Software Project Scheduling

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Introduction

A detailed plan for the project, however, must also include a schedule indicating the start and completion times for each activity. This will enable us to:

- ensure that the appropriate resources will be available precisely when required;
- avoid different activities competing for the same resources at the same time;
- produce a detailed schedule showing which staff carry out each activity;
- produce a detailed plan against which actual achievement may be measured;
- produce a timed cash flow forecast;
- replan the project during its life to correct drift from the target.

- To be effective, a plan must be stated as a set of targets, the achievement or nonachievement of which can be unambiguously measured.
- The activity plan does this by providing a target start and completion date for each activity. The starts and completions of activities must be clearly visible and this is one of the reasons why it is advisable to ensure that each and every project activity produces some tangible product or 'deliverable’.

- Monitoring the project's progress is then, at least in part, a case of ensuring that the products of each activity are delivered on time.

- As a project progresses it is unlikely that everything will go according to plan. Much of the job of project management concerns recognizing when something has gone wrong, identifying its causes and revising the plan to mitigate its effects.
- The activity plan should provide a means of evaluating the consequences of not meeting any of the activity target dates and guidance as to how the plan might most effectively be modified to bring the project back to target.

The objectives of Activity planning

- Planning is an ongoing process of refinement, each iteration becoming more detailed and more accurate than the last. Over successive iterations, the emphasis and purpose of planning will shift.
- During the feasibility study and project start-up, the main purpose of planning will be to estimate timescales and the risks of not achieving target completion dates or keeping within budget.
- As the project proceeds beyond the feasibility study, the emphasis will be placed upon the production of **activity plans** for ensuring resource availability and cash flow control.
- Throughout the project, until the final deliverable has reached to the customer, monitoring and replanning must continue to correct any drift that might prevent meeting time or cost targets.
- **Activity planning and scheduling** techniques place an emphasis on completing the project in a minimum time at an acceptable cost or, alternatively, meeting an arbitrarily set target date at minimum cost. These are not, in themselves, concerned with meeting quality targets, which generally impose constraints on the scheduling process.

The elements of a detailed planned activity are:

Feasibility assessment

- Feasibility assessment talks about an very early stage describing whether it is feasible for the project to exist within the specified time constraint.
- A detailed plan will help in forecasting of the project as it progresses from one stage to other stages of activities.
- The feasibility factor also lies in the availability of resources that includes specialized staff to carry out the activities.

Resource allocation

- The best way to allocate resources to the project depends on the availability factor.
- The project plan must analyze the available resources and the timescales for each and every activity.
- Additional usage of resources more than the stipulated timescale will result in slacking the progress of the project.

Estimation of costs(Detailed costing)

- The project plan must provide solutions to the following questions:
    - What is the total expenditure?
    - How much will the project costs?
    - What are the various estimating factors involved in the development process.
- These can be answered only when a detailed estimation of costs and timing is defined.

Personal encouragement (motivation)

- Staff involved in the development process must be motivated in an effective way so that they achieve the target without any delay.
- The targets provided to the staff are monitored and personal encouragement must be given to individual staff if achieve the target on time.
- Activity planning helps in completing the project in minimum time with an nominal cost with the help of project schedules.
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Coordination

- When do the staff in different departments need to be available to work on a particular project and when do staff need to be transferred between projects?
- Interaction and communication plays a vital role in handling complex projects.
- Effective team management must be established to carry out the activities in a well coordinated manner.
- In particular, the availability of staff for a set of integrated project schedules must be carefully allocated with no period of idleness.

Project Scheduling

- Project scheduling is the process of deciding how the work in a project will be organized as separate tasks, and when and how these tasks will be executed.
- You estimate the calendar time needed to complete each task, the effort required, and who will work on the tasks that have been identified.
- You also have to estimate the resources needed to complete each task, such as the disk space required on a server, the time required on specialized hardware, what the travel budget will be etc.
- An initial project schedule is usually created during the project start-up phase. Initial schedule is used to plan how people will be allocated to projects and to check the progress of the project against its contractual commitments.
- In traditional development processes, the complete schedule is initially developed and then modified as the project progresses.
- In agile processes, there has to be an overall schedule that identifies when the major phases of the project will be completed. An iterative approach to scheduling is then used to plan each phase.

Stages of Project Schedules

- Every project must be developed with a plan showing the start and end of the activity along with the availability of resources for each activity.
- A project schedule is established based on the constraints defined for each activity.
- There are four stages involved in the creation of project schedule:
  - First stage of project schedule provides solutions to the questions like:
    - ❖ What are the activities have to be carried out?
    - ❖ What is the sequence of order in which each activity has to be handled?
  - The next stage involves the risk factors that affect each activity like:
    - ❖ Can risk occur in this activity?
    - ❖ How does a particular activity handle the risk?
    - ❖ What are the potential problems that can arise in risk handling?

- Third stage of project schedule deals with allocation of resources:
  - ❖ How are resources allocated to specific activities?
  - ❖ What is the expected availability of resources?
  - ❖ What are the constraints defined for allocating a particular resource?
- The final stage includes the schedule production:
  - ❖ What are the planned start and end dates for each activity?
  - ❖ What are the resources allocated to each activity?
  - ❖ Explain the detailed project schedule?

Activities

- Project and its activities must be clearly defined to achieve the target. An activity plan will contain the following factors:
  - A project is composed of a number of interrelated activities.
  - A project may start when at least one of its activities is ready to start.
  - A project will be completed when all of the activities it encompasses have been completed.
  - An activity must have a clearly defined start and a clearly defined end-point, normally marked by the production of a tangible deliverable.
  - If an activity requires a resource (as most do) then that resource requirement must be forecastable and is assumed to be required at a constant level throughout the duration of the activity.
  - The duration of an activity must be forecastable – assuming normal circumstances, and the reasonable availability of resources.
  - Some activities might require that others are completed before they can begin (these are known as *precedence requirements*).

Approaches to Identify Activities

- The various approaches used in identifying activities are:
  - Activity-based approach
  - Product-based approach
  - Hybrid approach

Activity-based approach

- In the activity-based approach, all the activities are listed and created for the project.
- This is achieved by a brainstorming session where the entire project team analysis the various activities needed at different stages with the help of similar projects.
- This approach usually generates the list of activities using a work breakdown structure (WBS).
- WBS helps in identifying the lowest level of effort i.e. the task required to complete a project by breaking down into lower sets of tasks.

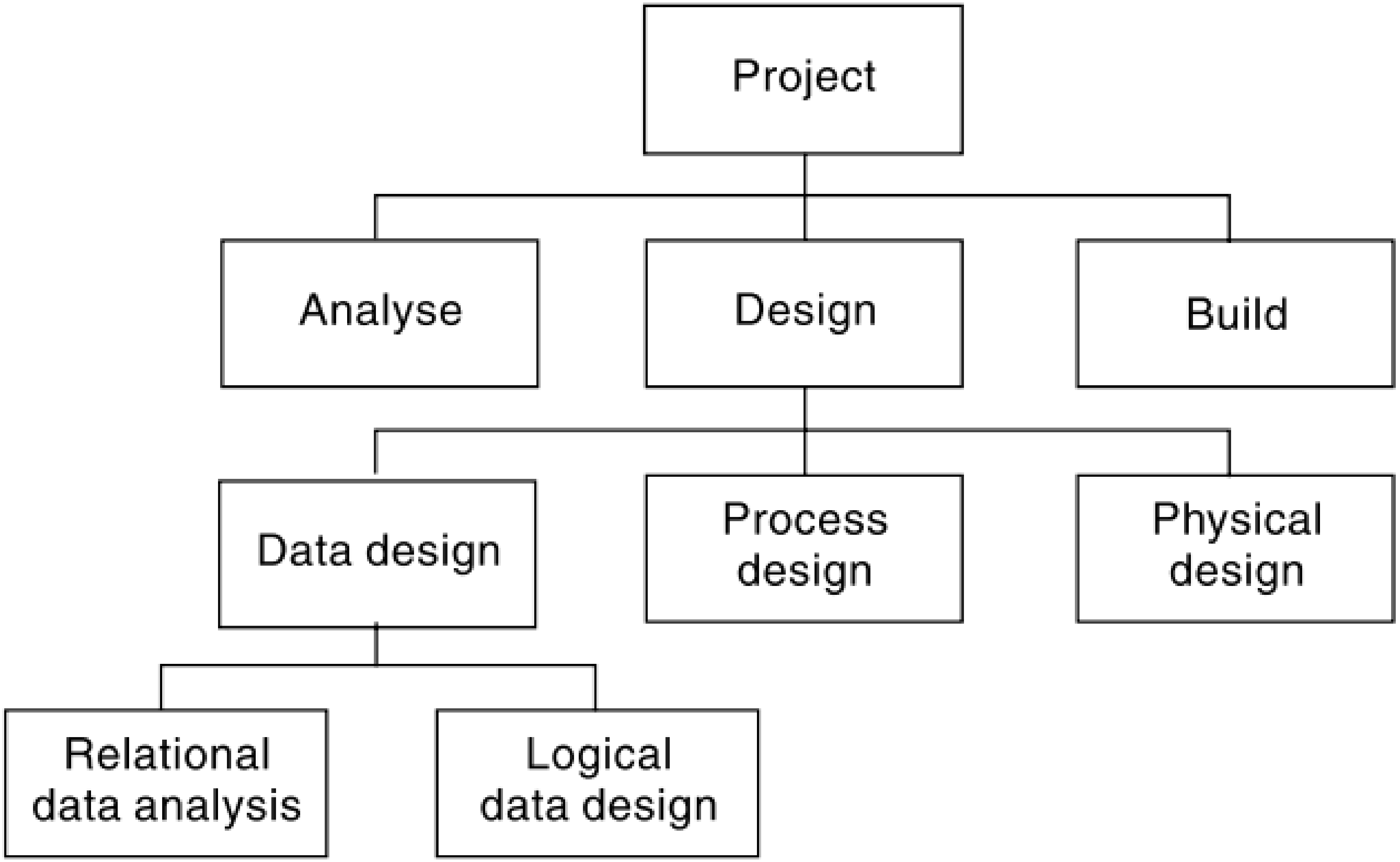


Fig: A fragment of an activity-based Work Breakdown Structure.

- Task defined at lower level includes everything that is required to complete the task at the higher level.
- The work breakdown structure provides an in-depth knowledge about the lowest level of activity that has to be completed.
- WBS is a refined structure that clearly defines the milestones that has to be achieved in accomplishing a specific task.
- The ordering of sequence of activities can also be done in this approach by defining those activities that have to be completed for others to start.
- In a purely activity-based approach, activities are identified and defined in five levels:

  Level 1 : Project – goals, objectives defined

  Level 2: Deliverables – software, manuals, training

  Level 3 : Components – work items, modules, tests

  Level 4 : Work-packages – major work items, related tasks

  Level 5 : Tasks – responsibility of an individual in accomplishing it

Product-based approach

- The product-based approach produces a product breakdown structure along with a product flow diagram.
- The approach accepts the products as inputs which is transformed into an ordered list of activities.
- A product based structure is very much similar to the work breakdown structure which includes dividing a complex and big scale product into its sub set products until simple, manageable, independent and smaller products are obtained at the leaf level.
- Product Flow Diagram(PFD) do not leave out any activity from its ordered list and adopts a methodology which clearly specifies what are the products required and what are the activities required to produce the product.
- This approach is particularly appropriate if using a methodology such as SSADM(or USDP (Unified Software Development Process), which clearly specifies, for each step or task, each of the products required and the activities required to produce it.
- Using Structured Systems Analysis and Design Method (SSADM), a generic activity network can be derived for a project-specific product breakdown structure.
- The development of a PFD indicates the sequence of activities of the activity network.
- In the USDP, products are referred to as *artifacts* below figure and the sequence of activities needed to create them is called a *workflow*

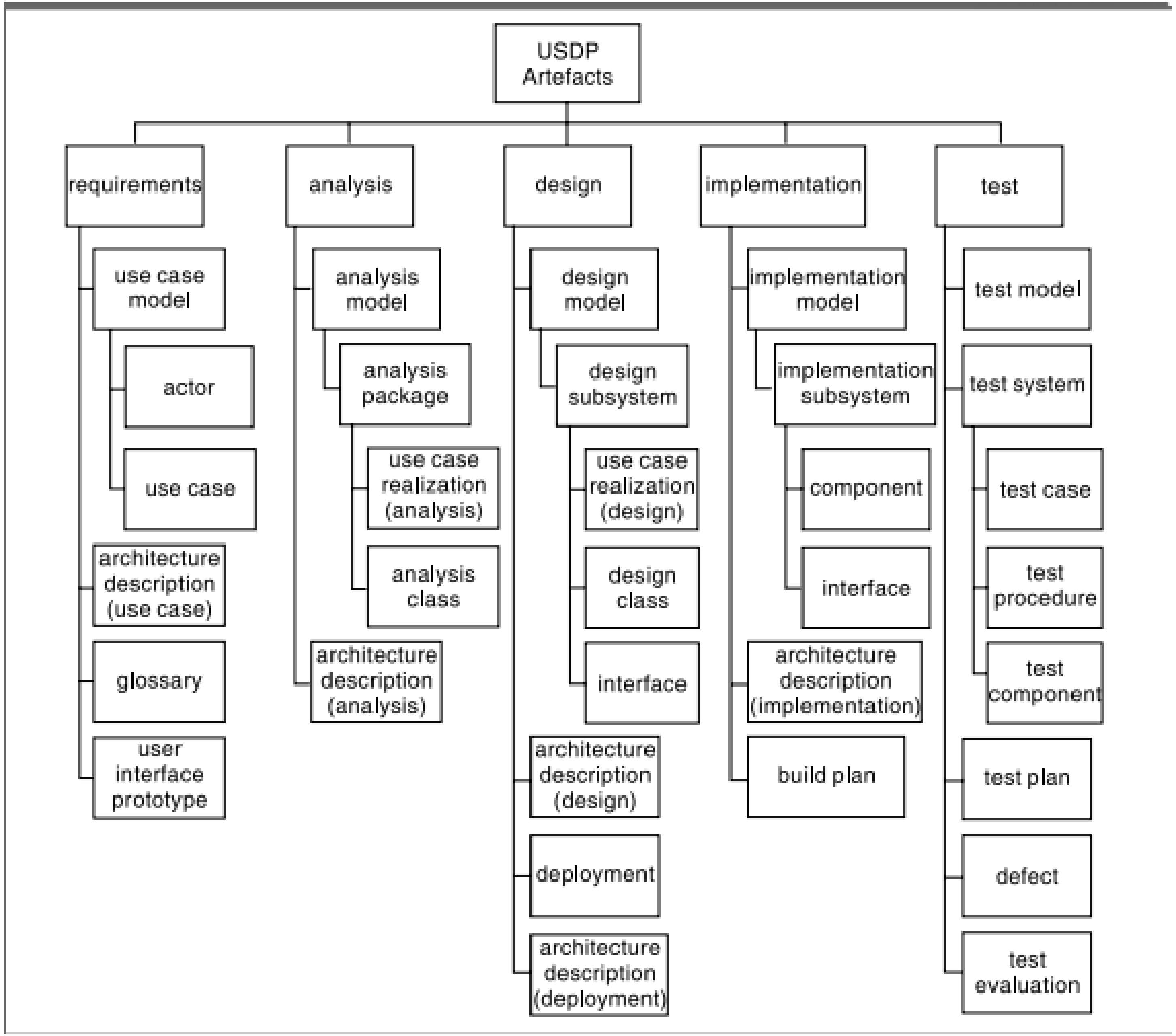


Fig: USDP product breakdown structure based on artefacts identified in Jacobson, Booch and Rumbaugh (1999).

Example:

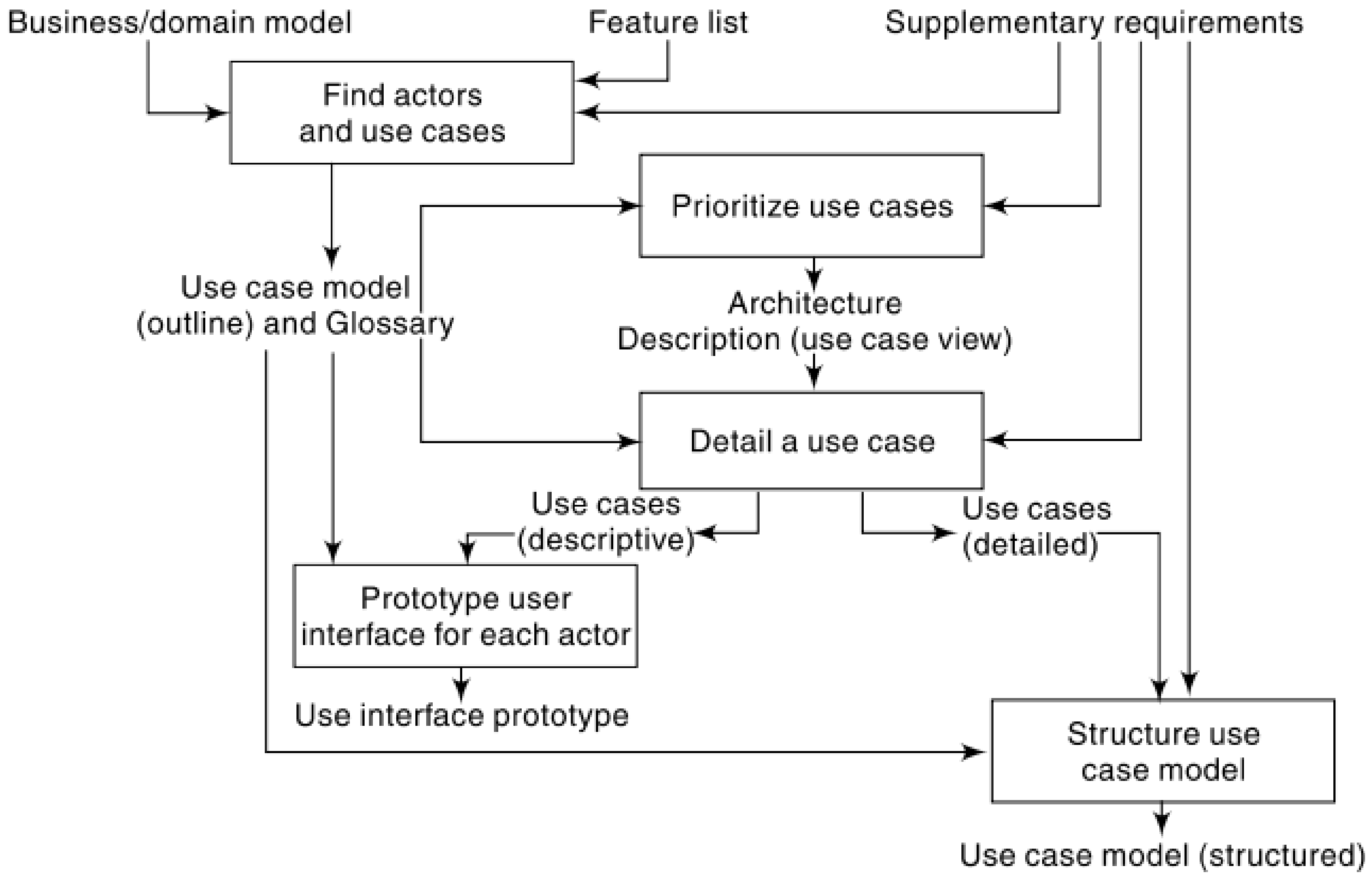


Fig: A structuring of activities for the USDP requirements capture workflow based on Jacobson, Booch and Rumbaugh (1999).

Hybrid approach

- WBS deals with list of final deliverables whereas PBS deals in producing the products using the product flow diagram.
- Hybrid approach combines both the activity-based and product-based approach to structure both activities and products.
- Structuring of product-based or activity-based approach depend on the nature of the project type.

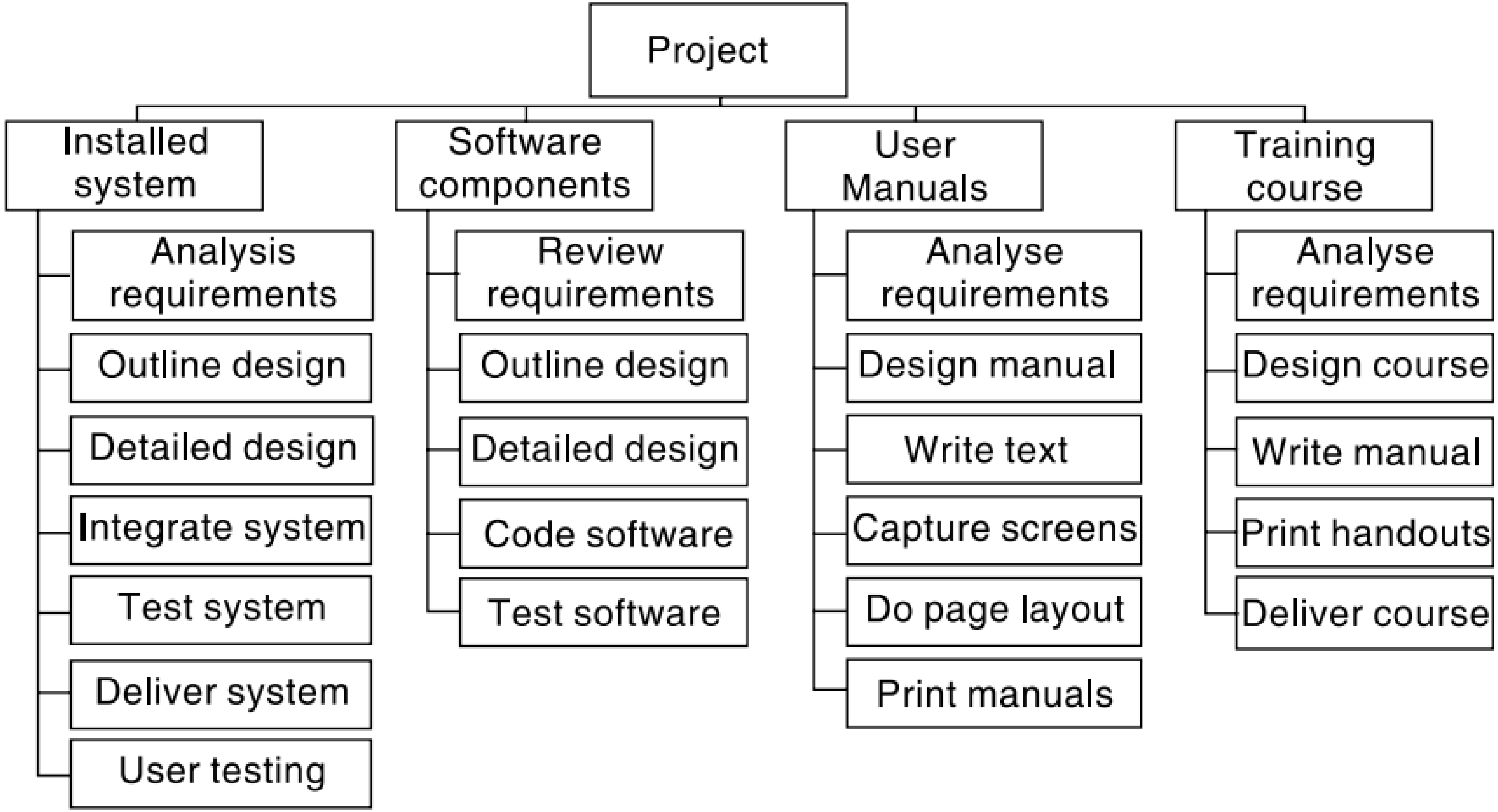
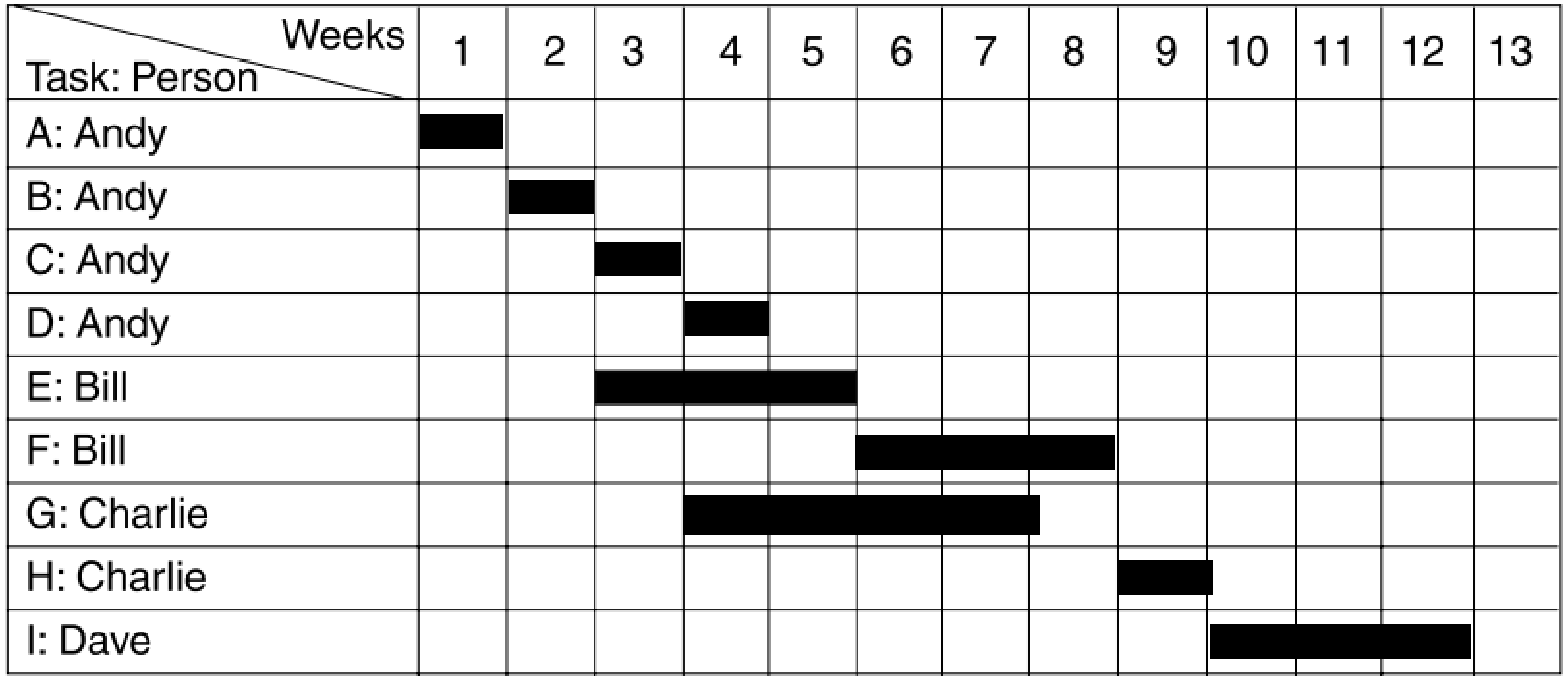


Fig: A hybrid Work Breakdown Structure based on deliverables and activities.

Sequencing and Scheduling

- Scheduling is required for every activity that is planned along with the resources and can be represented using a bar chart.
- The chart describes the nature of the development process and the resources available for completing the specified activities.
- The chart defines two factors: sequencing of tasks and the schedule of the task. Scheduling includes the staff availability and the activities allocated to them.
- Combining sequencing – scheduling approach is suitable only for smaller projects and needs to be separated for complex projects as individual process.
- In case of larger projects, it is better to separate out these two activities: to sequence the tasks according to their logical relationships and then to schedule them taking into account resources and other factors.
- The chart shown has been drawn up taking account of the nature of the development process (that is, certain tasks must be completed before others may start) and the resources that are available (for example, activity C follows activity B because Andy cannot work on both tasks at the same time).

- In drawing up the chart, we have therefore done two things – we have sequenced the tasks (that is, identified the dependencies among activities dictated by the development process) and scheduled them (that is, specified when they should take place).



Activity key

A: Overall design
B: Specify Module 1
C: Specify Module 2
D: Specify Module 3
E: Code Module 1
F: Code Module 3
G: Code Module 2
H: Integration testing
I: System testing

Fig: A project plan as a bar chart.

Network Planning Models

- A network model can be formulated for the project scheduling techniques for the activities and their relationships as a graph.
- In the network, time flows from left to right. Most frequently used techniques are the Program Evaluation Review Technique (PERT) and the CPM(Critical Path Method).
- Both of these techniques used an *activity-on-arrow* approach to visualizing the project as a network where activities are drawn as arrows joining circles, or nodes, which represent the possible start and/or completion of an activity or set of activities. This network can also be called as precedence network.
- This method uses *activity-on-node* networks where activities are represented as nodes and the links between nodes represent precedence (or sequencing) requirements.

Formulating a Network Model

- The first stage in creating a network model is to represent the activities and their interrelationships as a graph.
- In activity-on-node we do this by representing activities as nodes (boxes) in the graph – the lines between nodes represent dependencies.

Constructing precedence networks

There are some conventions used in the construction of precedence networks.

- **Only one start node and one end node must be defined for a project network:** There cannot be more than one start node for any project network and usually the duration of the start node is zero.
- Similarly, the completion of the project can be viewed by only one end node when the final activity is finished. If more than one start node or end node exists, it lead to confusion and uncertainty.
- **Every node must have duration:** Any node that represents an activity must be provided with the duration for its execution. Here, the activities must be carried out in the sequenced order defined in the project schedule.
- **Links do not have duration:** The relationship between activities are represented through links and generally does not have any duration for the establishment of creating it.

- **Precedents are the immediate preceding activities:** In below figure, the activity ‘Program test’ cannot start until both ‘Code’ and ‘Data take-on’ have been completed and activity ‘Instal’ cannot start until ‘Program test’ has finished. ‘Code‘ and ‘Data take-on’ can therefore be said to be precedents of ‘Program test’, and ‘Program test’ is a precedent of ‘Instal’.
- Note that we do not speak of ‘Code’ and ‘Data take-on’ as precedents of ‘Instal’ – that relationship is implicit in the previous statement.

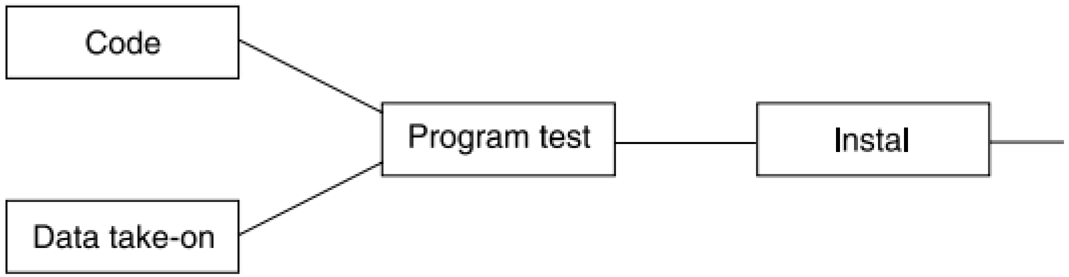


Fig: Fragment of a precedence network.

- **Flow of activities:** Activities are always started from the left most one and precedes in the forward direction. Usually, networks are drawn from left to right. Arrows can be drawn to show the flow of direction.
- **A network may not contain loops :** Figure below, demonstrates a loop in a network. A loop is an error in that it represents a situation that cannot occur in practice. While loops, in the sense of iteration, may occur in practice, they cannot be directly represented in a project network.

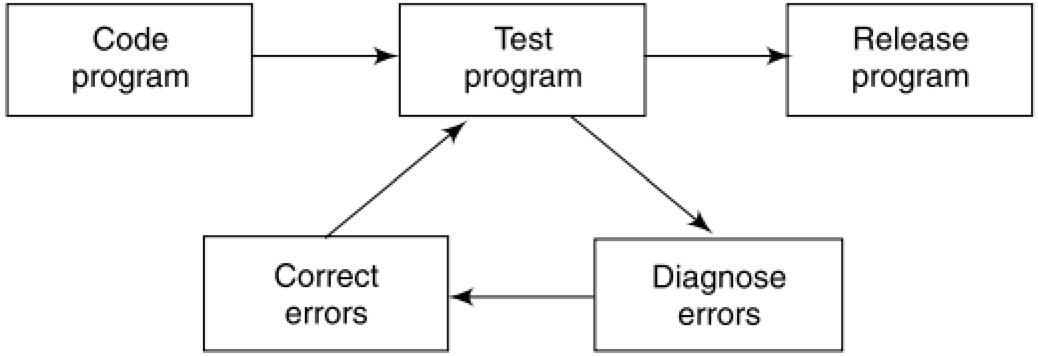


Fig: A loop represents an impossible sequence.

- **A network should not contain dangles:** Dangling activities are never shown in the network. These leads to errors in subsequent analysis of the development process. For example, an activity named “Write User Manual” should not be defined in the network as a non-connectivity activity, instead must be defined before the installation of the software.

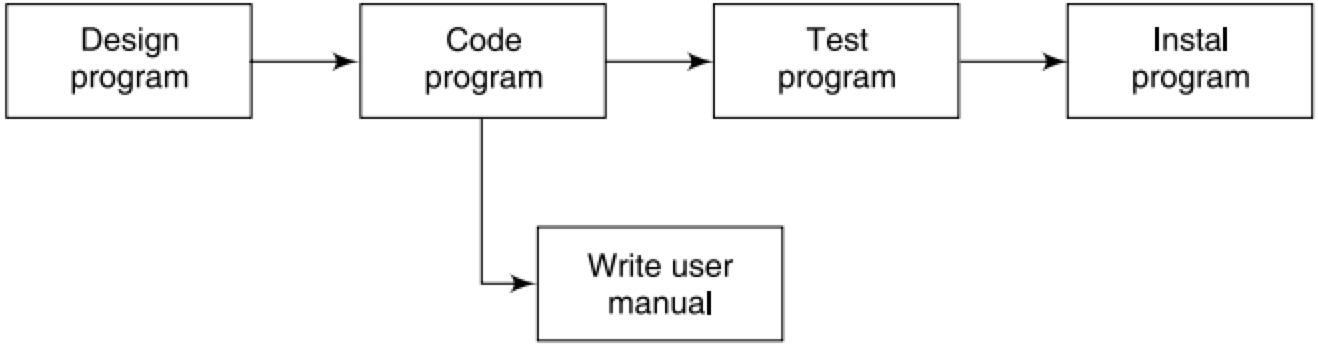


Fig a: A dangle.

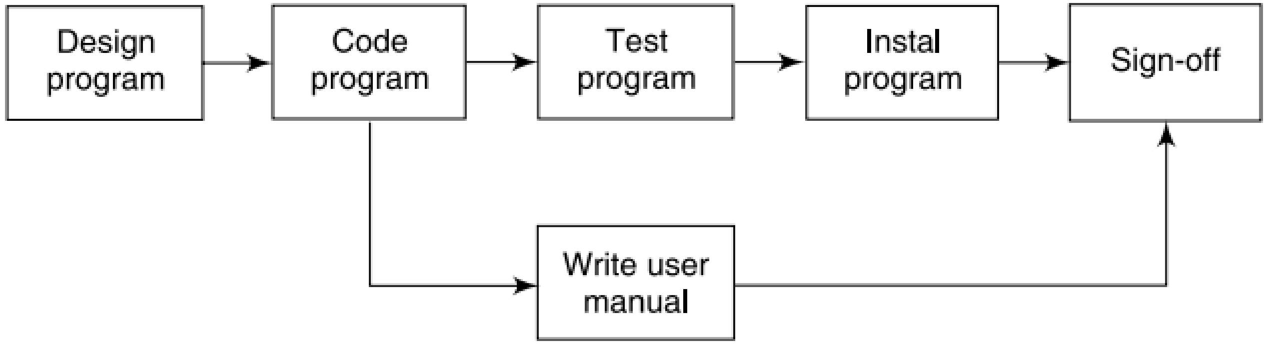


Fig b: Resolving the dangle.

- **Lagged and Hammock activities:**
- Where activities can occur in parallel with a time lag between them, we represent the lag with a duration on the linking arrow as shown in Fig below.
- This indicates that documenting amendments can start one day after the start of prototype testing and will be completed two days after prototype testing is completed.

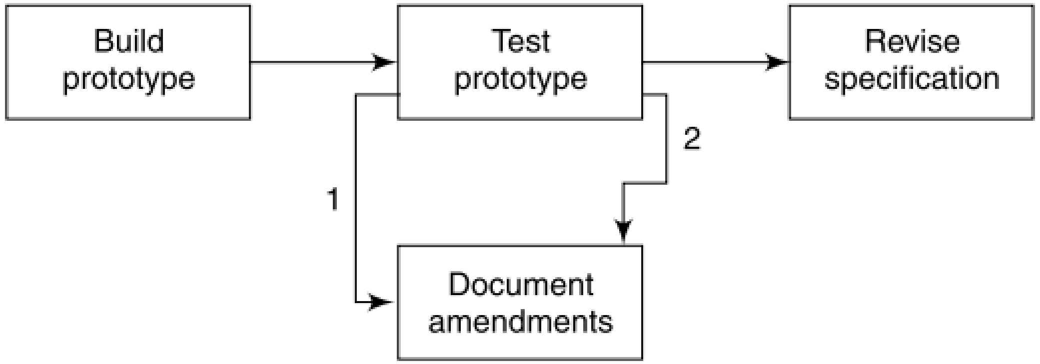


Fig: Indicating lags.

- **Hammock activities** have zero duration but are assumed to start at the same time for each activity and end at the same time for the last one. These activities normally represent overhead costs and resources that occur at regular intervals over the set of activities.

Forward Pass & Backward Pass Techniques

- The logical network model represents the inter-relationships between the activities and is used in estimating the duration of the activity.
- Critical Path Method ensures that the planned project must be completed as quickly as possible. It also governs those activities that have delay in execution which can affect the overall project schedule.
- The critical path method analyses the precedence of activities to predict the total project duration.
- The focus is based on the slack, free float and path float available between the activities. The method calculates which sequence of activities has the least amount of schedule flexibility.
- CPM analysis starts with a WBS that has singe point estimates for each activity and uses the precedence diagramming method to relate the precedence in the network.
- With the network drawn, two-pass analysis can be performed through the network of activities and calculate the node quantities for each activity.
- The network is then analyzed by carrying out a **forward pass**, to calculate the earliest dates at which activities may commence and the project be completed, and a **backward pass**, to calculate the latest start dates for activities and the **critical path**.

Forward pass

- The **forward pass** is carried out to calculate the earliest dates on which each activity may be started and completed.

Table 1**.** An example project specification with estimated activity durations and precedence requirements.

Activity		Duration (weeks)	Precedents
A	Hardware selection	6	
B	System configuration	4	
C	Instal hardware	3	A
D	Data migration	4	B
E	Draft office procedures	3	B
F	Recruit staff	10	
G	User training	3	E, F
H	Instal and test system	2	C, D

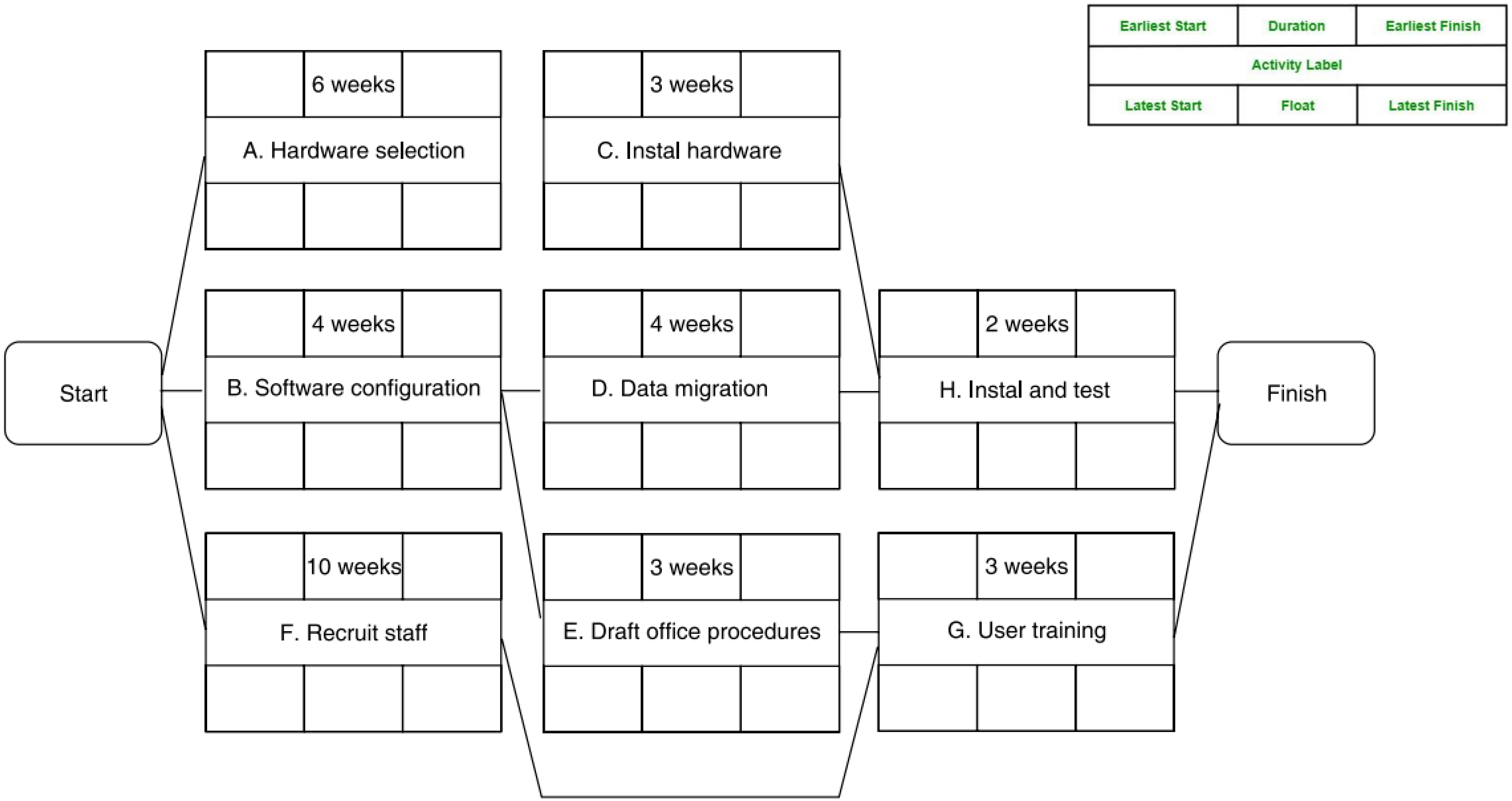


Fig 1a: The precedence network for the example project .

- **The forward pass rule**: the earliest start date for an activity is the earliest finish date for the preceding activity. Where there is more than one immediately preceding activity we take the *latest* of the *earliest finish dates* for those activities.
- The forward pass and the calculation of earliest start dates are carried out according to the following reasoning.
  - Activities A, B and F may start immediately, so the earliest date for their start is zero.
  - Activity A will take 6 weeks, so the earliest it can finish is week 6.
  - Activity B will take 4 weeks, so the earliest it can finish is week 4.
  - Activity F will take 10 weeks, so the earliest it can finish is week 10.
  - Activity C can start as soon as A has finished so its earliest start date is week 6. It will take 3 weeks so the earliest it can finish is week 9.
  - Activities D and E can start as soon as B is complete so the earliest they can each start is week 4. Activity D, which will take 4 weeks, can therefore finish by week 8 and activity E, which will take 3 weeks, can therefore finish by week 7.

- Activity G cannot start until both E and F have been completed. It cannot therefore start until week 10– the later of weeks 7 (for activity E) and 10 (for activity F). It takes 3 weeks and finishes in week 13.
- Similarly, Activity H cannot start until week 9 – the later of the two earliest finish dates for the preceding activities C and D.
- The project will be complete when both activities H and G have been completed. Thus the earliest project completion date will be the later of weeks 11 and 13 – that is, week 13.

- The results of the forward pass are shown in Figure below.

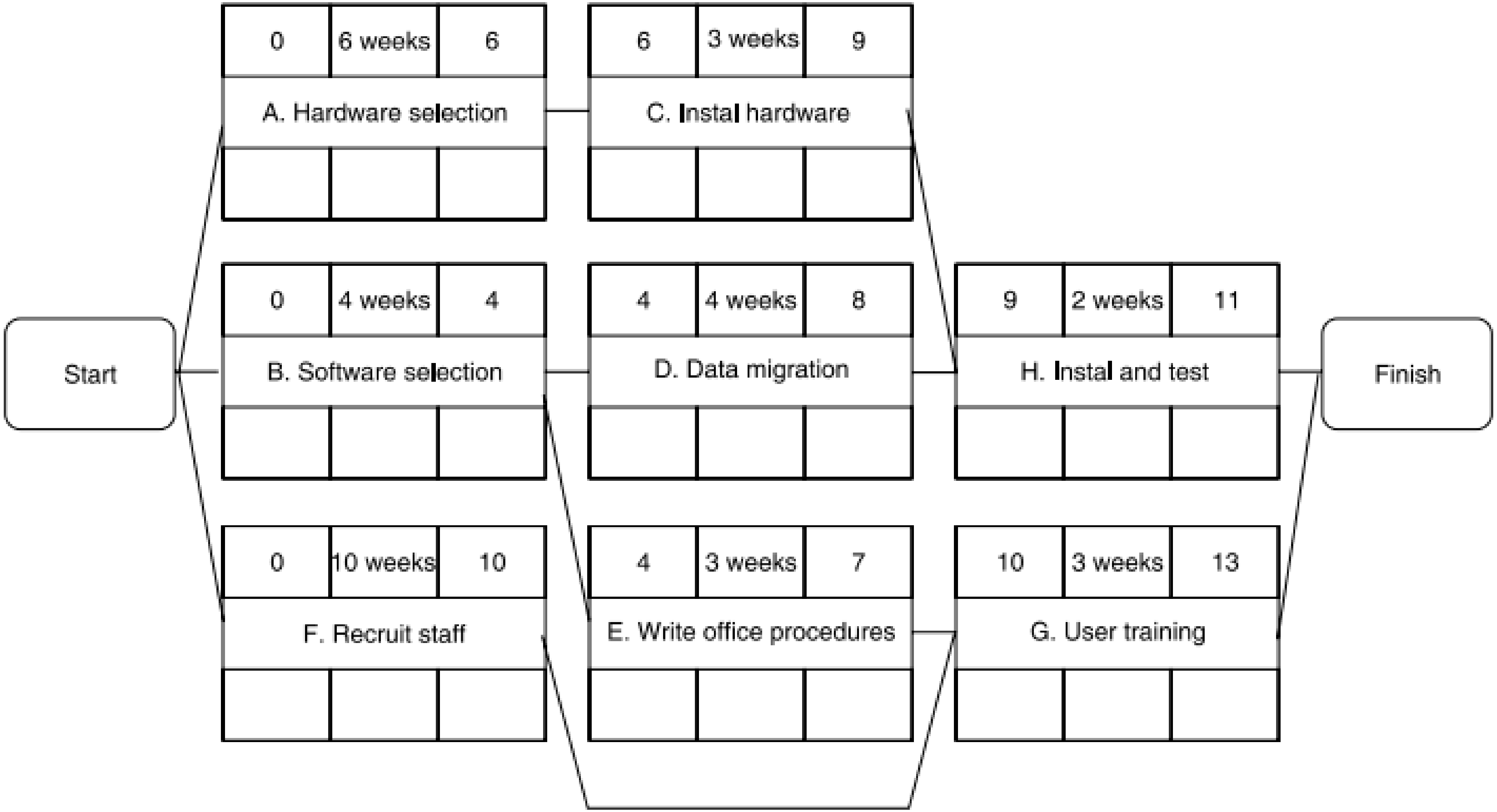


Fig 1b: The network after the forward pass.

Backward pass

- The second stage in the analysis of a critical path network is to carry out a backward pass to calculate the latest date at which each activity may be started and finished without delaying the end date of the project.
- **The backward pass rule:** the latest finish date for an activity is the latest start date for the activity that commences immediately that activity is complete. Where more than one activity can commence we take the earliest of the latest start dates for those activities.
- The latest activity dates are calculated as follows.
  - The latest completion date for activities G and H is assumed to be week 13.
  - Activity H must therefore start at week 11 at the latest (13 – 2) and the latest start date for activity G is week 10 (13 – 3).
  - The latest completion date for activities C and D is the latest date at which activity H must start – that is, week 11. They therefore have latest start dates of week 8 (11 – 3) and week 7 (11 – 4) respectively.
  - Activities E and F must be completed by week 10 so their earliest start dates are weeks 7 (10 – 3) and 0 (10 – 10) respectively.

- Activity B must be completed by week 7 (the latest start date for both activities D and E) so its latest start is week 3 (7 – 4).
- Activity A must be completed by week 8 (the latest start date for activity C) so its latest start is week 2 (8 – 6).
- The latest start date for the project start is the earliest of the latest start dates for activities A, B and F. This is week zero. This is, of course, not very surprising since it tells us that if the project does not start on time it won’t finish on time.

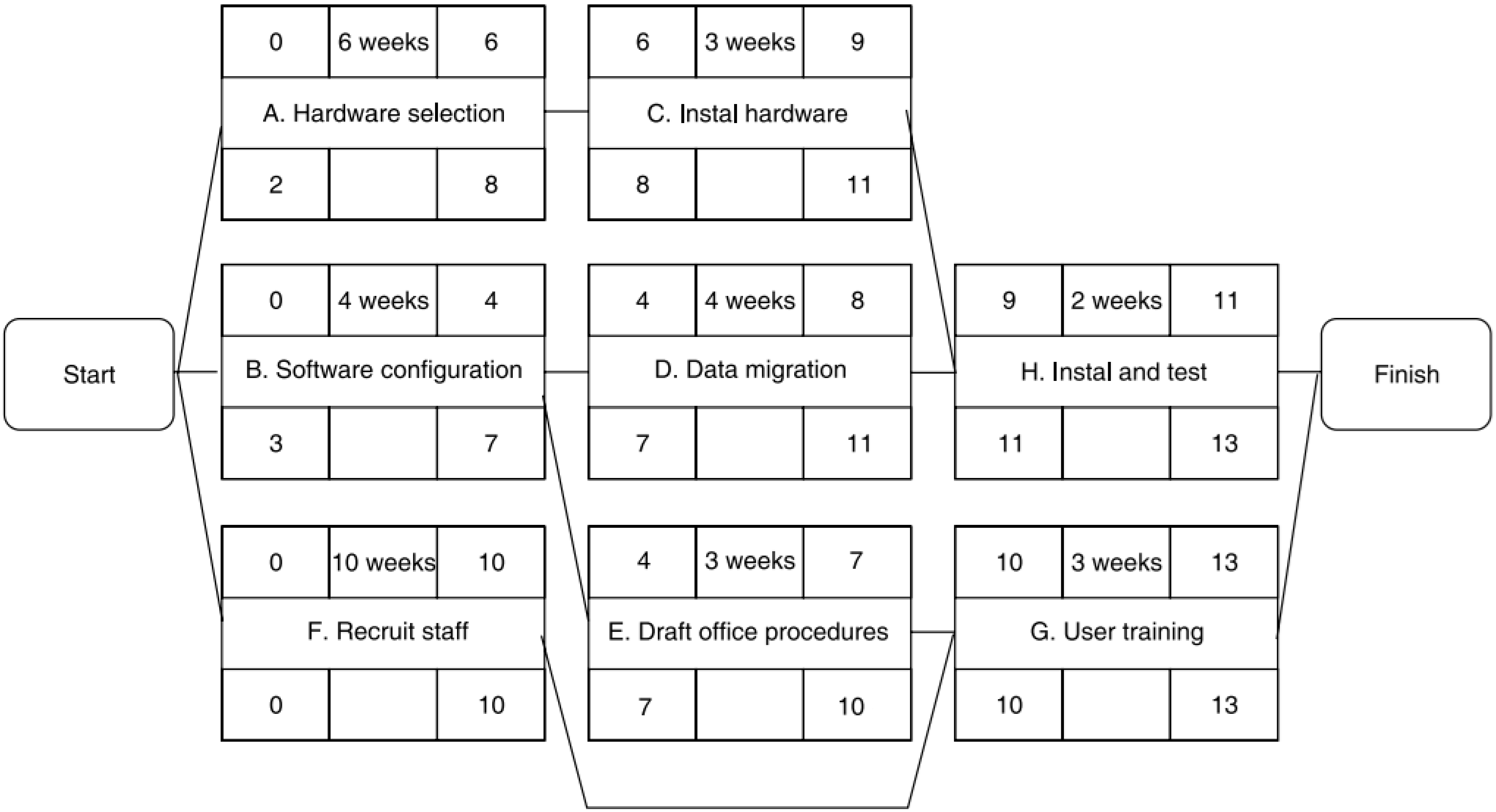


Fig 1c: The network after the backward pass.

Activity Float

- In project management, float, sometimes also referred to as “slack,” is a number that indicates the amount of time a task can be delayed without impacting subsequent tasks or the project's overall completion. It's important to track when you are maintaining your project schedule.
- There are two types of float:

  1. Total float is the amount of time a task or a project can be delayed without impacting the overall project completion time.

  $$Total\ Float = LF - EF$$

  $$Total\ Float = LS - ES$$

  Both of these formulas produce the same result

  ***2.* Free float** is the amount of time that a task can be delayed without impacting the subsequent task.

  $$Free\ Float = (ES_2 - EF_1)$$

Critical Path Method(CPM)

- The critical path is a single path that defines the duration of the project.
- Activity float is a measure which calculates the difference between the activity’s earliest start date and the latest start date.
- An activity with a float value to be zero is called critical because delay in carrying out the activity will affect the project completion date.
- Free float is the delay time taken by single activities that do not affect other activities where as interfering float represents how much the activity can be delayed without affecting the end date.
- At least one path exists in the network joining the critical activities which forms the critical path of the network.
- Critical path must be established because monitoring critical activities have a greater impact on the completion of the project and it shortens the overall duration of the project.
- To determine the critical path a network diagram is necessary, there are two types of network diagrams:
    1. Activity-on-arrow (AOA)
    2. Activity-on-node (AON)

1. Activity-on-Arrow Networks

- The developers of the CPM and PERT methods both originally used activity-on-arrow networks. Although now less common than activity-on-node networks, they are still used and introduce an additional useful concept – that of events.
- In activity-on-arrow networks activities are represented by links (or arrows) and the nodes represent events of activities (or groups of activities) starting or finishing.
- **Activity-on-arrow network rules and conventions**
  - A project network may have only one start node
  - A project network may have only one end node
  - A link has duration
  - Nodes have no duration
  - Time moves from left to right
  - Nodes are numbered sequentially
  - A network may not contain loops
  - A network may not contain dangles

Example:

Activity		Duration (weeks)	Precedents
A	Hardware selection	6	
B	System configuration	4	
C	Instal hardware	3	A
D	Data migration	4	B
E	Draft office procedures	3	B
F	Recruit staff	10	
G	User training	3	E, F
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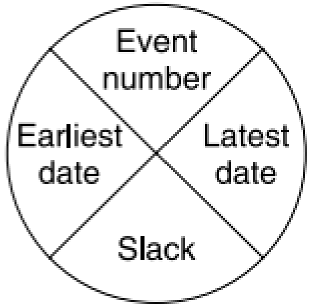
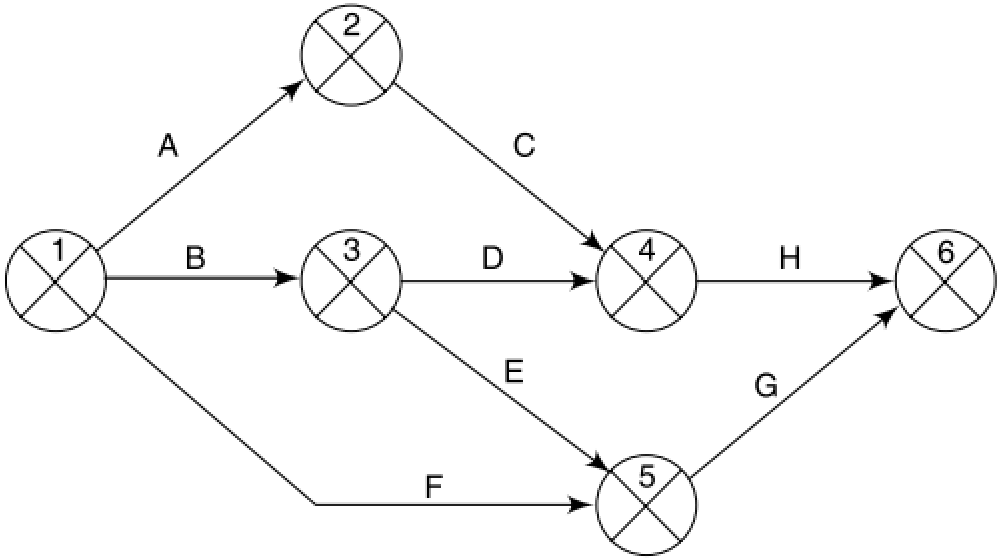




A. Draw the Network Diagram

Fig: An activity-on-arrow network.

B. Forward pass

- The forward pass is carried out to calculate the earliest date on which each event may be achieved and the earliest dates on which each activity may be started and completed.
- The earliest date for an event is the earliest date by which all activities upon which it depends can be completed.
  - Activities A, B and F may start immediately, so the earliest date for event 1 is zero and the earliest start date for these three activities is also zero.
  - Activity A will take 6 weeks, so the earliest it can finish is week 6 (recorded in the activity table). Therefore, the earliest we can achieve event 2 is week 6.
  - Activity B will take 4 weeks, so the earliest it can finish and the earliest we can achieve event 3 is week 4.
  - Activity F will take 10 weeks, so the earliest it can finish is week 10 – we cannot, however, tell whether or not this is also the earliest date that we can achieve event 5 since we have not, as yet, calculated when activity E will finish.

- Activity E can start as early as week 4 (the earliest date for event 3) and, since it is forecasted to take 3 weeks, will be completed, at the earliest, at the end of week 7.
- Event 5 may be achieved when both E and F have been completed, that is, week 10(the later of 7 and 10).
- Similarly, we can reason that event 4 will have an earliest date of week 9. This is the later of the earliest finish for activity D(week 8) and the earliest finish for activity C(week 9).
- The earliest date for the completion of the project, event 6, is therefore the end of week 13 – the later of 11(the earliest finish for H) and 13(the earliest finish for G).

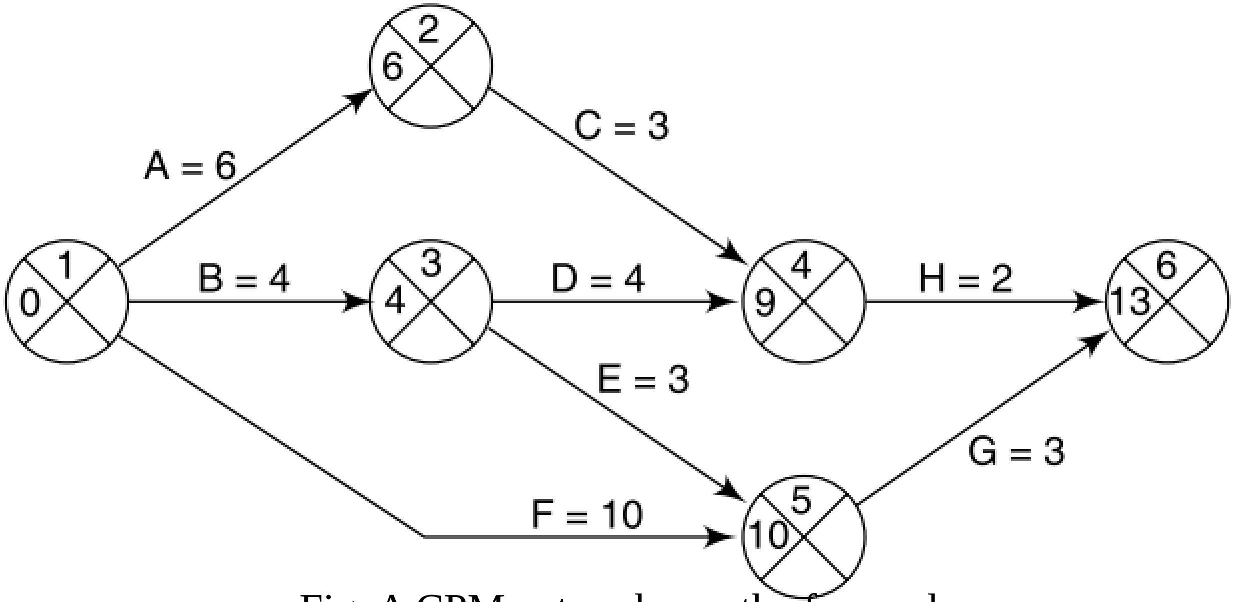


Fig: A CPM network a er the forward pass.

Table. The activity table after the forward pass.

Activity	Duration (weeks)	Earliest start date	Latest start date	Earliest finish date	Latest finish date	Total float
A	6	0		6		
B	4	0		4		
C	3	6		9		
D	4	4		8		
E	3	4		7		
F	10	0		10		
G	3	10		13		
H	2	9		11		

C. Backward pass ,backward pass to calculate the latest date at which each event may be achieved, and each activity started and finished, without delaying the end date of the project.

- The latest date for an event is the latest date by which all immediately following activities must be started for the project to be completed on time.
- As with activity-on-node networks, we assume that the latest finish date for the project is the same as the earliest finish date – that is, we wish to complete the project as early as possible

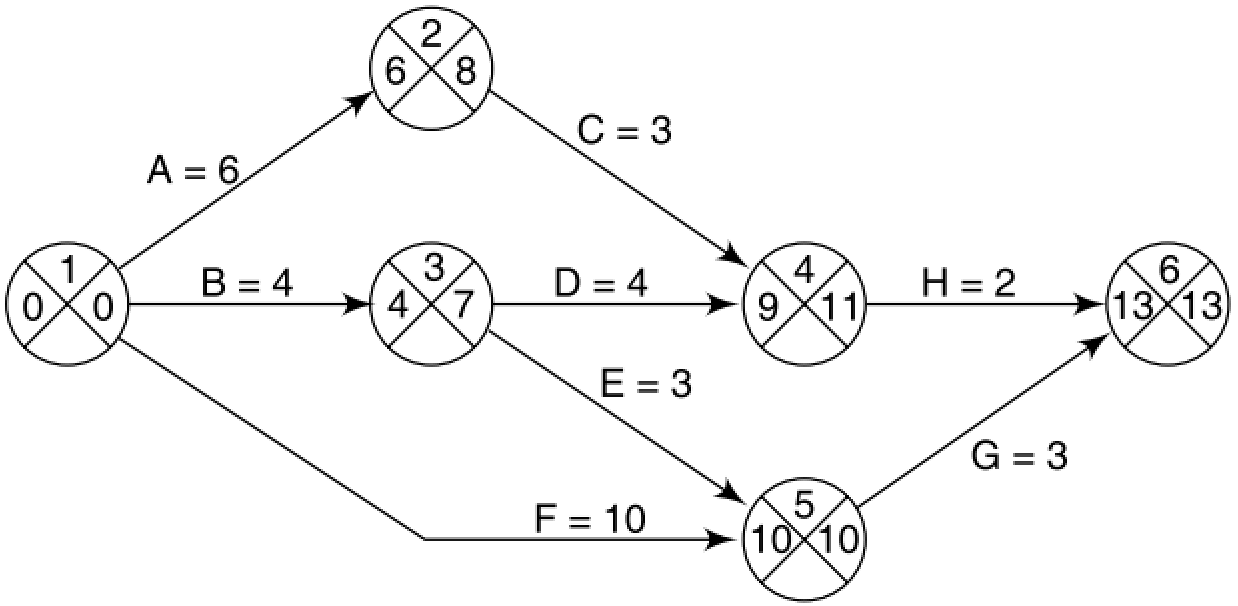


Fig: The CPM network after the backward pass.

Table. The activity table following the backward pass.

Activity	Duration (weeks)	Earliest start date	Latest start date	Earliest finish date	Latest finish date	Total float
A	6	0	2	6	8	
B	4	0	3	4	7	
C	3	6	8	9	11	
D	4	4	7	8	11	
E	3	4	7	7	10	
F	10	0	0	10	10	
G	3	10	10	13	13	
H	2	9	11	11	13	

D. Identifying the critical path

- **The critical path is the longest path through the network.**
- The **slack**, in identifying the path. (*Total Float/Slack) = LF – EF*
- Slack is the difference between the earliest date and the latest date for an event – it is a measure of how late an event may be without affecting the end date of the project.
- The critical path is the path joining all nodes with a zero slack .

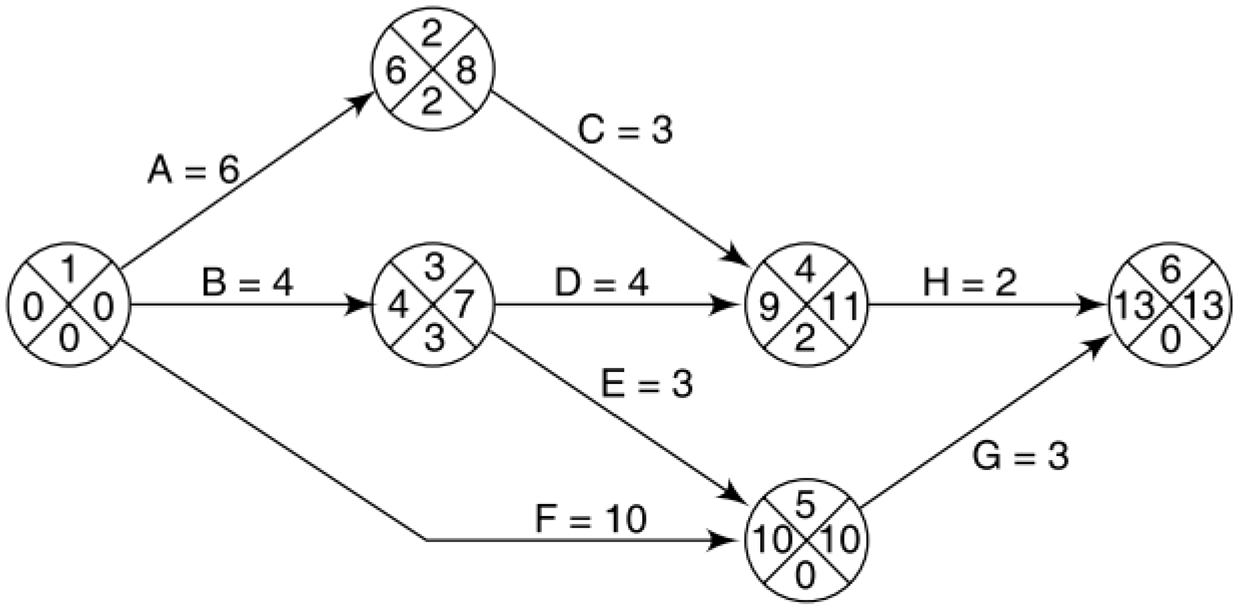


Fig: The critical path.

2. Activity-on-Node

For Example:

- Determining the critical path requires five steps:
  - A. Draw the Network Diagram
  - B. Enter task durations
  - C. Perform the Forward Pass
  - D. Perform the Backward Pass
  - E. Enter floats

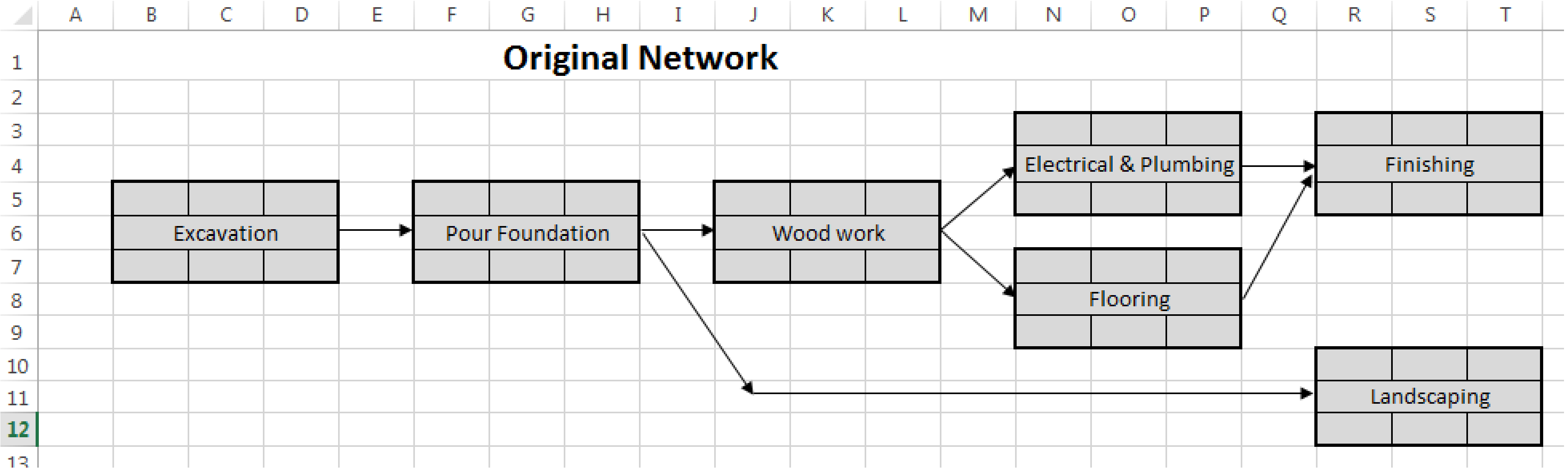
- Here's a hypothetical task list for a driveway construction project. This is often known as a "Dependency Table," a "Precedence Table," or a "Work Breakdown Structure."

Task List			
Task ID	**Name**	**Durations**	**Dependencies**
110	Excavation	6 days	
120	Pour Foundation	10 days	110
210	Wood work	20 days	120
310	Electrical & Plumbing	10 days	210
320	Flooring	8 days	210
330	Finishing	12 days	310,320
410	Landscaping	14 days	120

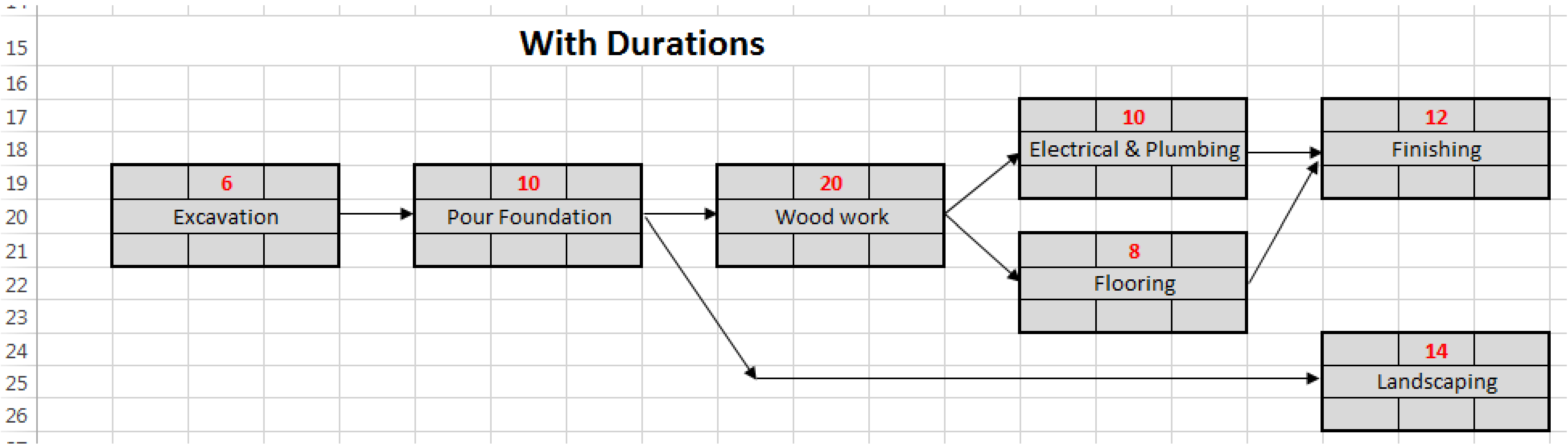
A. Drawing the Network Diagram : To determine the critical path a network diagram is necessary. Just for clarity, there are two types of network diagrams:

1. Activity-on-arrow (AOA), 2. Activity-on-node (AON)

The Activity-on-arrow approach has largely been deprecated in favor of Activity-on-node, therefore we will uses AON here. This can be done in MS Excel in the absence of dedicated project management software



B. Enter Task Durations : To start, simply enter the task durations into the top middle box.

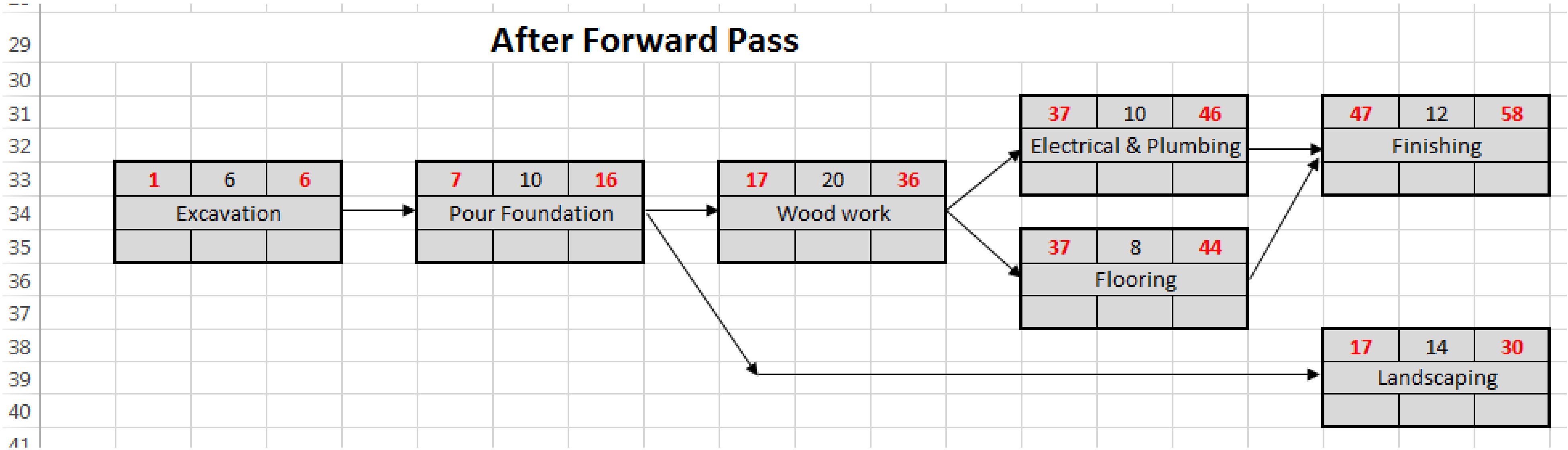


C. Perform the Forward Pass : The forward pass determines the Earliest Start (ES) and Earliest Finish (EF) of each task. These are defined as follows:

- ***Earliest Start (ES):*** The earliest date that the task can start.
- ***Earliest Finish (EF):*** The earliest date that the task can finish.

- The forward pass also defines the project completion date, because once the Earliest Finish of the final task is determined you can simply add the task's duration to obtain the completion date of the project.

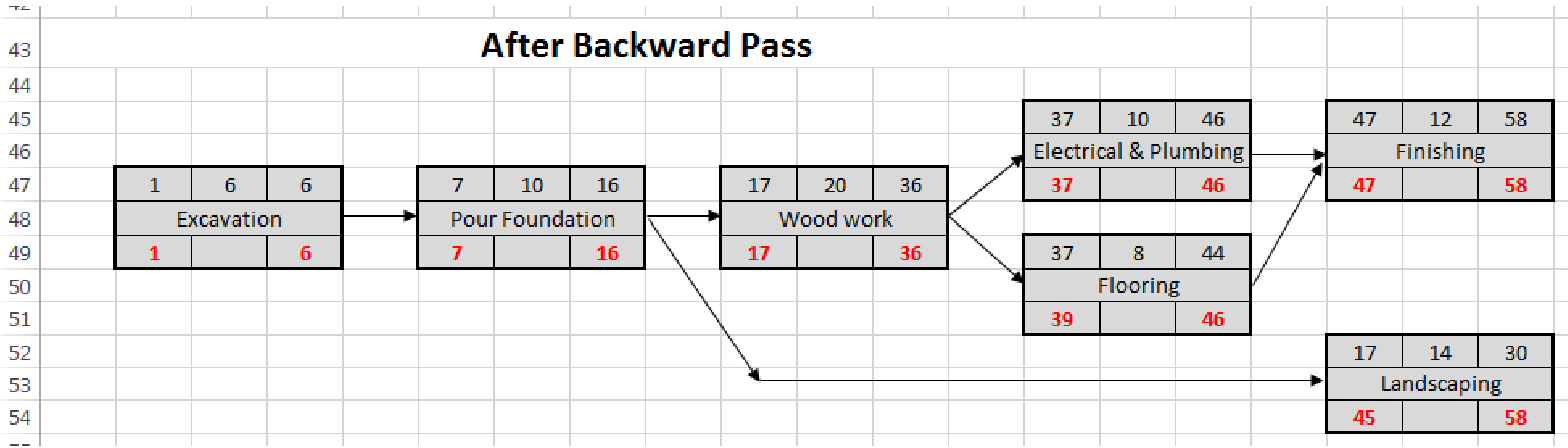
- To perform a forward pass, start at the left hand side of the network diagram and proceed to the right:
  - Start by entering a "1" in the top left box of the first task. This represents day 1, the starting date for the project, and earliest start (ES) date of the first task.
  - Determine the earliest finish (EF) of the first task and enter it into the top right box. $EF = ES + Duration - 1$. Note that the ES and EF dates are both inclusive of the task duration, therefore a one needs to be subtracted.
  - Proceed to the ES of the second task. $ES_2 = EF_1 + 1$. The ES of each task is simply one day after the EF of the previous task.
  - Proceed through each task by entering the ES and then the EF. When you have two EF's to choose from, as you do with task 330, Finishing, choose the ***higher*** one.



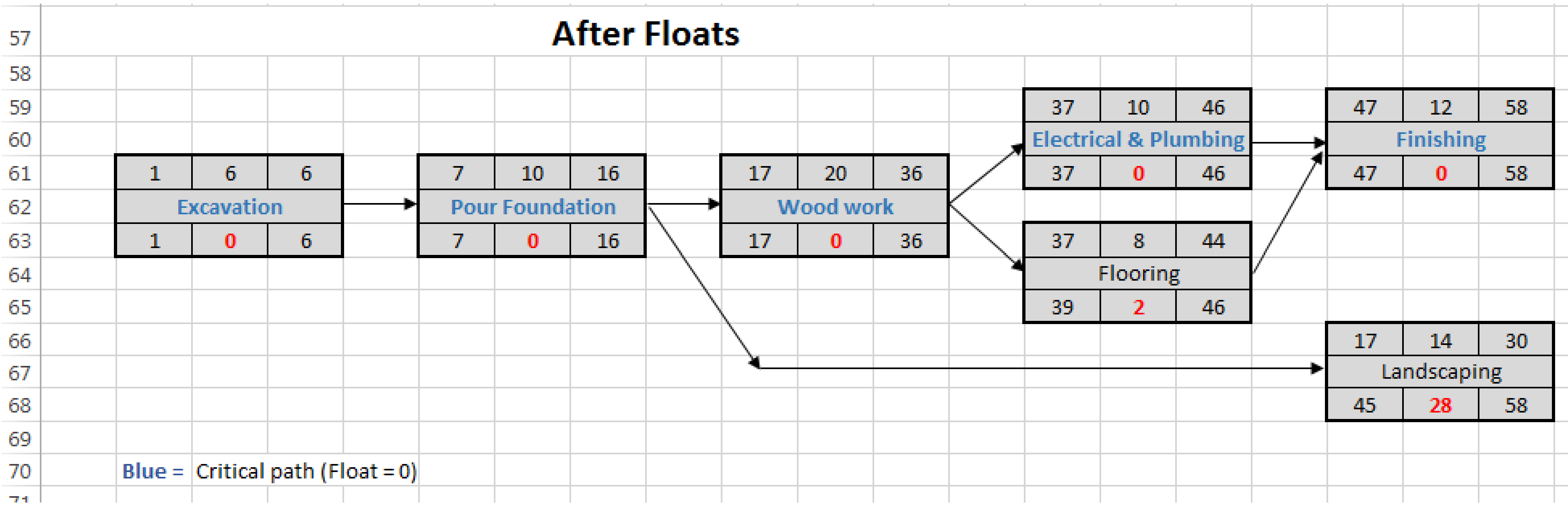
D. Perform the Backward Pass : The backward pass starts from the right side of the network diagram and proceeds to the left. It determines the Latest Start (LS) and Latest Finish (LF) of each task. These are defined as follows:

- ***Latest Start (LS):*** The latest date that the task can start.
- ***Latest Finish (LF):*** The latest date that the task can finish.

- The sequence to performing a backward pass are:
  - Start by choosing the highest EF of the final tasks, from the forward pass, and enter it into the bottom right box for each final task. In this case, 330 – Finishing, and 410 – Landscaping are both final tasks. The higher EF is 58. This value goes into the LF for both.
  - Determine the latest start (LS) and enter it into the bottom left box. $LS = LF - Duration + 1$.
  - Proceed to the LF of the previous task. $LF_1 = LS_2 - 1$.
  - Proceed through each task by entering the LF and then the LS. When you have two LF's to choose from, as you do with task 210 – Wood work, choose the ***lower*** one.



E. Enter Floats : Enter the float for each task in the bottom, center box. *Float = LS – ES*.



PERT (Project Evaluation Review Technique)

- A PERT chart is a project management tool used to schedule, organize, and coordinate tasks within a project. PERT stands for Program Evaluation Review Technique, a methodology developed by the U.S. Navy in the 1950s to manage the Polaris submarine missile program. It has the potential to reduce both the time and cost required to complete a project.
- PERT uses time as a variable which represents the planned resource application along with performance specification.
- In this technique, first of all, the project is divided into activities and events. After that proper sequence is ascertained, and a network is constructed. After that time needed in each activity is calculated and the critical path (longest path connecting all the events) is determined.
- The PERT method employs simple statistic calculations. It uses three-time estimations.
    - **Optimistic Estimate:** The shortest time required to complete the task.
    - **Pessimistic Estimate:** The longest time required to complete the task.
    - **Most Likely Estimate:** The most possible time (probable duration) required to complete the task.

Differences Between the PERT Method and CPM

- PERT is a project management technique, whereby planning, scheduling, organizing, coordinating and controlling of uncertain activities is done. CPM is a statistical technique of project management in which planning, scheduling, organizing, coordination and control of well-defined activities takes place.
- In the Critical Path Method activity durations are well defined but in *PERT Method*, time estimations are uncertain.
- The Critical Path Method is a method of control of time and costs, however, PERT is a technique of planning and control of time.
- There are three estimates in PERT such as optimistic, pessimistic, and most likely. In the Critical Path Method, there is only one estimate.
- PERT is set according to events while CPM is aligned towards activities.
- PERT technique is best suited for a high precision time estimate, whereas CPM is appropriate for a reasonable time estimate.
- PERT deals with unpredictable activities, but CPM deals with predictable activities.
- There is a demarcation between critical and non-critical activities in CPM, which is not in the case of PERT.
- PERT is best for research and development projects, but CPM is for non-research projects like construction projects.

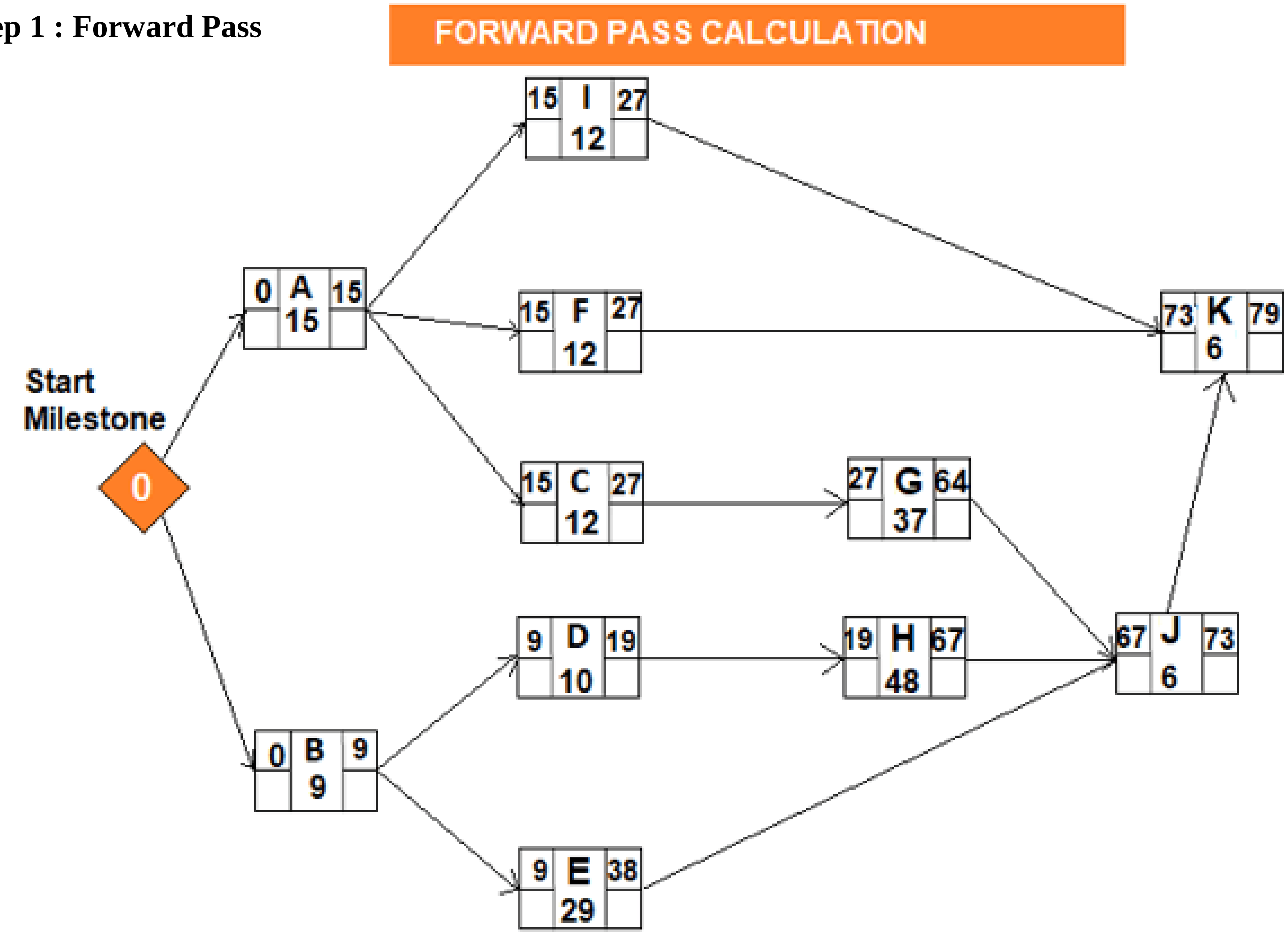
- Expected time is calculated with the help of the PERT Analysis formula below

Expected time = (Optimistic + 4 * Most likely + Pessimistic) / 6

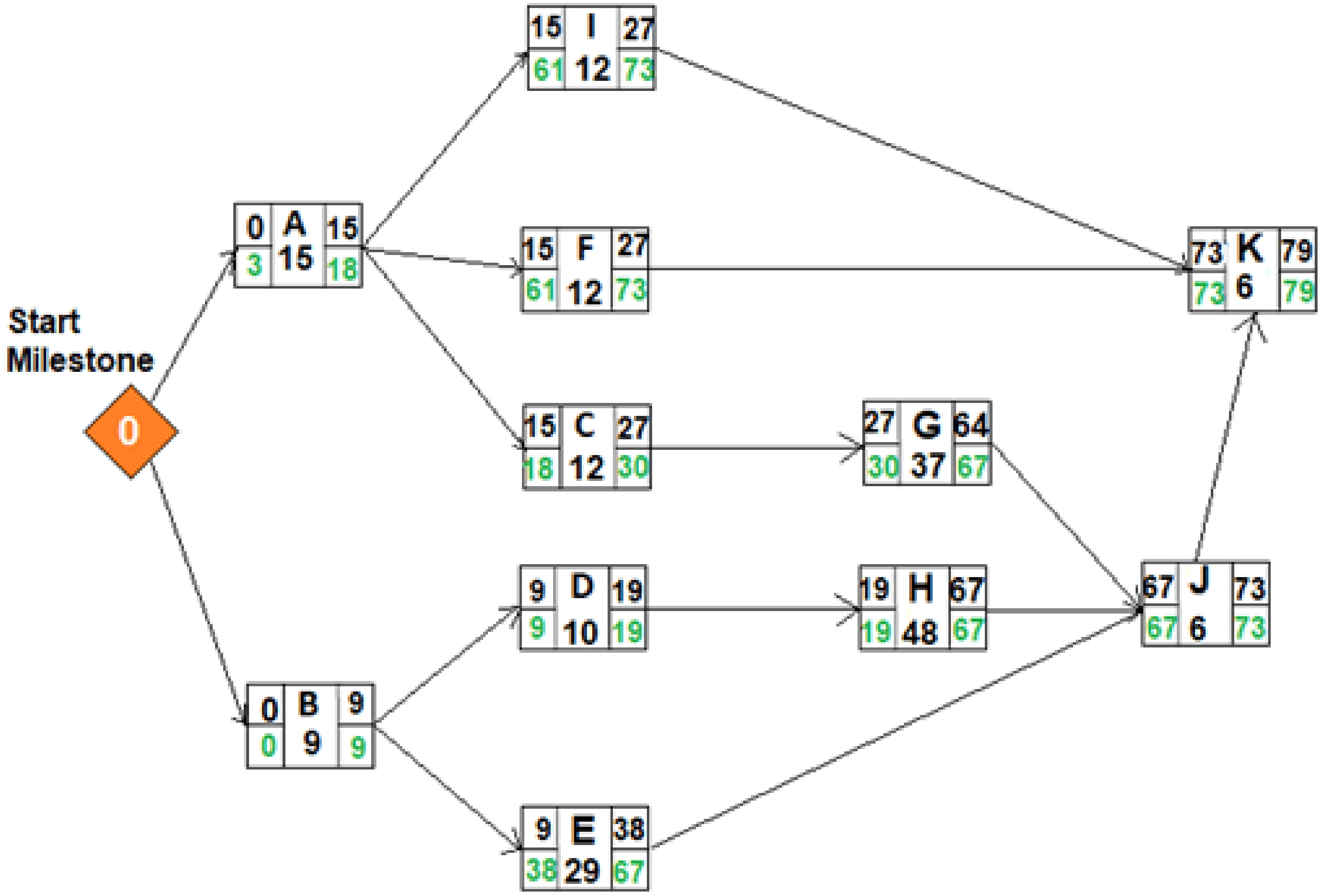
Example:

Activity	Description	Predecessors	Optimistic Duration (To)	Pessimistic Duration (Tp)	Most likely Duration (Tm)	Expected Duration (To + 4Tm + Tp)/6
0	Start Milestone	-	0	0	0	0
A	Select Technical Staff	0	12	18	15	15
B	Site Survey	0	6	12	9	9
C	Select Equipments	A	9	15	12	12
D	Prepare Designs	B	6	18	9	10
E	Bring Utilities to the Site.	B	18	36	30	29
F	Interview Applicants and Fill Positions	A	9	15	12	12
G	Purchase the Equipment.	C	36	42	36	37
H	Construct the Power Plant	D	42	54	48	48
I	Develop an Information System.	A	6	18	12	12
J	Install the Equipment.	H,G,E	3	9	6	6
K	Train the Staff to Run the System	F,J,I	3	9	6	6

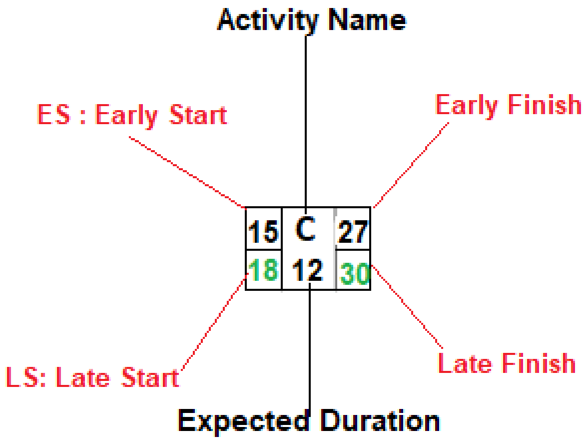
Step 1 : Forward Pass



BACKWARD PASS CALCULATION



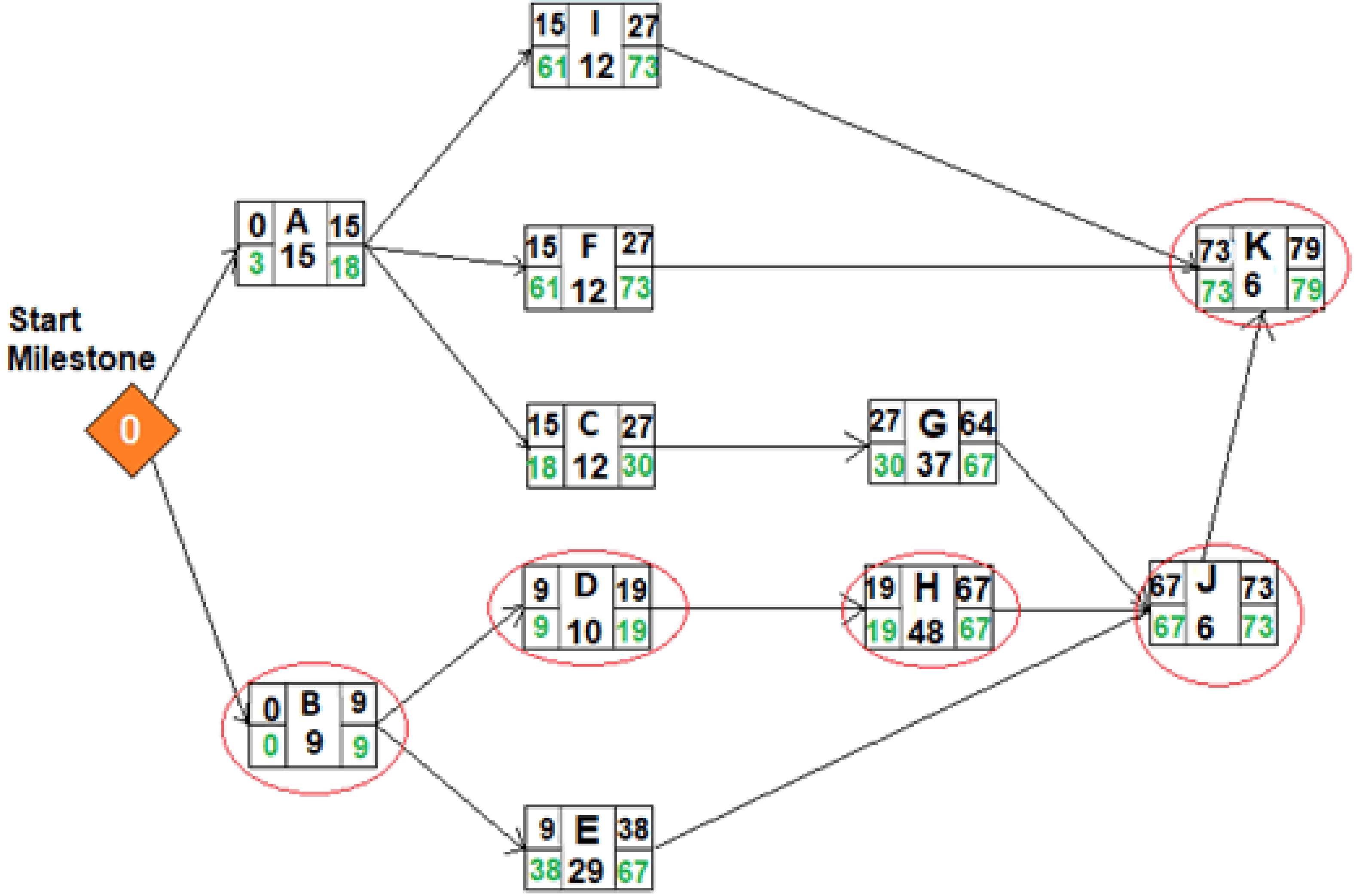
- After completing the backward pass calculation, you can easily determine the critical path.
- In project management, “float” or “slack” is the amount of time that a task can be delayed without affecting the deadlines of other subsequent tasks, or the project’s final delivery date.
- Total float/slack is 0 on the critical path.



- Total Float: LS – ES = 18-15 = 3
- Total Float: LF – EF = 30-27 = 3

- The total float can be calculated by subtracting the Early Start date of an activity from its Late Start date or Early Finish date from its Late Finish date.

CRITICAL PATH



Benefits of PERT

- Expected project completion time.
- Probability of completion before a specified date.
- The critical path activities that directly impact the completion time.
- The activities that have slack time and that can lend resources to critical path activities.
- Activities start and end dates.

Limitations of PERT

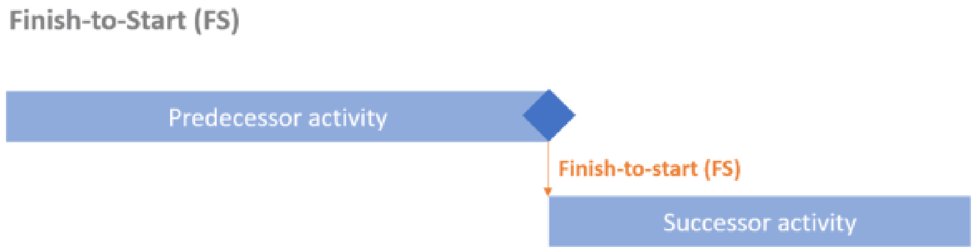
- The activity time estimates are somewhat subjective and depend on judgment. In cases where there is little experience in performing an activity, the numbers may be only a guess. In other cases, if the person or group performing the activity estimates the time there may be bias in the estimate.
- The underestimation of the project completion time due to alternate paths becoming critical is perhaps the most serious.

Precedence Diagramming Method (PDM)

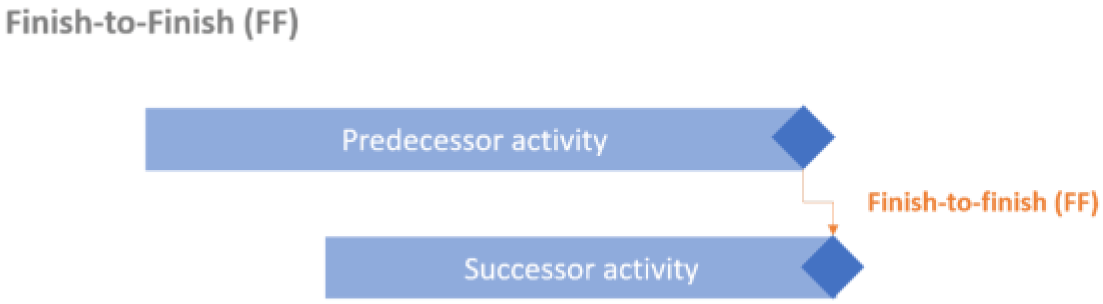
- The Program Evaluation and Review Technique (PERT) and Critical Path Method (CPM) techniques are essentially limited to “finish-start” relationships (i.e., activity B cannot start until activity A is completed).
- PDM was developed subsequent to the PERT/CPM techniques and its function is to permit a more accurate depiction of relationships among various activities.
- This diagram is often named as the activity-on-node (AON) method.
- Highlights relationships and dependencies among activities to ensure planning efficiency.
- Identifies possible missing activities.
- Helps identify critical activities to ensure better planning.
- Helps develop the overall project schedule.
- Good communication tool for project team members.

- Precedence diagramming method, four types of relationships are there in the activities to complete the network diagram of a project.

  - **Finish-to-Start (FS),** this means that the predecessor activity must be completed before the successor activity can start.

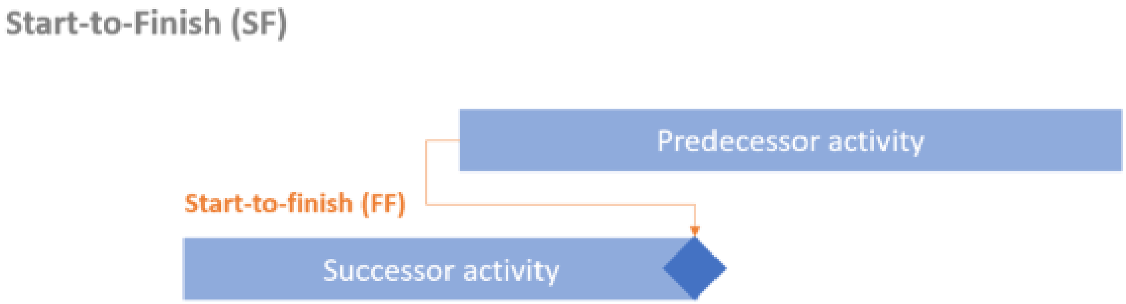


  - **Finish-to-Finish (FF),** a successor activity requires the predecessor activity to be finished before it can be completed.



- **Start-to-Start (SS),** , this means that the predecessor activity must have started before the successor activity can start.

- **Start-to-Finish (SF),** a predecessor activity must have started before the successor activity can be finished. In practice, this type of dependency does not occur very often.



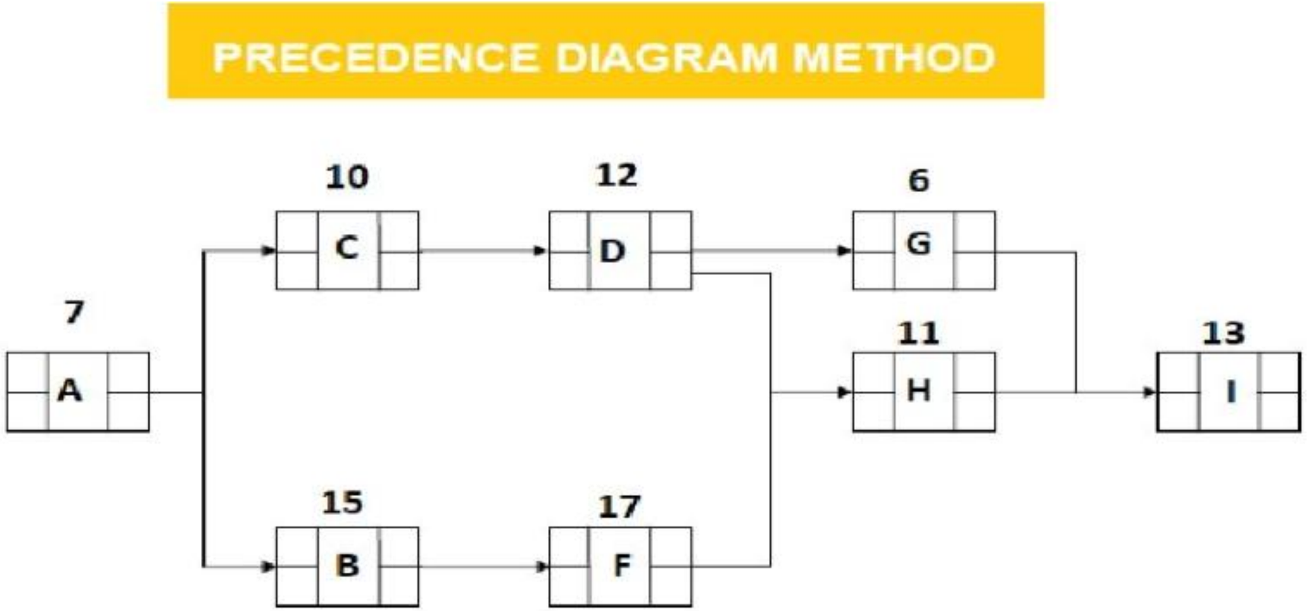
In this example A,B,C,D,F,G,H,I are the activities.

Numbers above the boxes are the durations.

Activity B is a predecessor activity that logically comes before a dependent activity F in this network system.

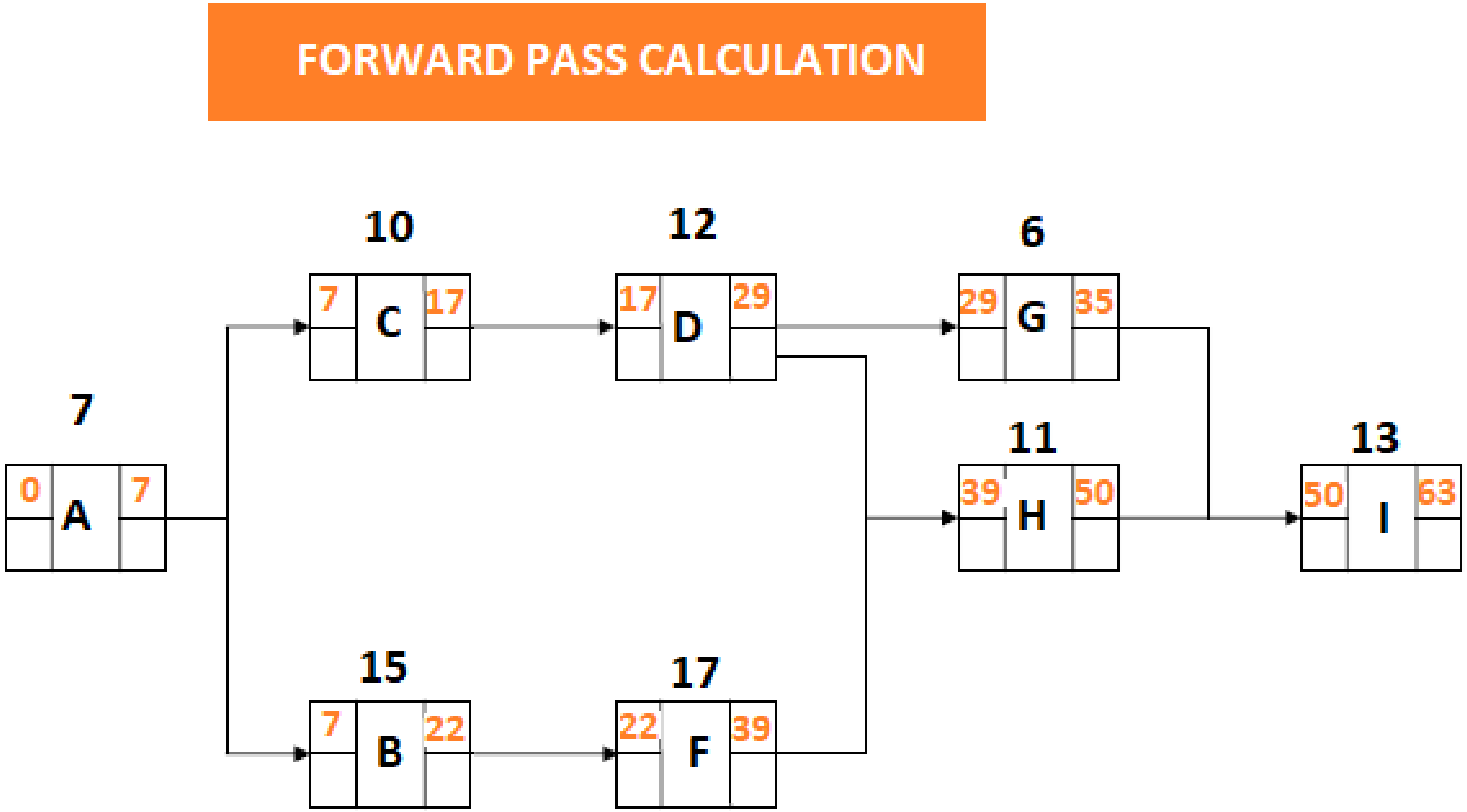
Activity F is a successor activity that logically comes after the Activity B.

There is a F-S Relationship between activity B and F.



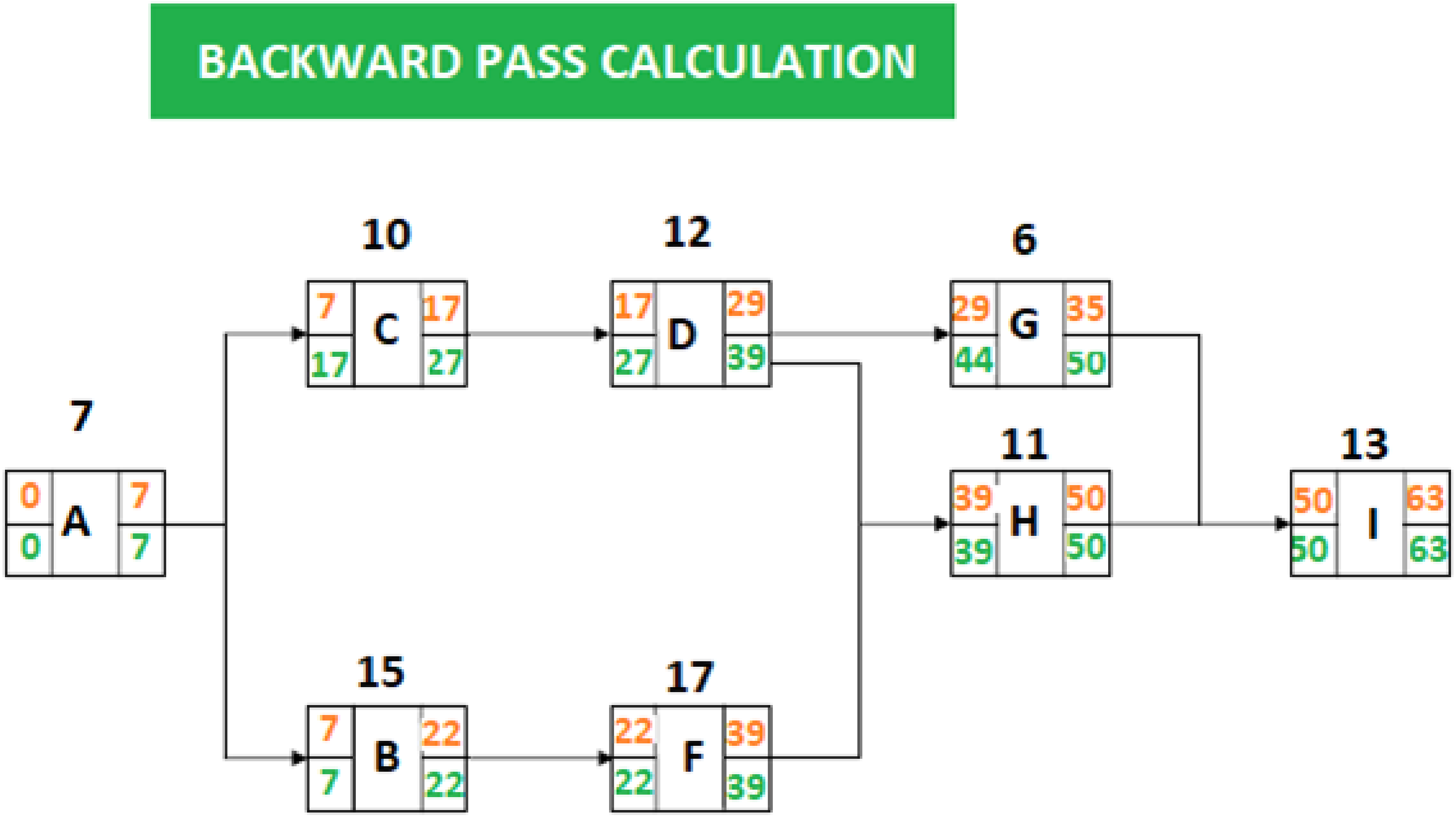
Step 1 : PDM Forward Pass Calculation

Forward Pass Calculations specify the minimum dates at which each activity can be performed and, ultimately, the minimum duration of a project.

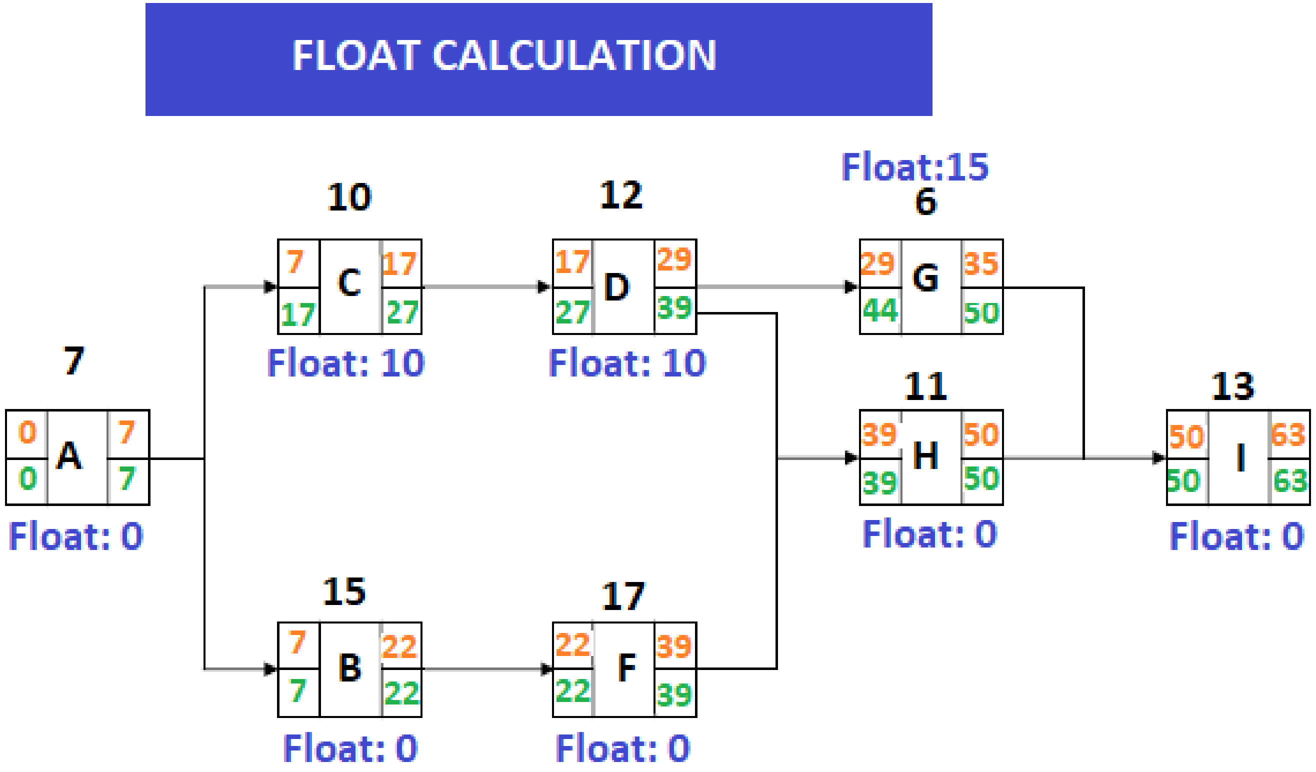


Step 2 : PDM Backward Pass Calculation

Backward Pass Calculations determine the latest dates by which each activity can be performed without increasing the projects minimum duration.



Step 3 : PDM Float Calculation for Each Activity



- Total float is the amount of time that an activity can be delayed without delaying the project completion date. Total float is 0 on the critical path.

Total Float: LS – ES = 17-7 = 10

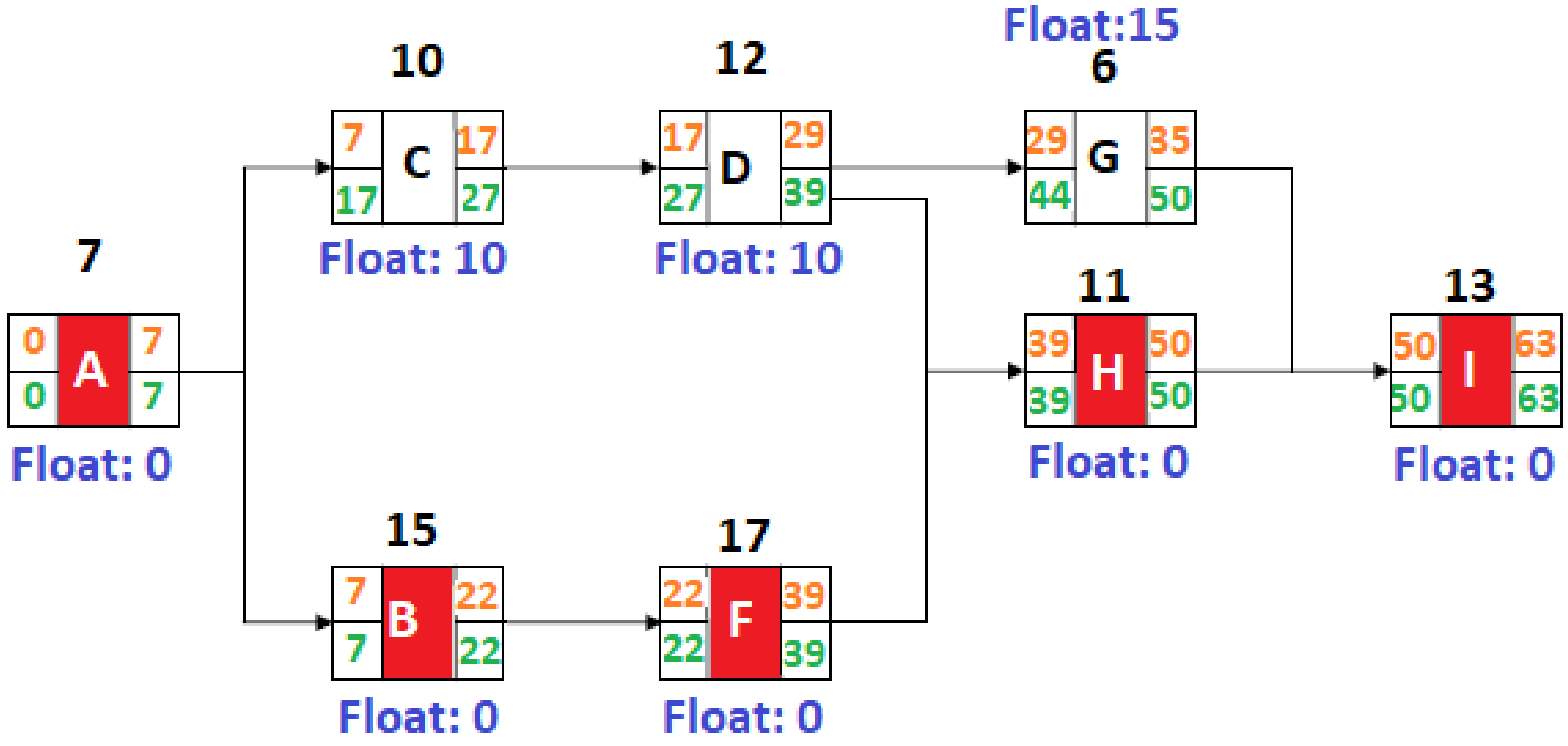
Total Float: LF – EF = 27-17 = 10

- Total float can be calculated by subtracting the Early Start date of an activity from its Late Start date or Early Finish date from its Late Finish date.

Step 4 : PDM Identifying the critical path

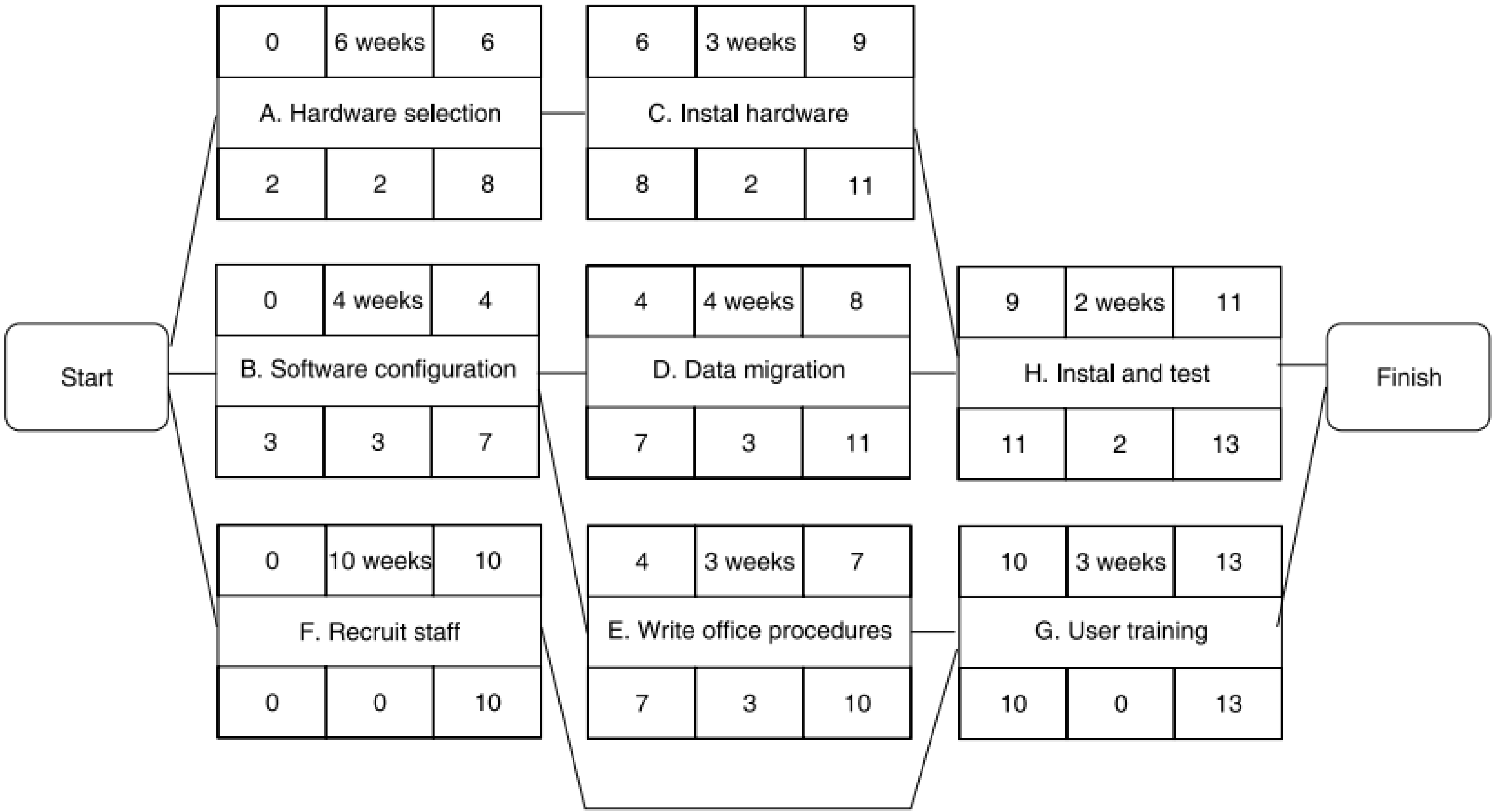
The critical path is the longest path in the network diagram and the total float of the critical path is zero.

CRITICAL PATH



Shortening the project duration

- If we wish to shorten the overall duration of a project we would normally consider attempting to reduce activity durations. In many cases this can be done by applying more resources to the task – working overtime or procuring additional staff, for example.
- The critical path indicates where we must look to save time – if we are trying to bring forward the end date of the project, there is clearly no point in attempting to shorten non-critical activities.
- Referring to Figure below, it can be seen that we could complete the project in week 12 by reducing the duration of activity F by one week (to 9 weeks)
- As we reduce activity times along the critical path we must continually check for any new critical path emerging and redirect our attention where necessary.
- What would the end date for the project be if activity F were shortened to 7 weeks? Why?


Start
0
6 weeks
6
A. Hardware selection
2
2
8
6
3 weeks
9
C. Instal hardware
8
2
11
0
4 weeks
4
B. Software configuration
3
3
7
4
4 weeks
8
D. Data migration
7
3
11
9
2 weeks
11
H. Instal and test
11
2
13
0
10 weeks
10
F. Recruit staff
0
0
10
4
3 weeks
7
E. Write office procedures
7
3
10
10
3 weeks
13
G. User training
10
0
13
Finish