EQUIPMENT SCHEDULING

CONSTRUCTION PROJECTS

- **1. Use of 3-D Modelling:** A 3-D model defines and communicates the architect's design vision to the various stakeholders and is a unique digital document that can be used for all phases of design, procurement, construction, and operation.
- It **can be used** for design, analysis, and fabrication, and can help detect conflicts, interferences, and incompatibilities, achieve improved tolerances and quality, and reduce change orders and rework.

- **2. Use of 4-D Models:** The 4-D software generates a sequence of configurations of the project representing its status through time, as determined from the schedule and the 3-D model, thus creating an animation of the construction process.
- **4-D modelling allows** communicating actual construction sequences and can help detect constructability problems, interferences among trades or subcontractors, and interference between moving equipment and on-going activities.

- **3. Web-based Project Management Systems:** It use project collaboration software to provide access for all parties (design consultants, contractors, subcontractors, managers, and others) on a large construction project in order to conduct all daily project management and administrative activities.

- **The main benefits of such systems are increased productivity, reduced cycle time, and elimination of multiple iterations of the work process for project management, invoice submittal processing, and payment operations by allowing the members of a geographically distributed group to interact as.**

- **4. Aesthetics:** Aesthetic enhancement of projects increases their attractiveness and desirability, can serve to establish the identity of a district or city, and represent a statement of its spirit.
- Furthermore, much of the aesthetics features of most projects can be enjoyed by the general public, and aesthetics thus contributes to the quality of life.

- **5. Marketing and Communications:** The success of many projects depends on funding and public support, which in turn often depends on how communication with the public, elected officials, decision makers, and the media is handled.
- **Successful communication techniques** stress the need for establishing and maintaining credibility, communicating the value of the project, ensuring that media coverage is more help than hindrance, avoiding mission expansion, and **building a sense of pride and ownership.**

- **6. Early Contractor Involvement:** A contractor brought on the project team early in the process can assist in suggesting and evaluating design, finish, and construction process alternatives, and in reviewing the design for constructability and completeness.
- **The project also benefits from the contractor's knowledge** of current and projected market and pricing conditions, including labour, material, and equipment availability.

- **7. Innovation, Risk, and Reward:**
- **For the risk of introducing an innovation to be taken, it is necessary that a potential reward, of sufficient value, exist.**
- **8. Process Flexibility and Opportunity for Innovation:**
- **For innovation to be considered, it is necessary that the contracting and procurement rules provide sufficient flexibility.**

- **9. Ownership of Process - Roles and Responsibilities:**
- **All the members of the project team have the opportunity throughout the life of the project to provide input, suggest improvements, introduce innovations, and contribute to the solution of unanticipated problems.**
- **Each team member has a stake in the successful completion of the project.**
- **These factors lead to the creation of a sense of commitment to, and pride in the project, of accomplishment, and of ownership of the process.**

- **10. Project Management and Project Delivery Systems:**
- **Project delivery systems, which enhances cooperation among the project team members and tends to foster innovation, cost effective solutions, and speedy project delivery.**
- **This provides better management continuity and knowledge of the project, including decisions and commitments.**
- **Such teams often use the most advanced project management techniques and risk management concepts to benefit the project.**

- 11. Removing Barriers to Innovation:
- Barriers to innovation are numerous.
- They include the distrust that may exist between the contractor and owner's representative, concerns for the safety of the public and for potential liability, the lengthy process of proving the safety of a proposed innovation, resistance to change, and the fear of taking risks.
- To foster innovation, a change is required in the prevailing attitude of risk avoidance.

- **12. Streamlining:**
- **Streamlining in the areas of construction-ready design documents, commissioning, and all-inclusive insurance policies may lead to substantial cost and schedule reductions, and quality enhancements.**
- **13. Procurement Methods:**
- **Design/Build and other alternate project delivery systems can deliver compelling and substantial benefits.**

- **14. Life-cycle Considerations:**
- **The durability and long-term viability of building projects is extremely important to owners.**
- **For widespread acceptance of life-cycle cost innovations, it is imperative to establish a sound economic rationale for decision-making, and to define and place realistic costs on indirect, but very real, costs such as user delays, traffic interruption, accidents on detours, and the like.**

- **15. Insurance:**
- **Insurance coverage and loss control activities are planned and pre-selected elements of risk mitigation.**
- **"Wrap up" insurance or an owner-controlled insurance program may provide cost savings, and remove a potential barrier to collaboration, especially during the planning and design phases.**

HORIZONTAL CONSTRUCTION PROJECTS

- Water & Sewer
- Storm Water Drainage & Detention
- Roadway & Street Design
- Paving & Grading
- Storm Water Pollution Prevention
- Storm Water Quality Management
- Runways
- Highway and Road Construction

- **Excavation Work**
- **Site work**
- **Aggregate Crushing and Hauling**
- **Potable Water Distribution Systems**

VERTICAL CONSTRUCTION PROJECTS

- Guard towers
- Pre-Engineered buildings
- Wash huts & Metal siding works
- Fence installation and site preparation
- Roads & Bridges
- Parking lots
- Underground utilities (water distribution, sanitary sewer system etc.)
- Runways
- Medical facilities / Housing and dining facilities etc.


CHIGO

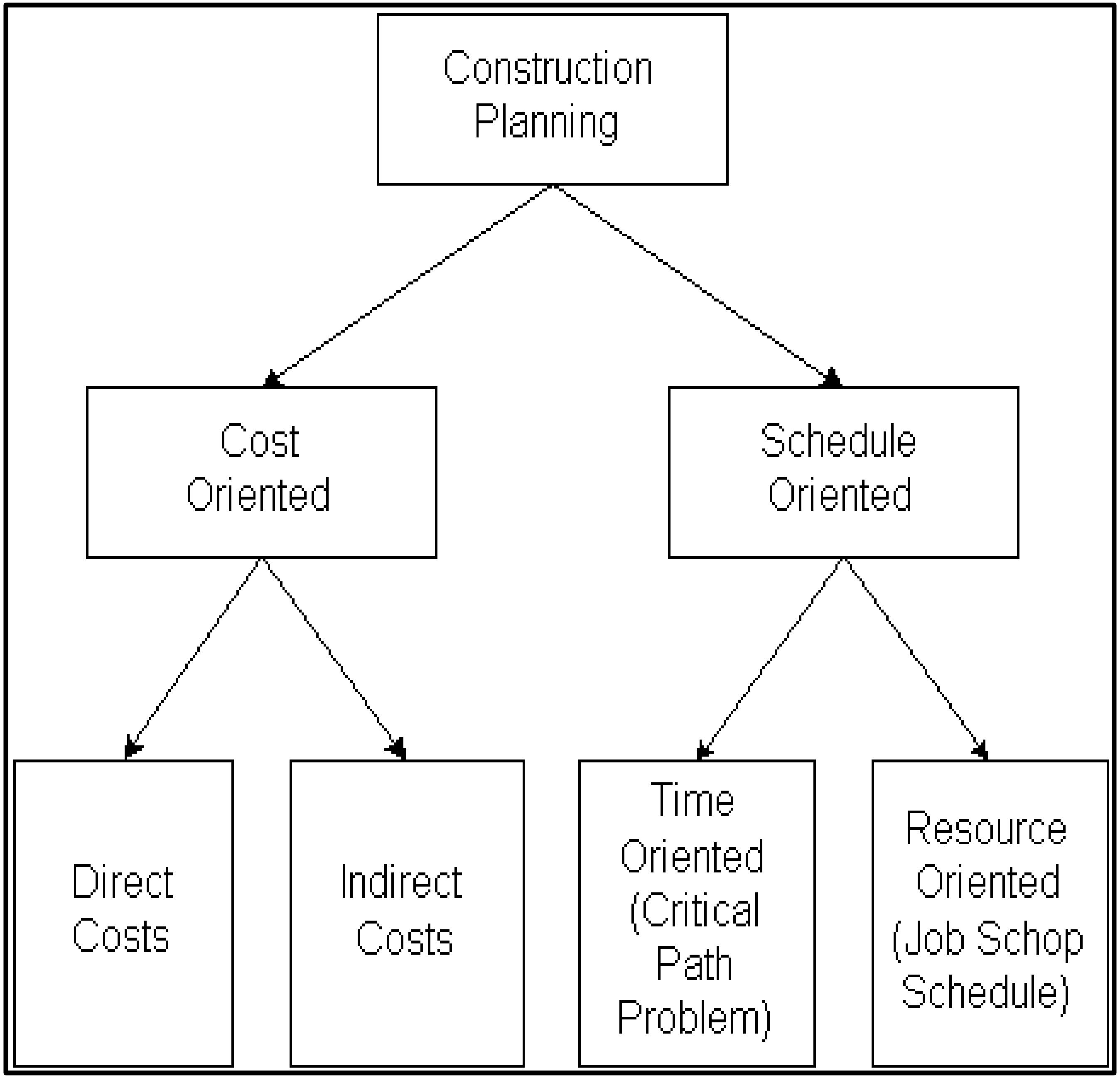


Basic Concepts in the Development of Construction Plans:

- **Construction planning** is a fundamental and challenging activity in the management and execution of construction projects.
- It involves **the choice of technology**, the definition of work tasks, **the estimation of the required resources** and durations for individual tasks, and the identification of any interactions among the different work tasks.
- A good construction plan is the basis for **developing the budget and the schedule.**

- **Developing the construction plan is a critical task in the management of construction.**
- **In addition to these technical aspects of construction planning, it may also be necessary to make organizational decisions about the relationships between project participants and which organizations to include in a project.**
- **For example, the extent to which sub-contractors will be used on a project is often determined during construction planning.**

- **Essential aspects of construction planning include the generation of required activities, analysis of the implications of these activities, and choice among the various alternative means of performing activities.**
- **In developing a construction plan, it is common to adopt a primary emphasis on either cost control or on schedule control as illustrated in Fig.**



Emphases in Construction Planning

- **Traditional scheduling procedures emphasize the maintenance of task precedence (resulting in critical path scheduling procedures) or efficient use of resources over time (resulting in job shop scheduling procedures).**
- **Finally, most complex projects require consideration of both cost and scheduling over time, so that planning, monitoring and record keeping must consider both dimensions.**

Choice of Technology and Construction Method:

- As in the development of appropriate alternatives for facility design, choices of appropriate technology and methods for construction are often ill-structured yet critical ingredients in the success of the project.
- For example, a decision whether to pump or to transport concrete in buckets will directly affect the cost and duration of tasks involved in building construction.

- **A decision between these two alternatives should consider the relative costs, reliabilities, and availability of equipment for the two transport methods.**
- **Unfortunately, the exact implications of different methods depend upon numerous considerations for which information may be sketchy during the planning phase, such as the experience and expertise of workers or the particular underground condition at a site.**

- **It may be necessary to formulate a number of construction plans based on alternative methods or assumptions.**
- **Once the full plan is available, then the cost, time and reliability impacts of the alternative approaches can be reviewed.**
- **This examination of several alternatives is often made explicit in bidding competitions in which several alternative designs may be proposed or value engineering for construction methods may be permitted.**

- In forming a construction plan, a useful approach is to simulate the construction process either in the imagination of the planner or with a formal computer based simulation technique.
- By observing the result, comparisons among different plans or problems with the existing plan can be identified.
- For example, a decision to use a particular piece of equipment for an operation immediately leads to the question of whether or not there is sufficient access.

Fundamental Scheduling Procedures

Relevance of Construction Schedules:

- **Good scheduling** can eliminate problems due to production, facilitate the timely procurement of necessary materials, and otherwise insure the completion of a project as soon as possible.
- In contrast, **poor scheduling** can result in considerable waste as labourers and equipment wait for the availability of needed resources or the completion of preceding tasks.

- **Many owners require detailed construction schedules** to be submitted by contractors as a means of monitoring the work progress.
- **Progressive construction firms use formal scheduling procedures** whenever the complexity of work tasks is high and the coordination of different workers is required.
- **Sharing schedule information via the Internet** has also provided a greater incentive to use formal scheduling methods.

- **A basic distinction exists between resource oriented and time oriented scheduling techniques.**
- **For resource oriented scheduling, the focus is on using and scheduling particular resources in an effective fashion.**
- **For example, on a high-rise building site might be to insure that cranes are used effectively for moving materials; without effective scheduling in this case, delivery trucks might queue on the ground and workers wait for deliveries on upper floors.**

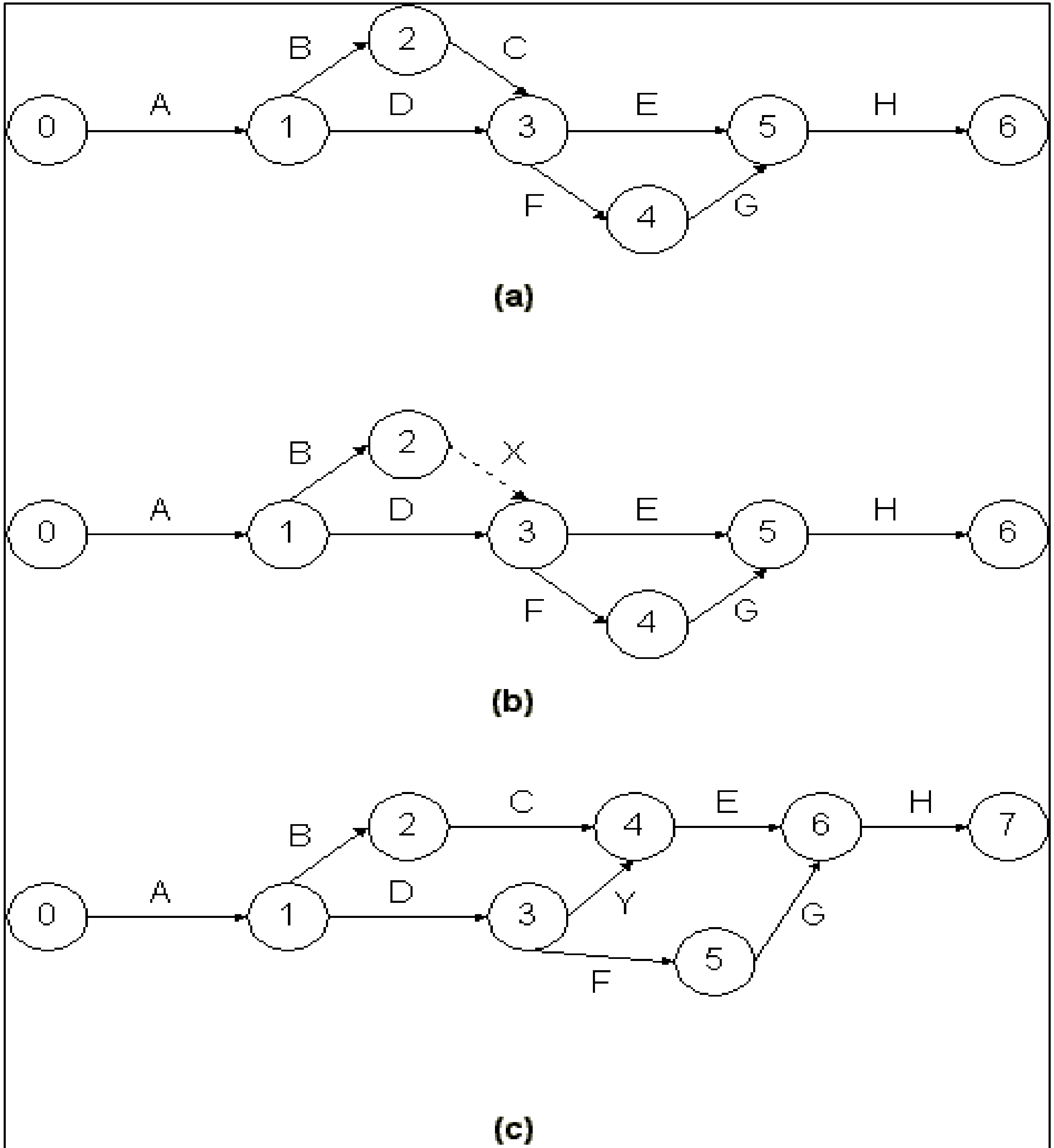
- **For time oriented scheduling**, the emphasis is on determining the completion time of the project given the necessary precedence relationships among activities.
- **Hybrid techniques for resource levelling** or resource constrained scheduling in the presence of precedence relationships also exist.
- **Most scheduling software is time-oriented**, although virtually all of the programs have the capability to introduce resource constraints.

The Critical Path Method:

- The most widely used scheduling technique is the critical path method (CPM) for scheduling, often referred to as **critical path scheduling.**
- This method calculates **the minimum completion time** for a project along with the possible **start and finish times for the project activities.**
- The critical path itself represents the set or sequence of **predecessor/successor** activities which will take the longest time to complete.

- **The duration of the critical path is the sum of the activities' durations along the path.**
- **Thus, the critical path can be defined as the longest possible path through the "network" of project activities.**
- **Formally, critical path scheduling assumes that a project has been divided into activities of fixed duration and well defined predecessor relationships.**
- **A predecessor relationship implies that one activity must come before another in the schedule.**

- To use critical path scheduling in practice, construction planners often represent a resource constraint by a precedence relation.
- A constraint is simply a restriction on the options available to a manager, and a resource constraint is a constraint deriving from the limited availability of some resource of equipment, material, space or labour.
- For example, one of two activities requiring the same piece of equipment.



Activities in a Project Network

Presenting Project Schedules:

- Communicating the project schedule is a vital ingredient in successful project management.
- A good presentation will greatly ease the manager's problem of understanding the multitude of activities and their inter-relationships.
- Graphical presentations of project schedules are particularly useful since it is much easier to comprehend a graphical display of numerous pieces of information than to sift through a large table of numbers.

- A useful variation on project network diagrams is to draw a *time-scaled* network.
- In time-scaled network diagrams, activities on the network are plotted on a horizontal axis measuring the time since project commencement.
- The following Figure gives an example of a time-scaled activity-on-branch diagram.
- In this time-scaled diagram, each node is shown at its earliest possible time.

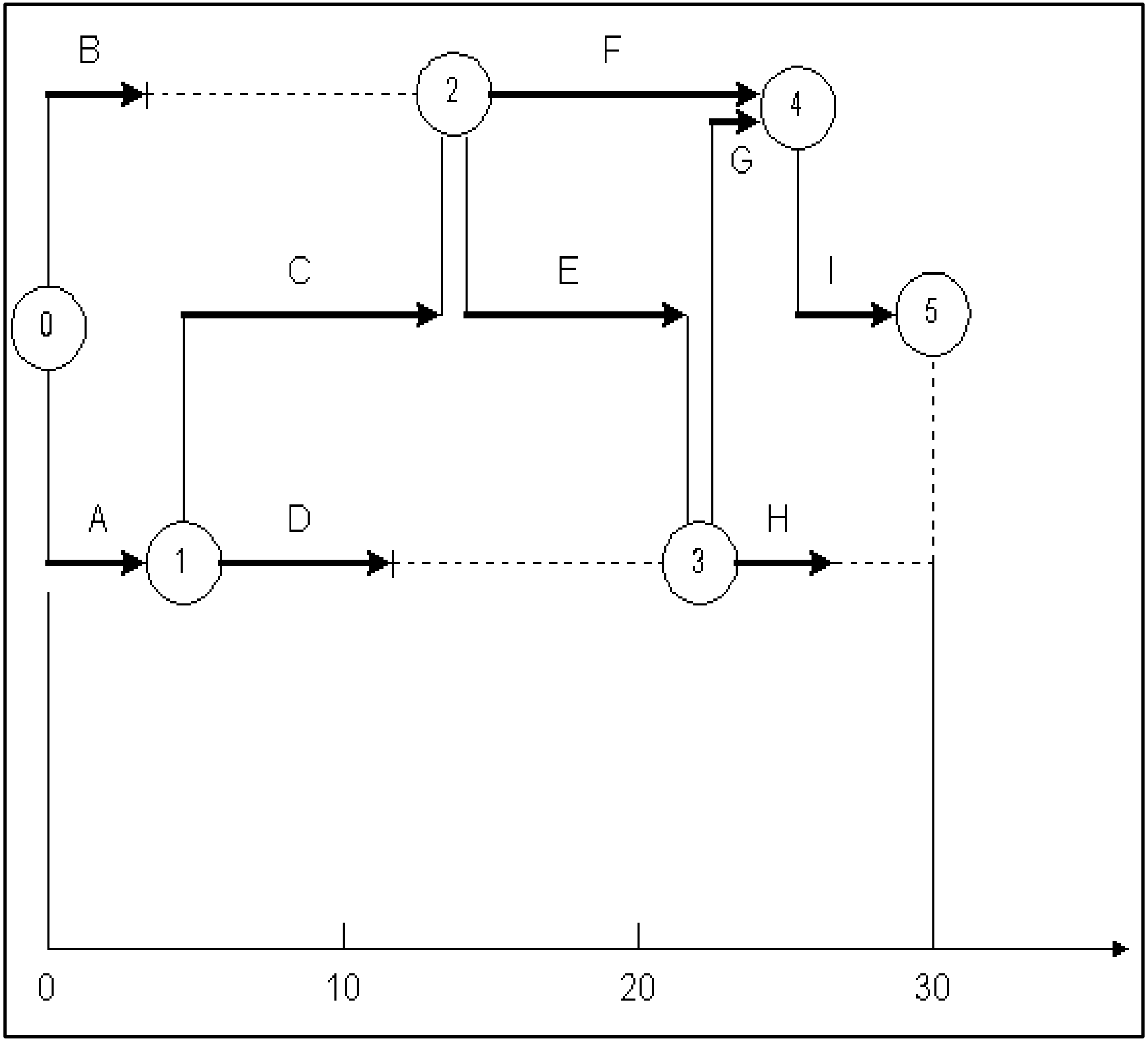
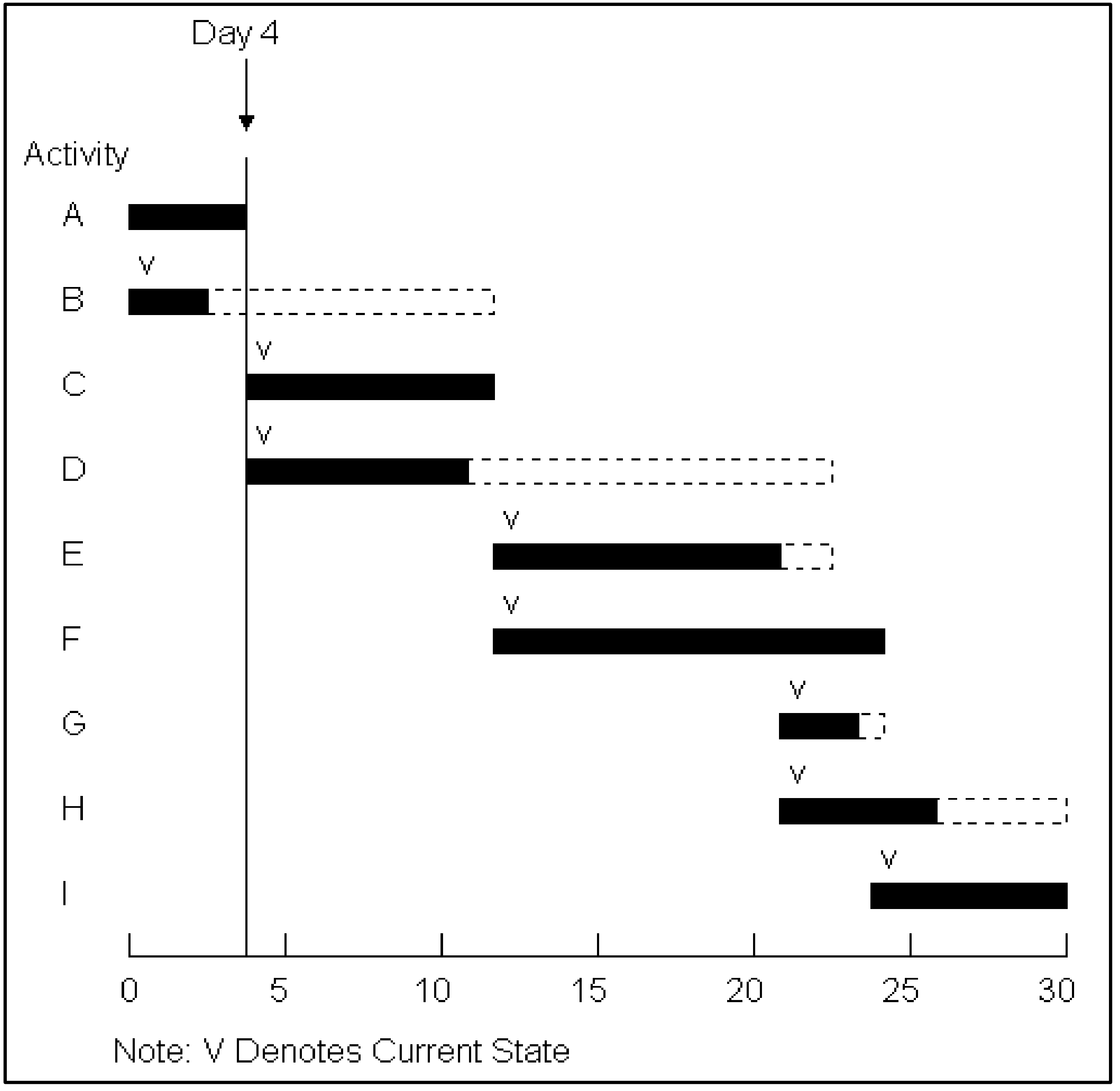


Illustration of a Time Scaled Network Diagram

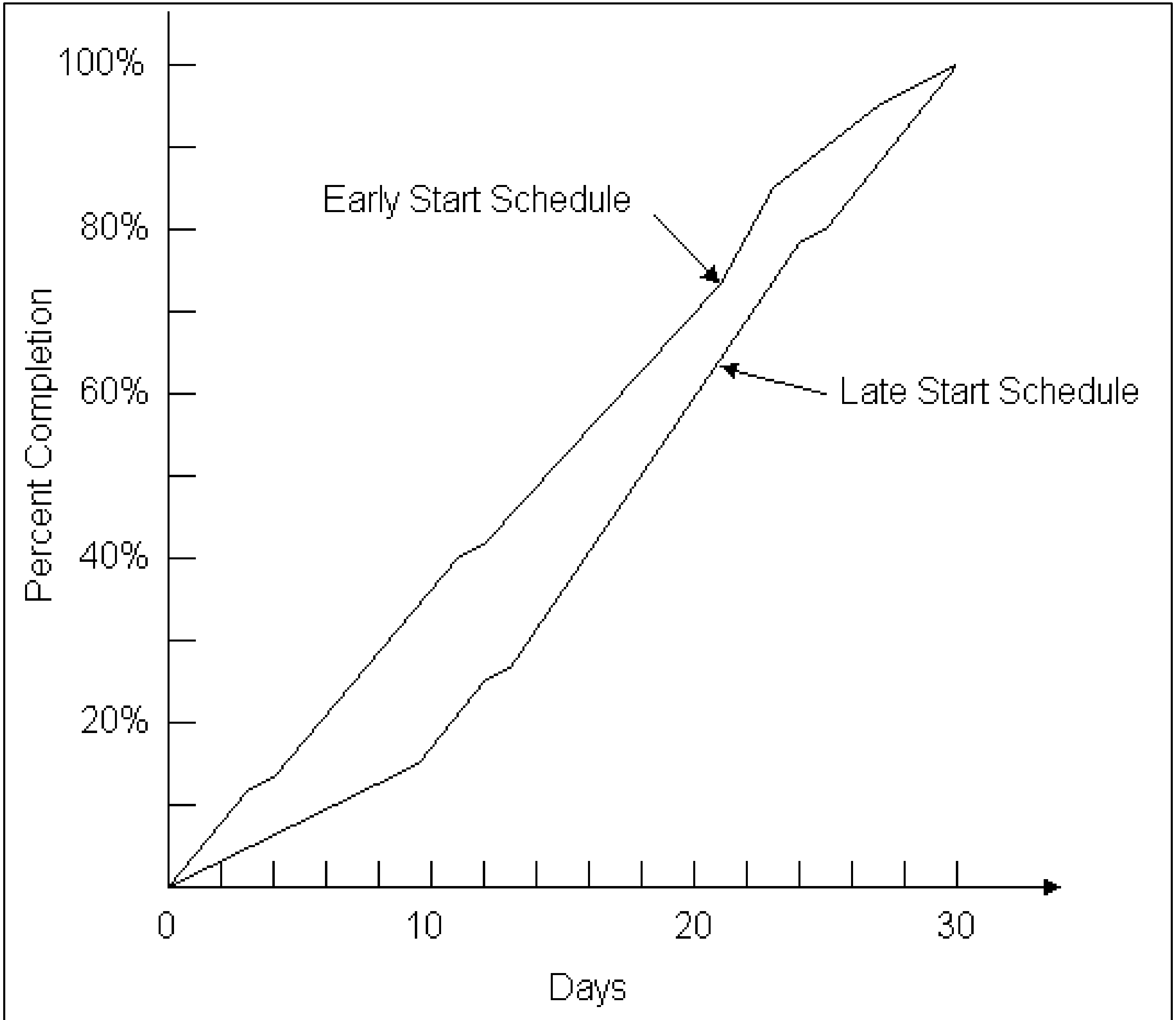
- **Another useful graphical representation tool is a bar or Gantt chart illustrating the scheduled time for each activity.**
- **The bar chart lists activities and shows their scheduled start, finish and duration.**
- **Activities are listed in the vertical axis, while time project commencement is shown along the horizontal axis.**
- **During the course of *monitoring* a project, useful additions to the basic bar chart include a vertical line to indicate the current time plus small marks v to indicate the current state of work on each activity.**



An Example Bar Chart

Other graphical representations are also useful in project monitoring:

- **Time and activity graphs are extremely useful in portraying the current status of a project as well as the existence of activity float.**
- **For example, the following Figure shows two possible schedules for the project.**
- **The first schedule would occur if each activity was scheduled at its earliest start time, ES(i,j) consistent with completion of the project in the minimum possible time.**



Example of Percentage Completion versus Time

- **With this schedule, Figure shows the per-cent of project activity completed versus time.**
- **The second schedule in Figure is based on latest possible start times for each activity, LS(i,j).**
- **The horizontal time difference between the two feasible schedules gives an indication of the extent of possible float.**
- **Time versus completion curves are also useful in project monitoring.**

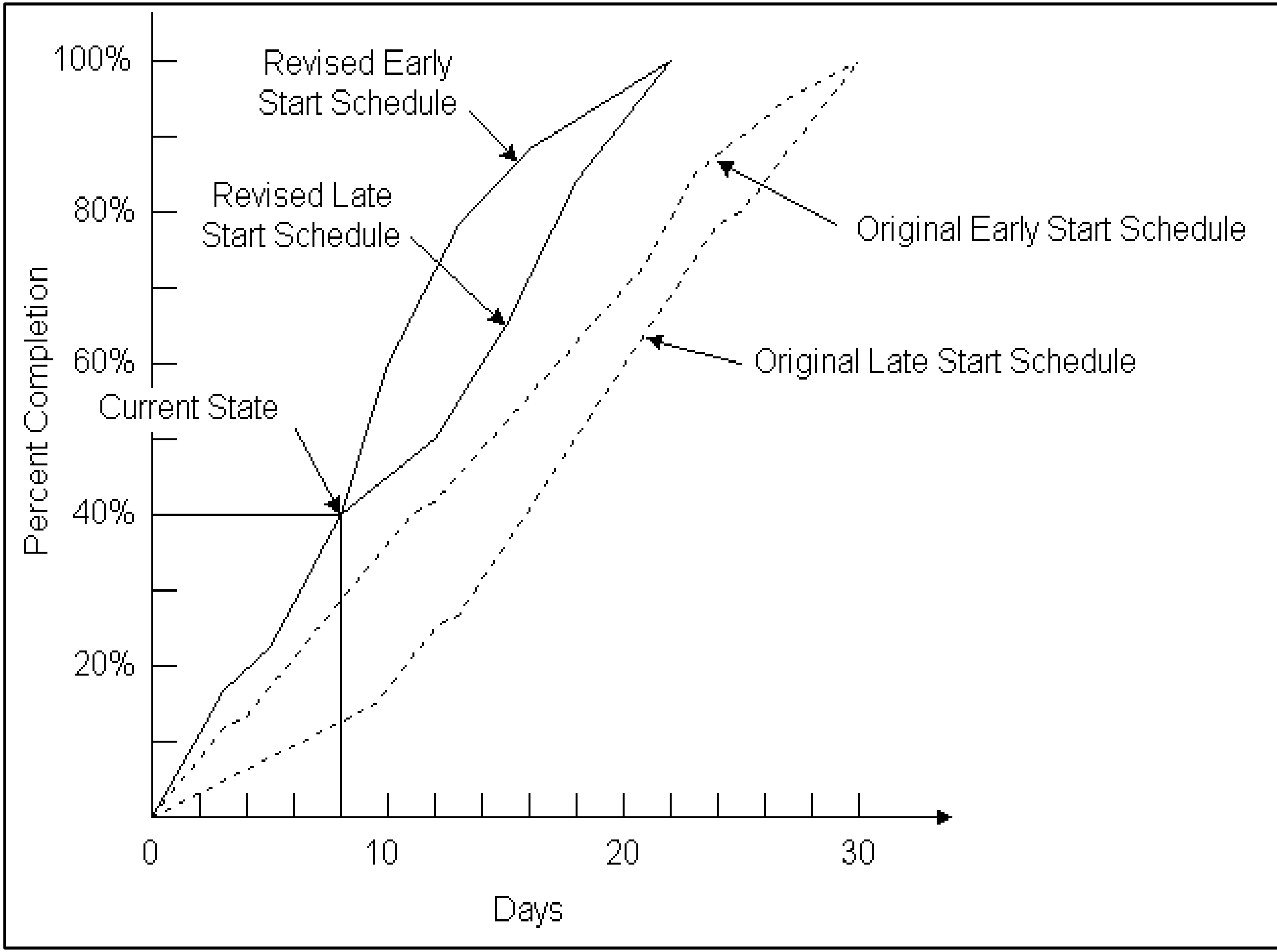
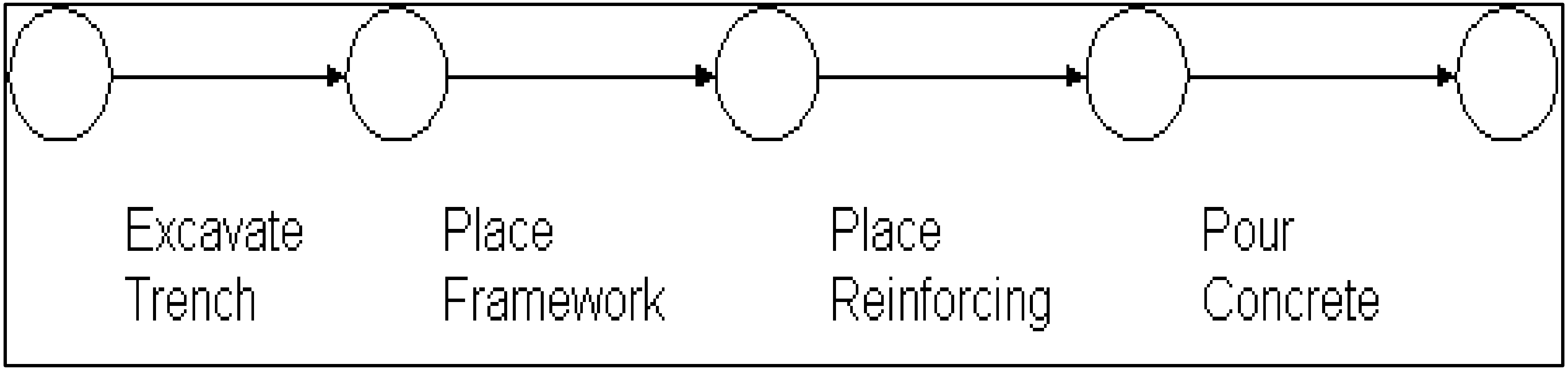


Illustration of Actual Percentage Completion versus Time

Defining Precedence Relationships Among Activities:

- **Once work activities have been defined, the relationships among the activities can be specified.**
- ***Precedence* relations between activities signify that the activities must take place in a particular sequence.**
- **Numerous natural sequences exist for construction activities due to requirements for structural integrity, regulations, and other technical requirements.**

- For example, design drawings cannot be checked before they are drawn.
- Diagrammatically, precedence relationships can be illustrated by a *network* or *graph* in which the activities are represented by arrows as in Figure are called *branches* or *links* in the *activity network*, while the circles marking the beginning or end of each arrow are called *nodes* or *events*.
- In this figure, links represent particular activities, while the nodes represent milestone events.



Illustrative Set of Four Activities with Precedence

- **For example, one activity might not be able to start for several days after the completion of another activity.**
- **As a common example, concrete might have to cure (or set) for several days before formwork is removed.**
- **This restriction on the removal of forms activity is called a *lag* between the completion of one activity (i.e., pouring concrete in this case) and the start of another activity (i.e., removing formwork in this case).**
- **Many computer based scheduling programs permit the use of a variety of precedence relationships.**

- **Finally, it is important to realize that different types of precedence relationships can be defined and that each has different implications for the schedule of activities:**
- **Some activities have a necessary technical or physical relationship that cannot be superseded.**
- **For example, concrete pours cannot proceed before formwork and reinforcement are in place.**

- **Some activities have a necessary precedence relationship over a continuous space rather than as discrete work task relationships.**
- **For example, formwork may be placed in the first part of an excavation trench even as the excavation equipment continues to work further along in the trench.**
- **Formwork placement cannot proceed further than the excavation, but the two activities can be started and stopped independently within this constraint.**

- Some "precedence relationships" are not technically necessary but are imposed due to implicit decisions within the construction plan.
- For example, two activities may require the same piece of equipment so a precedence relationship might be defined between the two to insure that they are not scheduled for the same time period.
- As a second example, reversing the sequence of two activities may be technically possible but more expensive.

Precedence Definition for Site Preparation and Foundation Work:

- Suppose that a site preparation and concrete slab foundation construction project consists of nine different activities:
- A. Site clearing (of brush and minor debris),
  B. Removal of trees,
  C. General excavation,
  D. Grading general area,
  E. Excavation for utility trenches,
  F. Placing formwork and reinforcement for concrete,
  G. Installing sewer lines,
  H. Installing other utilities,
  I. Pouring concrete.

Estimating Activity Durations:

- In most scheduling procedures, each work activity has an associated time duration.
- These durations are used extensively in preparing a schedule.
- For example, suppose that the durations shown in Table were estimated.
- The entire set of activities would then require at least 3 days, since the activities follow one another directly and require a total of 1.0 + 0.5 + 0.5 + 1.0 = 3 days.

Durations and Predecessors for a Four Activity Project Illustration

Activity	Predecessor	Duration (Days)
Excavate trench	---	1.0
Place formwork	Excavate trench	0.5
Place reinforcing	Place formwork	0.5
Pour concrete	Place reinforcing	1.0

- **If another activity proceeded in *parallel* with this sequence, the 3 day minimum duration of these four activities is unaffected.**
- **More than 3 days would be required for the sequence if there was a delay or a lag between the completion of one activity and the start of another.**
- **All formal scheduling procedures rely upon estimates of the durations of the various project activities as well as the definitions of the predecessor relationships among tasks.**

- **For example,** the duration of an activity D_{ij} such as concrete formwork assembly might be estimated as:

$$D_{ij} = \frac{A_{ij}}{P_{ij} N_{ij}}$$

where A_{ij} is the required formwork area to assemble (in square yards), P_{ij} is the average productivity of a standard crew in this task (measured in square yards per hour), and N_{ij} is the number of crews assigned to the task.

- **Linear Scheduling Method** (LSM) is a graphical scheduling method focusing on continuous resource utilization in repetitive activities.
- It is believed that it originally adopted the idea of Line-Of-Balance method.
- The Linear Scheduling Method is a graphical scheduling method that focuses on continuous use of resources, in a repetitive manner, **along both a time and a distance axis, along the optimal Right of Way (ROW.)**

- **LSM is used mainly in the construction industry to schedule resources in repetitive activities commonly found in highway, pipeline, high-rise building and rail construction projects.**
- **These projects are called repetitive or linear projects.**
- **The main advantages of LSM over Critical Path Method (CPM) is its underlying idea of keeping resources continuously at work.**

- **In other words, it schedules activities in such a way that:**
  - **resource utilization is maximized;**
  - **interruption in on-going process is minimized, including hiring-and-firing; and**
  - **the effect of the learning curve phenomenon is maximized**

Vertical Mast lifts

Vertical Wheel Loaders

Vertical Hoist

Crane in Construction

Horizontal Construction Equipment's

Horizontal Underground Equipment's

Horizontal Navigators

Horizontal Grinders & Pavers