typical building project [6]

BAR CHART/GANTT CHART (Cont'd....)

Advantages

- The simple graphical form of bar chart results in relatively easy general comprehension. [8]
- It gives the pictorial representation of the status of a project at any point of time, which is easily understood by the laymen.
- The overall performance of the activity can be judged from chart without going through the status or detailed report. [6]
- It is useful for reporting who are not involved in day to day management.
- Bar chart is used as the preliminary planning tool.

BAR CHART/GANTT CHART (Cont'd....)

Limitation /Disadvantages

- If too many activities are shown separately in a bar chart, then it becomes messed up. Hence it is not suitable for large and complicated project.
- Lack of interrelationship and interdependencies among the activities.
- It cannot be used as control tool for large projects.
- Each activity receives the consideration with no indication where management attraction should be focused.
- Critical activities are difficult to be identified and floats are unknown.

LINKED BAR CHART

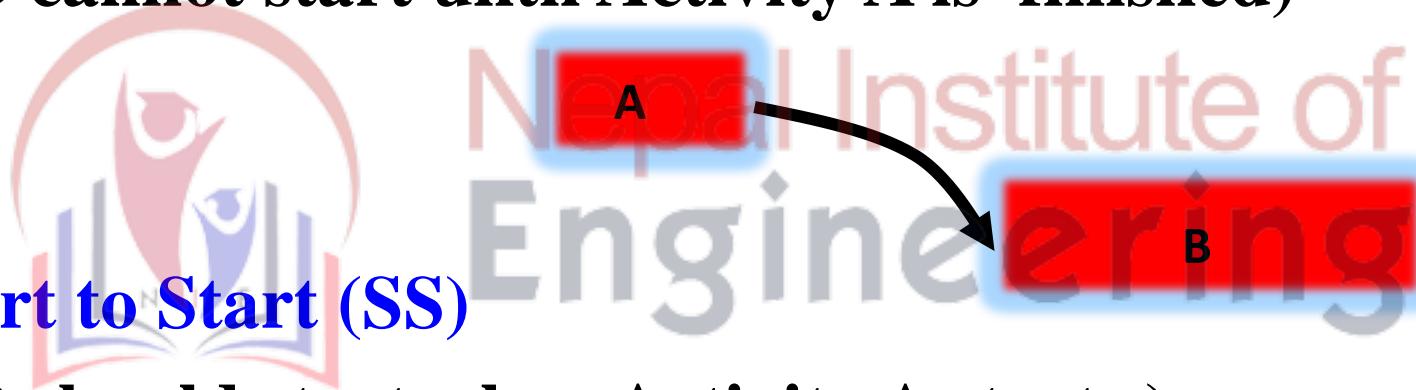
- One of the major limitation of bar chart is it does not show the inter relationship and inter dependencies among the activities.
- So a linked bar chart is introduced which is a modified form to overcome some of the limitation of bar chart.
- It shows the **link between an activity and the preceding activities** which have to be completed before this activity can start and the succeeding activities which are dependent on this activity.
- Linked bar chart uses the links (arrow) to show the relationship between activities.

LINKED BAR CHART (Cont'd...)

Four Types of Link:

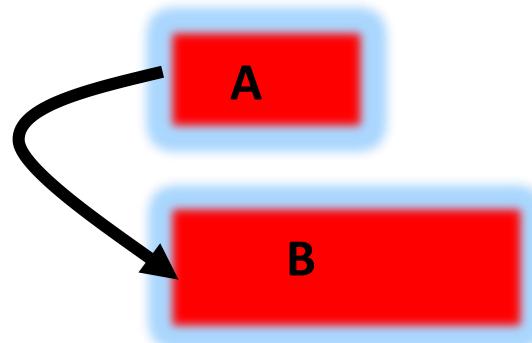
Type 1 Finish to Start (FS)

(Activity B cannot start until Activity A is finished)



Type 2 Start to Start (SS)

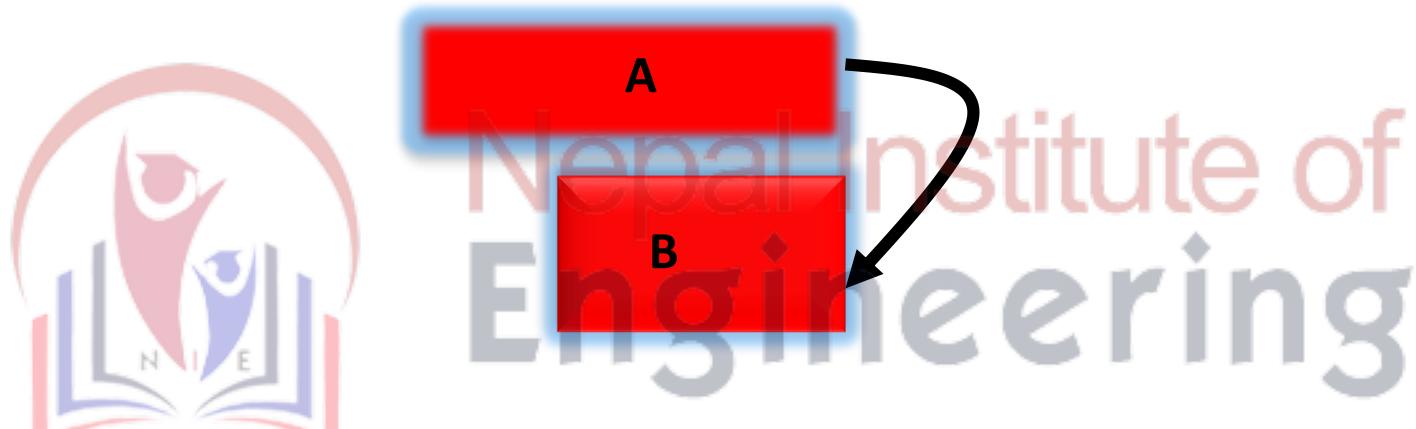
(Activity B should start when Activity A starts)



LINKED BAR CHART (Cont'd...)

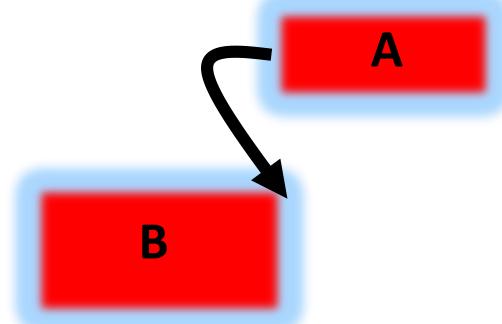
Type 3 Finish to Finish (FF)

(Activity B should be finished when Activity A finishes)



Type 4 Start to Finish (SF)

(Activity B should be finished when Activity A starts)



MILESTONE CHART

- It is a modification over the original bar chart.
- When a particular activity represented by a bar on a bar chart is very long, the details lack.
- A Chart that graphically depicts key events along a timescale, usually with triangles representing each event, is called milestone chart.
- Milestones provide a sense of accomplishment and show project team how the work they're doing contributes to the overarching project objective.
- It only identify the scheduled start or completion of major deliverables and key external interfaces. [4]

MILESTONE CHART (Cont'd...)

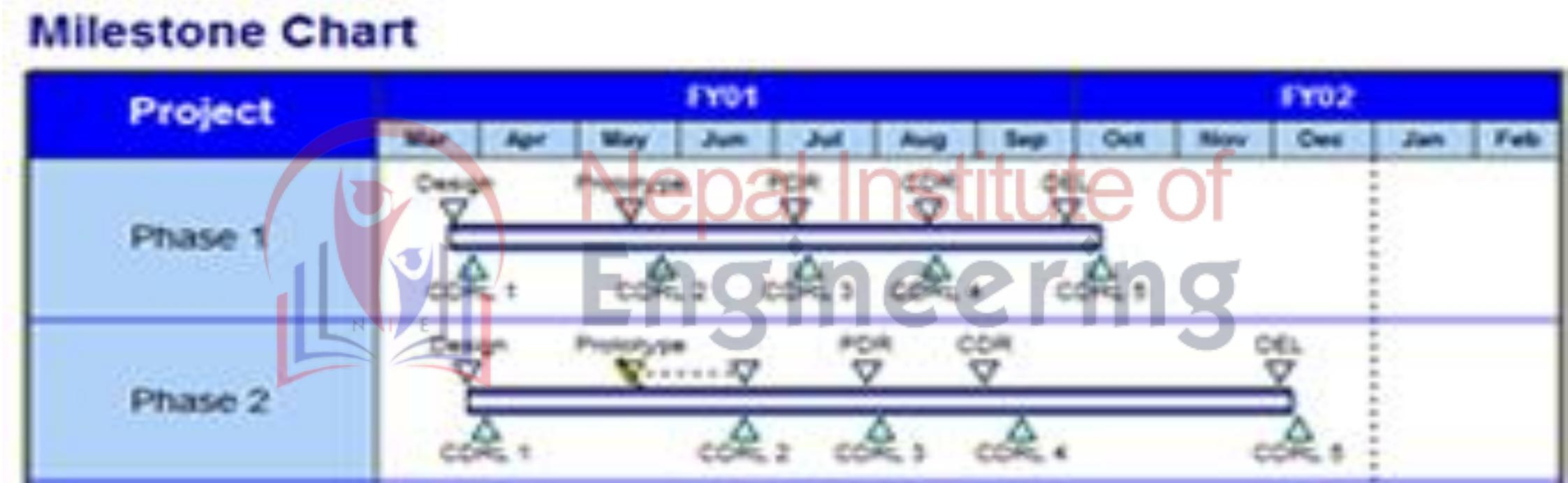


Fig Source: [9]

NETWORK ANALYSIS (Cont'd..)

- For proper planning, scheduling and control of the activities of a project, given their inter-relationships and constraints on the availability of resources, network analysis have been found quiet useful. [3]
- A network is the combination of different activities of the project. These activities are so connected that it defines the whole project. [4]
- Most commonly used network analysis techniques are: Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT).

NETWORK ANALYSIS (Cont'd..)

Steps for Network analysis;

- Whole Project is divided or broken down into a series of activities or work packages.
- Activities are linked together according to their technological sequence of operation or logical relationship (preceding, succeeding and concurrent)
- The time of completion or duration of each activity is estimated
- The network diagram is drawn and from diagram the completion time of whole project is determined.

CRITICAL PATH METHOD (CPM)

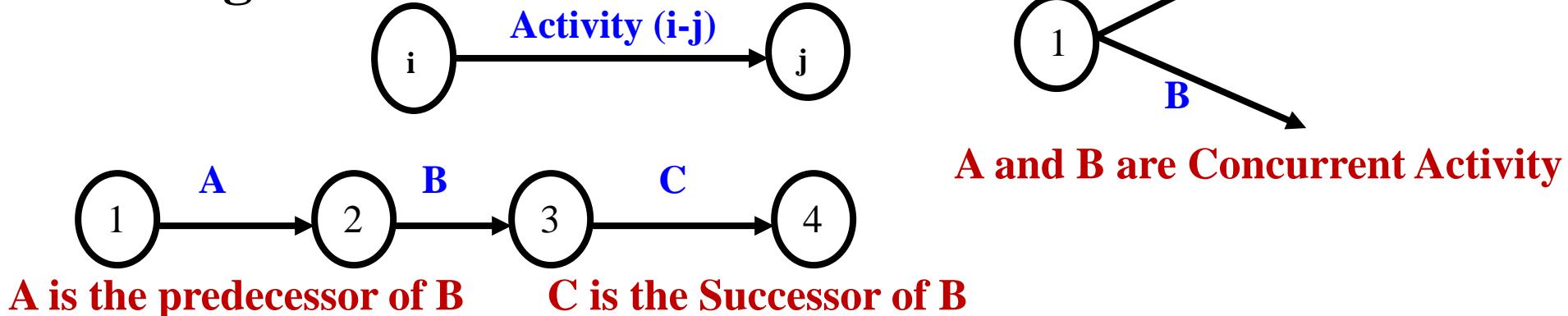
- The technique of network based scheduling by critical path method(CPM) is used for planning and scheduling projects involving sequential operation. [5]
- It is a deterministic approach and an **activity oriented network diagram** showing the interdependencies and relationship between the various activities.
- CPM developed in the year 1957 by Morgan R. Walker of DU Pont and James E. Kelly of Remington Rand for preparing shutdown schedule of a chemical plant.

CRITICAL PATH METHOD (CPM)

TERMINOLOGIES (Cont'd...)

1. Activity(s):

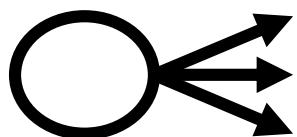
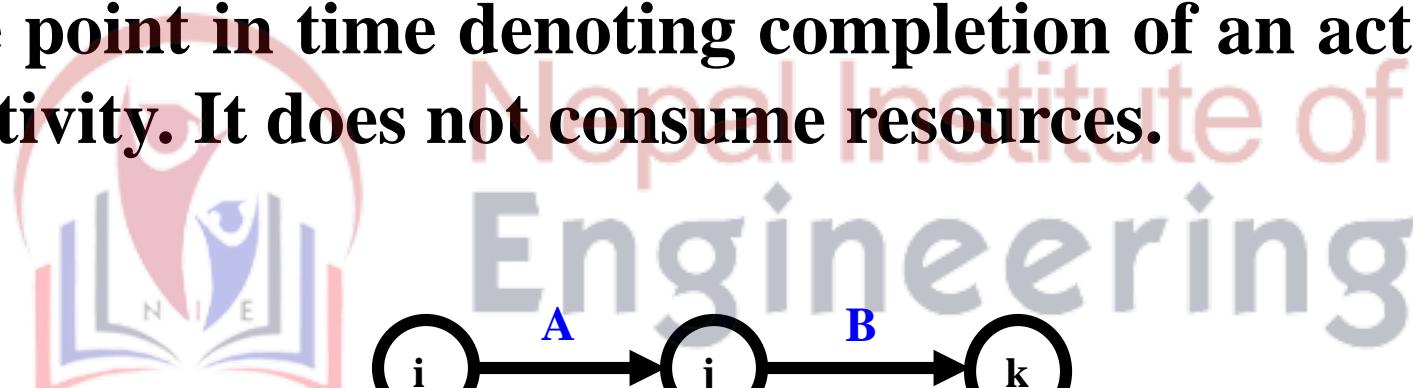
- An activity is a task or closely related group of tasks whose performance contributes to the completion of the overall project.
[6]
- Arrow in a network diagram represents activity and consume resources like manpower, material, money, time etc.
- Examples: Excavation of foundation, construction of wall, electrical wiring etc.



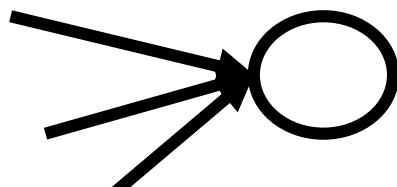
CRITICAL PATH METHOD (CPM) TERMINOLOGIES (Cont'd...)

2. Event/Node:

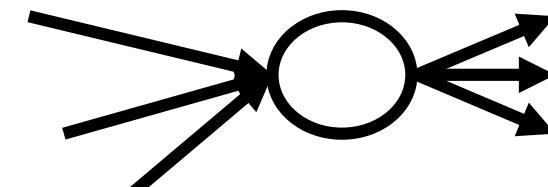
- It is the point in time denoting completion of an activity and start of an activity. It does not consume resources.



Tail/ Burst event



Head/ Merge event



Dual role event

CRITICAL PATH METHOD (CPM)

TERMINOLOGIES (Cont'd...)

3. Duration (t)

- Estimated time to perform a definite activity/task.
- It is mentioned alongside with activity name.
- The time unit for the project can be minutes, hours, work days, calendar days, weeks or months.

Activity Duration = Work Quantity/ Production rate

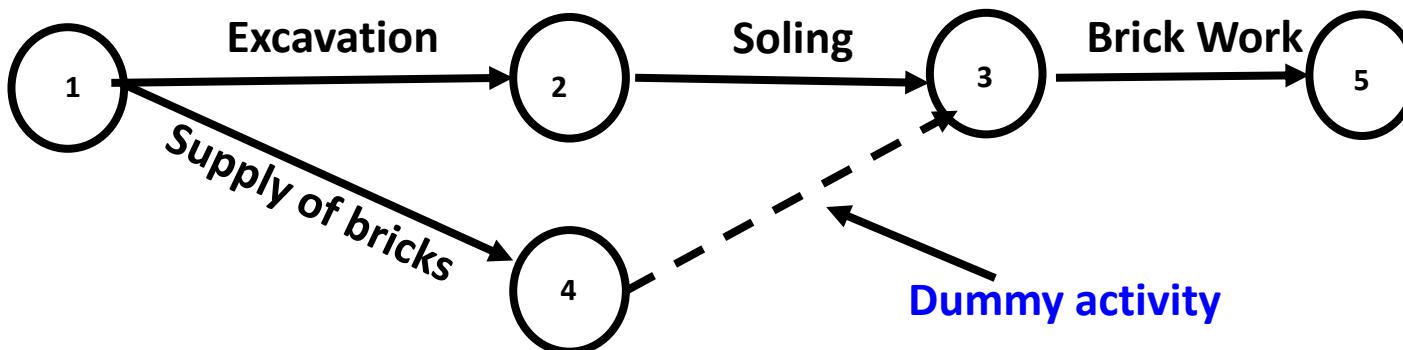


CRITICAL PATH METHOD (CPM)

TERMINOLOGIES (Cont'd...)

4. Dummy Activity

- A dummy activity is an **imaginary (hypothetical) activity** included in a network.
- Since it is not a real activity, it does not consume time, manpower, material and other resources.
- It is included in a network to **maintain the relationship** between activities appropriately. It is represented by dotted arrow.

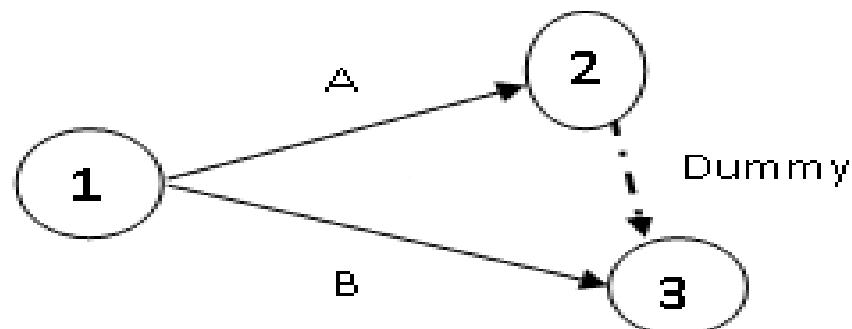


CRITICAL PATH METHOD (CPM)

TERMINOLOGIES (Cont'd...)

Grammatical purpose:

- It is used to prevent two arrows having common beginning and end nodes for two or more activities.
- For example, consider the arrows of activities A and B; both starts from node 1 and end at node 2.
- Due to this an inconvenience results when the network is used for computation, i.e., uniqueness in the identification is lost. This inconvenience frequently leads to mistake. [7]

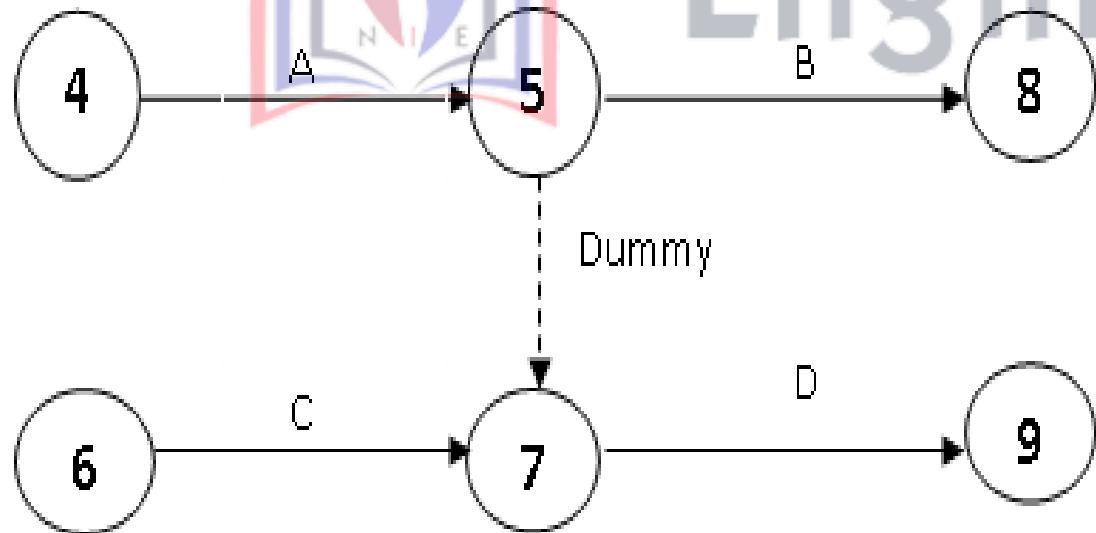


CRITICAL PATH METHOD (CPM)

TERMINOLOGIES (Cont'd...)

Logical purpose

- Dummies are also used to give logical clear representation in a network having an activity common to two sets of operations running parallel to each other.



Here, Activity D cannot be started until Activity A is completed. The inter dependency or logical relation between two activities are clearly known.

CRITICAL PATH METHOD (CPM)

TERMINOLOGIES (Cont'd...)

Graphical Representation of activities and events

1. Activity on Arrow (AOA) system

- In this system, an activity is represented by an arrow with circles at both ends drawn from left hand side to the right hand side.
- The tail end of the arrow represents the start of an activity and head of arrow represents completion of activity.

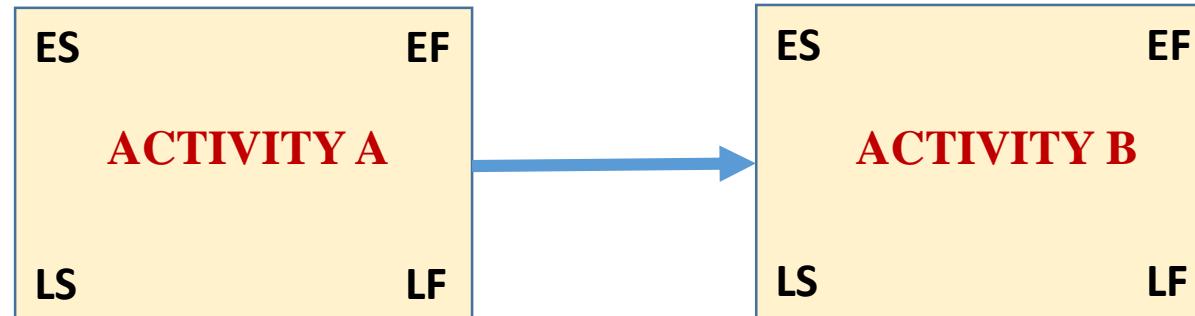


CRITICAL PATH METHOD (CPM)

TERMINOLOGIES (Cont'd...)

2. Activity on Node (AON) system

- In this system, activities are represented by nodes or circles.
- Arrow only shows the dependence of activities on each other.
- No dummy activity is required to represent the inter dependency between succeeding and preceding activity.
- It is also called precedence diagramming method (PDM)



CRITICAL PATH METHOD (CPM)

TERMINOLOGIES (Cont'd...)

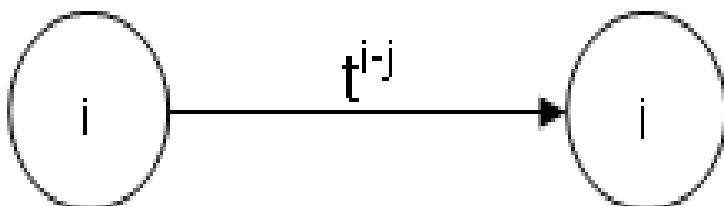
5. Earliest start time (EST)

➤ It is the earliest possible time that the activity can start.

6. Earliest finish time (EFT)

➤ It is the earliest possible time for completion of an activity or operation without delaying the project completion time.

➤ It can be computed by adding activity duration by EST.



$$\text{EFT (i-j)} = \text{EST (i-j)} + t^{i-j}$$

CRITICAL PATH METHOD (CPM)

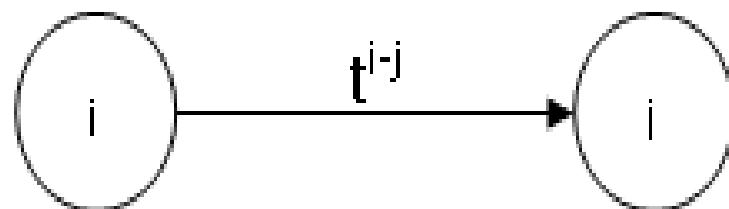
TERMINOLOGIES (Cont'd...)

7. Latest finish time (LFT)

➤ It is the latest possible time that an activity can be finished based on the logic and duration identified on the network without extending the project duration. [8]

8. Latest start time (LST)

➤ It is the latest possible time; an activity can be started without delaying the project.



$$\text{LST (i-j)} = \text{LFT (i-j)} - t^{i-j}$$

CRITICAL PATH METHOD (CPM)

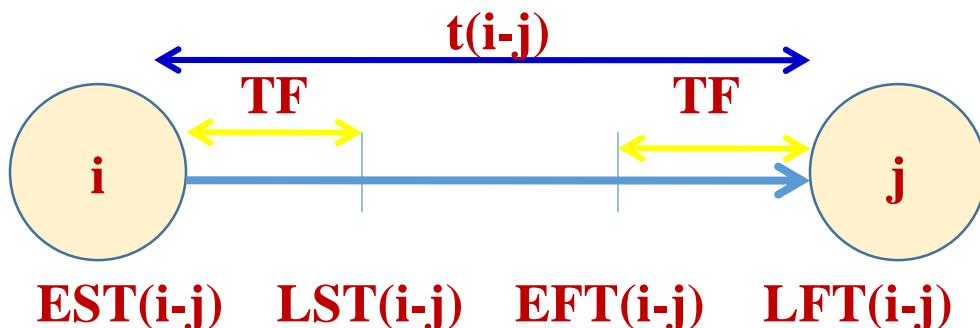
TERMINOLOGIES (Cont'd...)

9. Float / Slack

➤ The free time available to the activity is called float or slack.

(a) Total float (TF)

- It is the extra time available when the start or finish of an activity can be delayed, without delaying the completion of the project. [5]



$$EFT(i-j) = EST(i-j) + t(i-j)$$

$$LFT(i-j) = LST(i-j) + t(i-j)$$

$$LFT(i-j) - EFT(i-j) = LST(i-j) - EST(i-j)$$

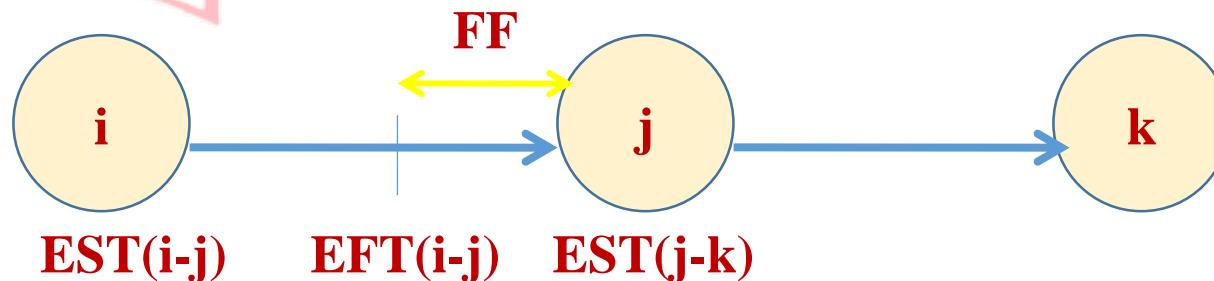
$$TF = LFT(i-j) - EFT(i-j) \text{ OR } LST(i-j) - EST(i-j)$$

CRITICAL PATH METHOD (CPM)

TERMINOLOGIES (Cont'd...)

(b) Free float (FF)

- It is the delay that can be permitted in an activity so that succeeding activities in the path are not affected. [2]
- In other words, It is the extra time available when the activity is delayed without delaying the early start time of succeeding activity.



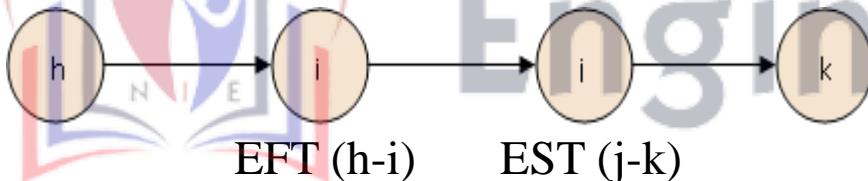
$$FF = EST(j-k) - EFT(i-j)$$

CRITICAL PATH METHOD (CPM)

TERMINOLOGIES (Cont'd...)

(c) Independent float (IF_1)

- It is the spare time available for the activity, if preceding activity is started as late as possible and succeeding activities are finished as early as possible.



$$IF_1 = EST(j-k) - EFT(h-i) - t_{i-j}$$

Also $IF = FF(i-j) - \text{Tail event slack}$

(d) Interfering Float (IF_2)

- It is the name given to head event slack. It is the difference between total float and free float.

$$IF_2 = TF(i-j) - FF(i-j)$$

CRITICAL PATH METHOD (CPM)

TERMINOLOGIES (Cont'd...)

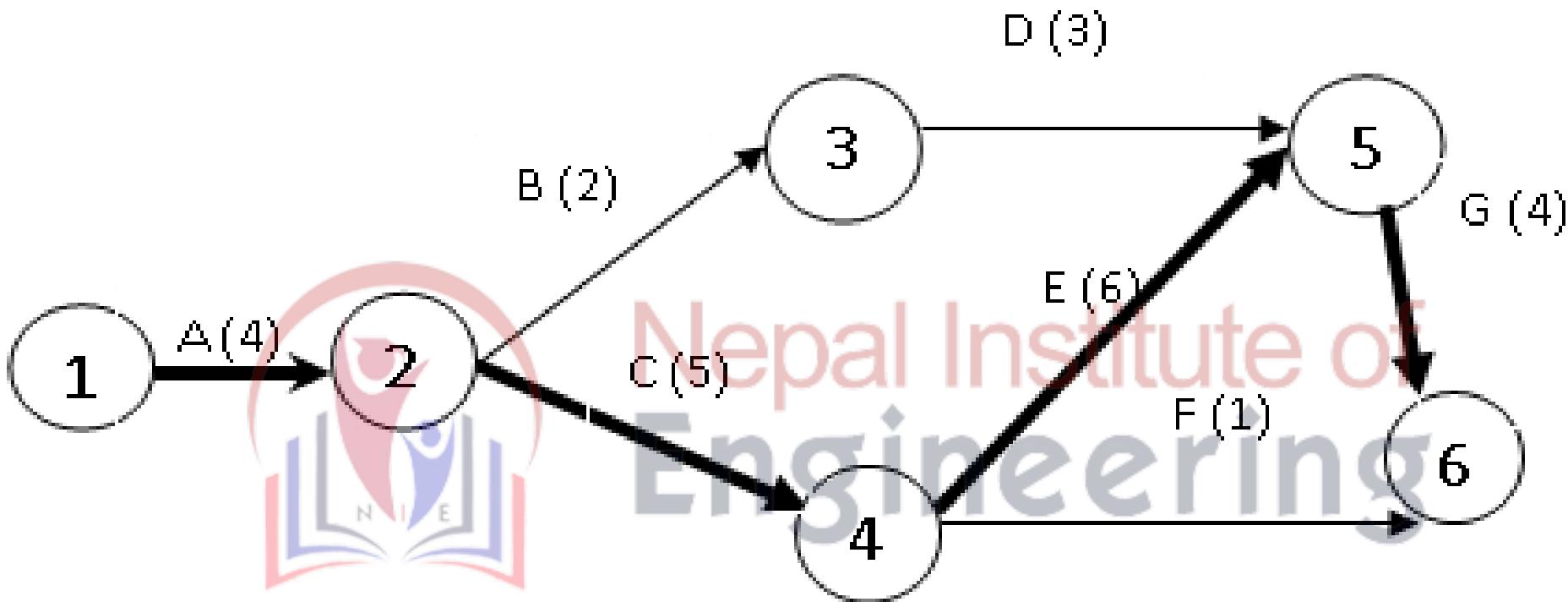
10. Critical Path

- In a network diagram, the activities are represented by arrows and arrows flow from left to right.
- In a network, there may be many paths starting from the initial event and leading to the last event.
- If the duration of all the activities that lie on particular paths is added, it gives the duration of the path.
- Each path in a network will have a different duration.

Critical Path (Cont'd....)

- The path that has the **longest duration** is called the critical path and the activities lying on the critical path are **critical activities**.
- In a network diagram, the path along which the project takes the **maximum time from start to finish** is called critical path.
- It is the longest path of the network and gives the total time taken to complete the project. Any delay along this path **delays the project**.

Critical Path (Cont'd....)



Path	Description	Duration	Remarks
1	1 - 2 - 3 - 5 - 6	$4+2+3+4 = 13 \text{ days}$	
2	1 - 2 - 4 - 5 - 6	$4+5+6+4 = 19 \text{ days}$	Longest/Critical path
3	1 - 2 - 4 - 6	$4+5+1 = 10 \text{ days}$	

CHARACTERISTICS OF CRITICAL PATH

[2]

- Critical path is the **longest path (time wise)** connecting the initial and final events.
- Critical activity may **run through dummy activity/activities** also.
- The number of activities lying on critical path may be less than the number of activities in other non critical activities.
- It is possible that a network may have **more than one critical path** i.e. if two or more paths have the same time duration which is maximum, then all such paths will be critical paths.

CHARACTERISTICS OF CRITICAL PATH

(Cont'd....)

Super critical activity

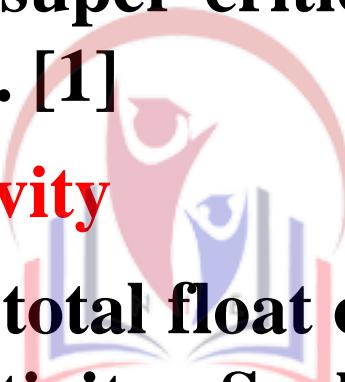
- When the total float of the activity is negative, then this activity is called the super critical activity and demand very special attention and action. [1]

Critical activity

- When the total float of the activity is zero, then this activity is called critical activity. Such activity permit no freedom of action and demand normal action.

Sub critical activity

- When the total float is positive, then the activity is known as sub critical activity and permit freedom and demand normal attention.



CALCULATION PROCEDURE OF CPM

Forward pass calculation

- In the forward pass calculation, all activities in the network are assumed to start as early as possible.
- The calculation begins from the left to the right side of the network.
- When two or more activities merge into a event, the largest value is taken as an earliest occurrence time of that event.
- Forward pass calculation gives the EST and EFT of each activity.

CALCULATION PROCEDURE OF CPM

(Cont'd....)

Backward pass calculation

- In the backward pass calculation, all activities in the network are assumed to start as late as possible.
- The calculation begins from the right to the left side of the network.
- When two or more activity merges at a node, the smallest value is taken as a latest occurrence time of that event.
- Backward pass calculation gives the LST and LFT of each activity.

ADVANTAGES AND DISADVANTAGES OF CPM

Advantages

- 1. Makes dependencies visible between the project activities.**
- 2. Organizes large and complex projects, hence allowing a more systematic approach to project planning and scheduling.**
- 3. Enables the calculation of float or slack of each activity.**
- 4. Enables the Project Manager to optimize efficiency**
- 5. Provides opportunities to respond to the negative risk going over schedule.**
- 6. Encourages the Project Manager to reduce the project duration by optimizing the critical path**

ADVANTAGES AND DISADVANTAGES OF CPM (Cont'd..)

Disadvantages

- CPM is not suitable for the project involving some uncertainties like research and development project.
- Reduced Attention to High-Float Tasks: When using the critical path method, project managers focus on critical path tasks. For large and complex projects, there'll be thousands of activities and dependency relationships. [9]
- For large projects with thousands of activities, it may be difficult to print the project network diagram.
- The Critical Path Method does not account for resource and resource allocation.

PROGRAM EVALUATION AND REVIEW TECHNIQUE (PERT) (Cont'd..)

- It is a **probabilistic approach** for estimating the duration of an activity and **event oriented network diagram**.
- PERT is used in the **completely newly developed** project such as Research and design, space and aerospace industry where there may not be record of past experiences in the particular field.
- PERT system is preferred for those projects in which correct time determination for various activities cannot be made.
- PERT is a technique that statistically presents knowledge about the activities and the uncertainty related with activities. [4]

PROGRAM EVALUATION AND REVIEW TECHNIQUE (PERT) (Cont'd..)

- In research and development project, where there is some extent of uncertainty, the exact estimation of time of completion of various activity is difficult.
- Therefore, PERT uses **three time estimates** for each activity with a view to overcome uncertainty in time estimates.
 - (a) The most optimistic time (t_o)
 - (b) The most pessimistic time (t_p)
 - (c) The most likely time (t_m)

PROGRAM EVALUATION AND REVIEW TECHNIQUE (PERT) (Cont'd..)

(a) The most optimistic time (t_o)

- It is the **shortest possible time** in which an activity can be completed under ideal conditions. [5]
- This time assumes that everything **will go according to plan** and with a minimal amount of difficulties. [3]

(b) The most pessimistic time (t_p)

- It is the **maximum possible time** it would take to complete an activity under worst conditions.
- In arriving at the pessimistic time, it is assumed that **everything is unfavorable** for completing the activity in time and every possible delay and difficult situation is encountered. E.g. Force Majeure

PROGRAM EVALUATION AND REVIEW TECHNIQUE (PERT) (Cont'd..)

(c) The most likely time (t_m)

- It is also called the most reliable time or the most probable time.
- The most optimistic and pessimistic times are two ends of a spectrum denoting the range of variation in the activity duration.
[1]
- Somewhere in between the optimistic and pessimistic time, there lies the most probable time.
- It is the time in which an activity can be completed under normal conditions which is neither favorable nor non favorable.

PROGRAM EVALUATION AND REVIEW TECHNIQUE (PERT) (Cont'd..)

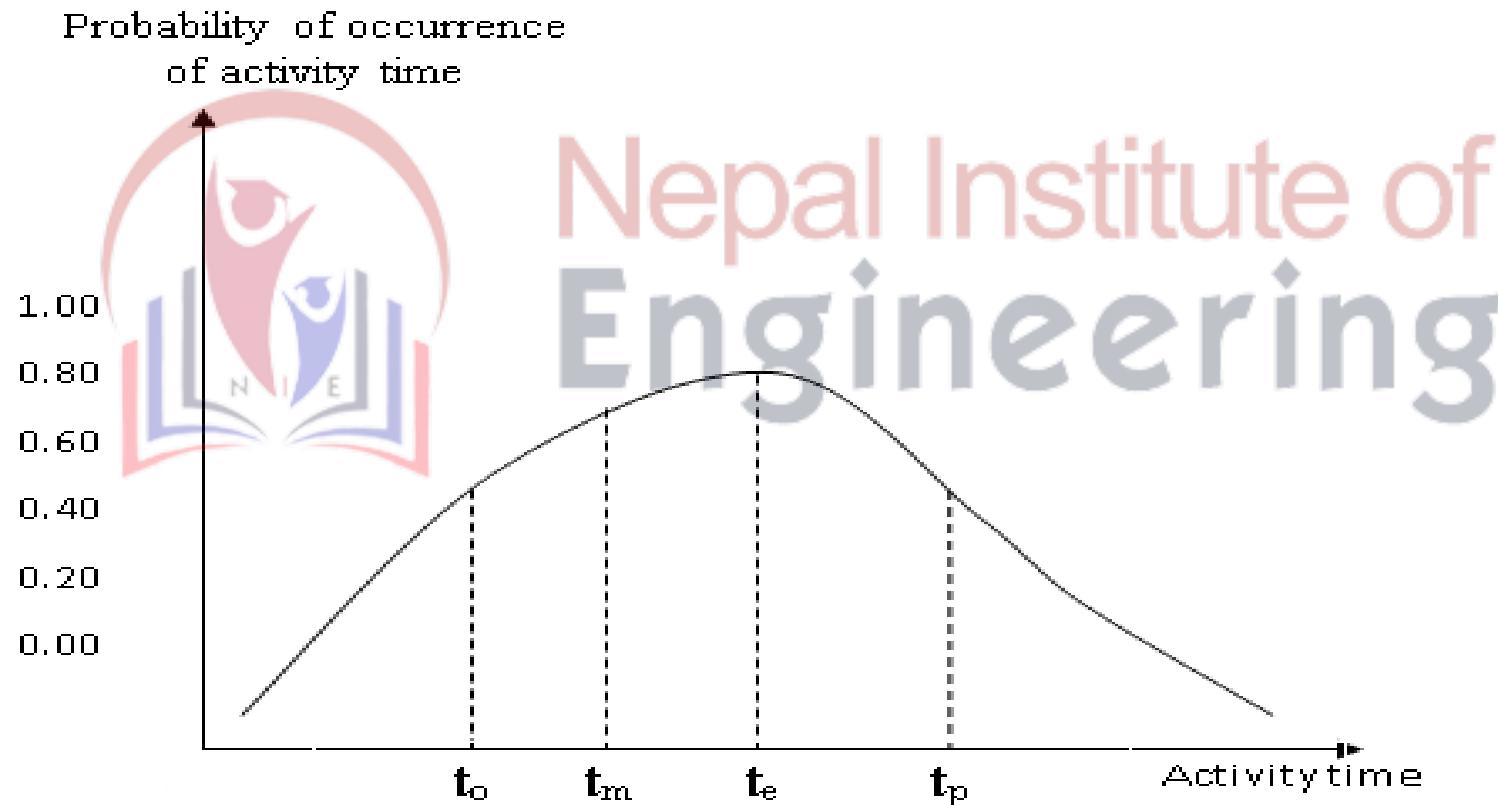


Fig Source: [2]

PROGRAM EVALUATION AND REVIEW TECHNIQUE (PERT) (Cont'd..)

- The formula, $t_e = \frac{t_o + 4t_m + t_p}{6}$ is a linear approximation of Beta distribution whose accuracy is considered reasonably sufficient. [2]
- After having arrived at the expected time (t_e) for each activity, the critical path is found out by making forward pass computation and backward pass computation as in CPM.
- The variability of each activity's time duration is then measured by calculating the standard deviation (σ) and variance (σ^2) of each activity:

$$\text{Variance } (\sigma^2) = \left[\frac{t_p - t_0}{6} \right]^2$$

$$\text{Standard deviation } (\sigma) = \left[\frac{t_p - t_0}{6} \right]$$

DIFFERENCE BETWEEN CPM AND PERT

<u>CPM</u>		<u>PERT</u>	
1. Activity oriented network diagram	2. Useful of cost evaluation	1. Event oriented network diagram	2. Useful for time evaluation
3. Uses Only a single time estimates for activities.	4. Includes relationship between activities time and cost.	3. Uses 3-time estimates for activities.	4. PERT analysis doesn't include costs.
5. Doesn't uses statistical tools	6. Used for repetitive work such as construction, repair, maintenance etc.	5. It uses statistical tools.	6. Used for completely new project involved with factor of uncertainty such as R&D project.

PROJECT SCHEDULING WITH LIMITED RESOURCES

- A resource is a physical variable, such as men, materials, machines, space and money that is required for completing various activities of a project.
- The network analysis (CPM and PERT) is valid only if the availability of resources is liberal or unlimited.
- In a real life project, it is a very common experience that the resources are frequently in a limited supply causing delay in completion of project. [1]

PROJECT SCHEDULING WITH LIMITED RESOURCES (Cont'd...)

- In some cases, particular material or some machinery may not be available in the middle of the project due to some reasons beyond the control of project manager.
- Availability of skilled and unskilled labor and the equipment may be restricted as well as availability of fund may be restricted.
- Usually activities of project are scheduled in such a way that the demand of various resources is more or less uniform all along the project duration. [4]
- This is not always the case and the project has to be rescheduled considering the constraints of resources which is project scheduling with limited resources.

PROJECT SCHEDULING WITH LIMITED RESOURCES (Cont'd...)

Following constraints are imposed due to the limited resources:

- Starting of an activity is delayed.
- Non critical job may be critical due to delay in starting.
- More than one type of resource may be scarce at a time.
- Resource may be scarce in the middle of performance of a particular job etc.

These above mentioned constraints can be overcome by the proper allocation of the resources.

RESOURCE ALLOCATION

- Resource allocation in project management involves identifying and assigning the best available best-fit resources to every project for a specific period of time.[6]
- It also monitors the resource's workload throughout the project life cycle and reassigned them if necessary.
- Resource aggregation, or resource loading, is simply the summation, on a period-by-period basis, of the resources required to complete all activities based on the resource allocation carried out in the previous stage.

RESOURCE ALLOCATION (Cont'd...)

- The requirements of various resources for a given network of the project are determined using the early start and late start schedule of each activity.
- The resource usage profile are usually shown graphically as a histogram.
- Such aggregation may be done on an hourly, daily, or weekly basis, depending on the time unit used to allocate resources.
- Two methods are commonly used for the resource allocation:
 - (a) Resource Levelling**
 - (b) Resource Smoothing**

RESOURCE ALLOCATION (Cont'd...)

(a) Resource Levelling

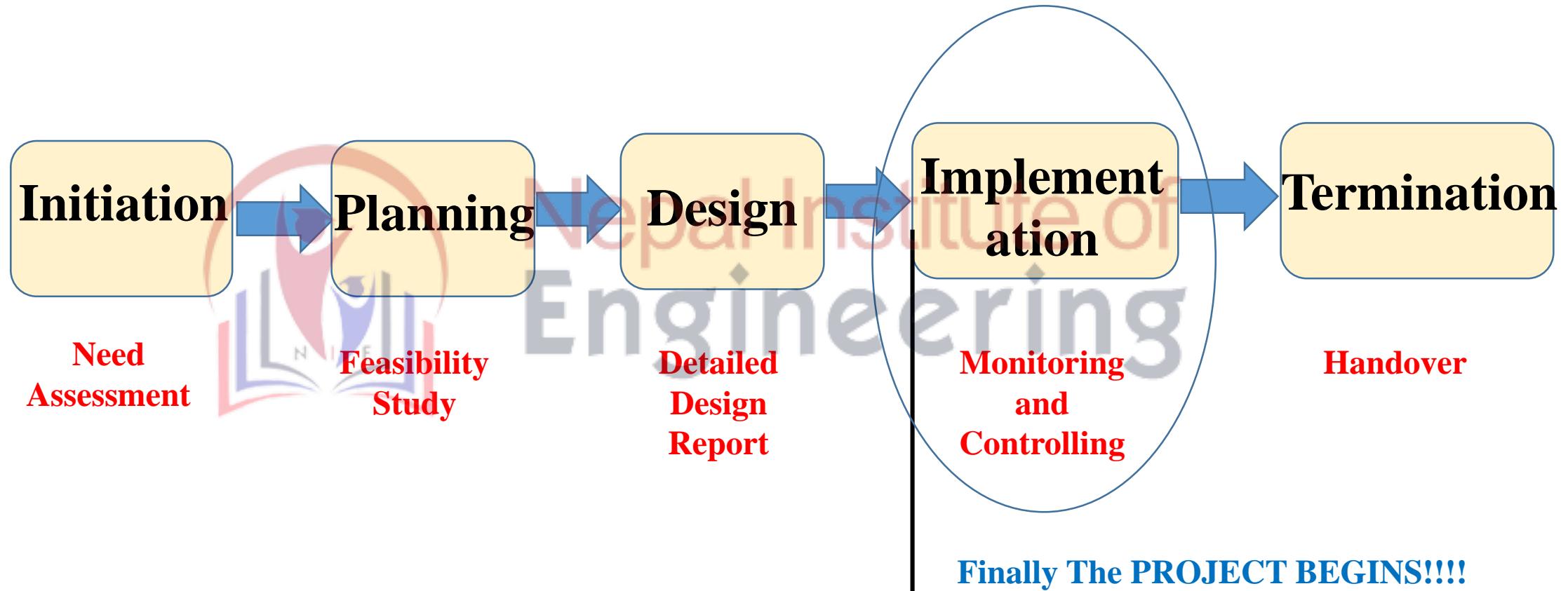
- It is an attempt to reduce peak resources requirement and smooth out period to period assignments within the constraints of project duration.
- A project manager often comes across mismatch between the availability of resources and the requirement of resources. This means that there are surplus resources available on someday and there is deficit of resource on some other days.
[2]
- Resource leveling is the process that ensures resource demand does not exceed resource availability.

RESOURCE ALLOCATION (Cont'd...)

(b) Resource Smoothing

- There is no constraint on project completion time. There is only constraint of resource availability.
- However it doesn't mean that the project duration can be stretched too far. Increase in project duration will lead to indirect expenses (overheads).
- Hence the project duration can be extended to satisfy resource constraint.
- It shall be done in such a way that the project duration is extended to the minimum possible extent and at the same time satisfying the resource constraints. [2]

Recalling the Project Life Cycle



PROJECT MONITORING AND CONROLLING

(Cont'd....)

Monitoring

- Monitoring simply means to **maintain a constant check** on the progress of the project activities systematically.
- It involves **gathering information** on the **progress of the project** to review and analyse the project implementation.
- Monitoring means to make sure sufficient intelligence is gained on the status of the project so that an accurate and timely evaluation can be conducted. [2]
- It aims to ensure that project inputs, schedules, outputs and other actions are proceeding according to the plan.

PROJECT MONITORING AND CONTROLLING (Cont'd....)

Evaluation

- Evaluation simply means to **appraise or set value**. It is the appraisal of how the project work is going on.
- Evaluation is an objective and systematic judgmental process for determining relevance, efficiency effectiveness and impact of project performance. [3]
- It is done to **improve project implementation** and to improve future project planning and decision making.
- Monitoring is usually an ongoing activity throughout the life of the project whereas **evaluation is periodic**.

PROJECT MONITORING AND CONTROLLING

(Cont'd....)

Types of Evaluation

- a) **On-going:** It is conducted during the implementation phase and its purpose is to correct deficiencies as they occur to improve project performance.
- b) **Mid-term:** It is carried out mid way during implementation and its purpose is to improve implementation.
- c) **Terminal:** It is conducted after project completion and it provides lessons for future project planning.
- d) **Ex post:** It is conducted some years after project completion to evaluate the impact of the project.

PROJECT MONITORING AND CONTROLLING

(Cont'd....)

Controlling

- Controlling is the management function of comparing the actual achievements with the planned ones at every stage and taking necessary action, if required, to ensure the attainment of the planned goals.
- Controlling ensures that right things are done in right manner at right time. [4]
- The main purpose of controlling is to regulate results by changing activities and to conserve the project's resources. [5]

PROJECT MONITORING AND CONTROLLING (Cont'd....)

- Controlling includes three step processes – measuring, evaluating and correcting. [6]



Fig: Project Controlling

Measuring: Determining through formal and informal reports the degree to which the progress towards objective is being made

Evaluating: Determining cause of and possible ways to act upon significant deviations from planned performances

Correcting: Taking control action to correct an unfavorable trends or to take advantage of an unusually favorable trend

PROJECT MONITORING AND CONTROLLING

(Cont'd....)

Areas of control

While managing a project three important resource parameters - quality (performances), cost, and progress (time) - need control. So the areas of control are:

- **Progress (time) control (according to schedule)**
- **Cost control, (according to allocated budget) and**
- **Quality (performance) control (according to specification)**

Management must control these three resource parameters – progress (time) cost, and quality (performances),) – in an integrated manner, not in isolation.

Earned Value Analysis

- Earned Value Analysis (EVA) is a method that allows the project manager to measure the amount of work actually performed on a project beyond the basic review of cost and schedule reports.
[4]
- “EVA is a standard method of measuring a project’s progress (performance) at any given point in time, forecasting its completion date and final cost and analyzing variances in the schedule and budget as the project proceeds”.
- It compares the planned amount of work with what has actually been completed, to determine if the cost, schedule and work accomplished are progressing in accordance with the plan.

Earned Value Analysis (Cont'd....)

EVA compares three pieces of Information

1. Budgeted Cost of Work Scheduled (BCWS) / Planned Value

➤ It is the budgeted amount of cost of the work *scheduled* to be accomplished in a given time period (including support and allocated overhead)

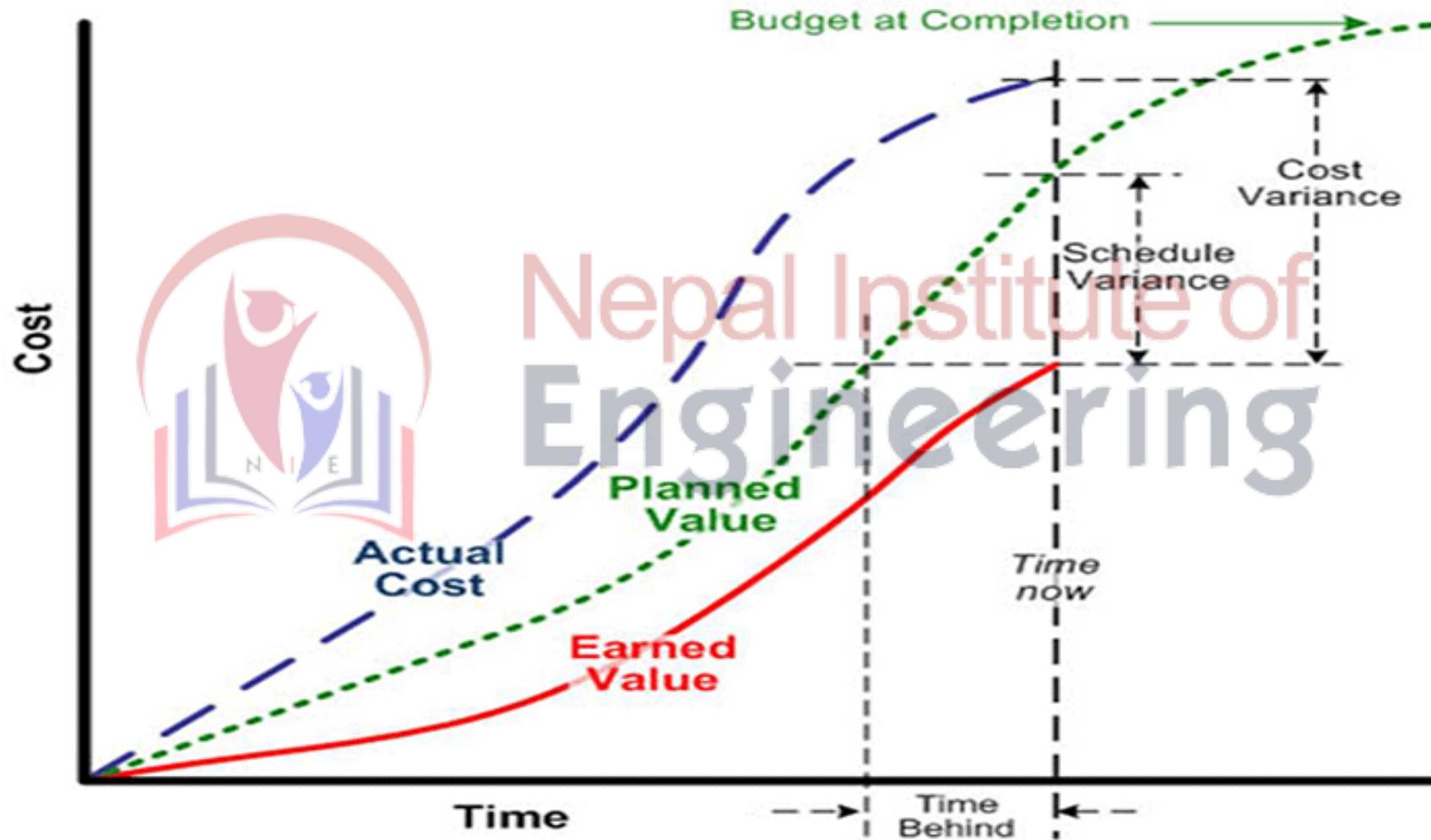
2. Actual cost of work performed (ACWP) /Actual Value

➤ It is the amount actually expended in completing the particular work accomplished within a given time period.

3. Budgeted cost of work performed (BCWP)/Earned value

➤ The value, in terms of your baseline budget, of the work accomplished by now (in dollars or hours), called the Earned Value.

Earned Value Analysis (Cont'd....)



Source: [5]

Earned Value Analysis (Cont'd....)

Some Derived Metrics in EVA (parameters in EVA)

1. Variances	Formula	Interpretation
Cost Variance	$CV = BCWP - ACWP$ 	<ul style="list-style-type: none">If CV is +ve, cost under run (actual budget expense is less than planned)If CV is -ve, cost overrun (actual budget expense is greater than planned)If CV is 0 No cost variance (actual expense is equal to planned)
Schedule Variance	$SV = BCWP - BCWS$	<ul style="list-style-type: none">If SV is +ve, Schedule under run (actual schedule is ahead of planned)If SV is -ve, Schedule overrun (actual schedule is behind of planned)If SV is 0 No Schedule variance (actual Schedule is equal to planned)

Earned Value Analysis (Cont'd....)

2. Variances expressed in percentage

CV %	$\frac{BCWP - ACWP}{BCWP} * 100 \%$	Over budget or under budget expresses in % , by what % does the cost under run or over run
SV %	$\frac{BCWP - BCWS}{BCWS} * 100 \%$	Behind or Ahead Schedule expressed in % , by what % does the Schedule under run or over run

3. Indices

Cost performance index	$CPI = \frac{BCWP}{ACWP}$	<ul style="list-style-type: none">• If $CPI \geq 1$, Better Performance for Cost, less budget• If $CPI < 1$, Poor Performance for Cost, more budget
Schedule Performance Index	$SPI = \frac{BCWP}{BCWS}$	<ul style="list-style-type: none">• If $SPI \geq 1$, Better Performance in Schedule, ahead of schedule• If $SPI < 1$, Poor Performance in Schedule, behind of schedule

Earned Value Analysis (Cont'd....)

4. Trends & Fore Cast		
Estimate at Completion	$EAC = \text{Total project Cost} / CPI$	
Schedule at Completion	$SAC = \text{Original project duration} / SPI$	

OBJECTIVE QUESTIONS

- 1. Which from the following represents the correct project cycle?**
 - (a) Planning→Initiating→Executing→Closing
 - (b) Planning→Executing→Initiating→Closing
 - (c) Initiating→Planning→Executing→Closing
 - (d) Initiating→Executing→Planning→Closing
- 2. Five dimensions that must be managed on a project**
 - a) Constraint, Quality, Cost, Schedule, Staff
 - b) Features, Quality, Cost, Schedule, Staff
 - c) Features, priority, Cost, Schedule, Staff
 - d) Features, Quality, Cost, Schedule, customer

3. Which one of the following is not the characteristics of a project?

- (a) unique (b) repetitive
- (c) specific task not routinely performed (d) Temporary.

4. Which of the following activity is not carried out in the initiation phase of the project?

- (a) Conceptual study (b) feasibility study (c) market study (d) contract study.

5. Select the correct statement

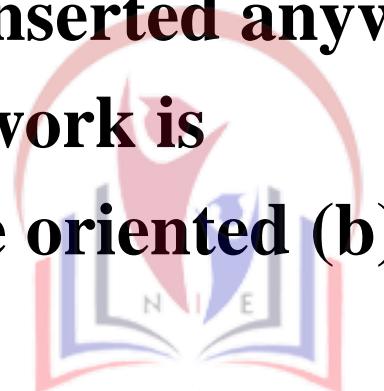
- (a) PERT is applicable to construction projects only
- (b) PERT is useful for deterministic activities
- (c) PERT is applicable to large projects only
- (d) PERT is useful for R/D projects.

6. A dummy activity

- (a) Has neither head even or tail event**
- (b) Doesn't consume neither time nor resources**
- (c) Reduces computation work in network analysis**
- (d) Can be inserted anywhere in a network.**

7. CPM network is

- (a) Resource oriented**
- (b) Event oriented**
- (c) Slack oriented**
- (d) Activity oriented**



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8. In PERT analysis the probability of completion by a due date follows

- (a) Binomial distribution**
- (b) Beta distribution**
- (c) Normal distribution**
- (d) Poissons distribution**

9. Standard deviation is equal to

- (a) $(\text{Variance})^{1/2}$**
- (b) $(\text{Variance})^2$**
- (c) $(\text{Variance})^6$**
- (d) $(\text{Variance})^{1/6}$**

10. The time by which the start or finish of an activity can be delayed without delaying the EST of the succeeding activity is called

- (a) Total Float (b) Free Float (c) Independent Float (d) Interfering Float**

11. When two or more activities merge into a node than the smallest value should be taken as the latest occurrence time of that particular node in

- a) Forward pass calculation
b) Backward pass calculation
c) Middle pass calculation
d) Both (a) and (b)**

12. If the duration and the earliest finish time of preceding activity is 2 days and 5 days respectively and the earliest start time of the succeeding activity is 7 days then the free float of preceding activity is

- (a) -2 (b) 2 (c) -3 (d) 3

13. If the planned value, actual value and the earned value of an activity is Rs 7,000, Rs. 8000 and Rs. 6000 respectively, then the cost variance will be

- a) - 2000 b) 2000 c) -1000 d) 1000

14. If the optimistic time is 2 days, pessimistic time is 10 days and the most likely time is 3 days, then the most expected time of an activity will be

- a) 2 days
- b) 3 days
- c) 4 days
- d) 5 days