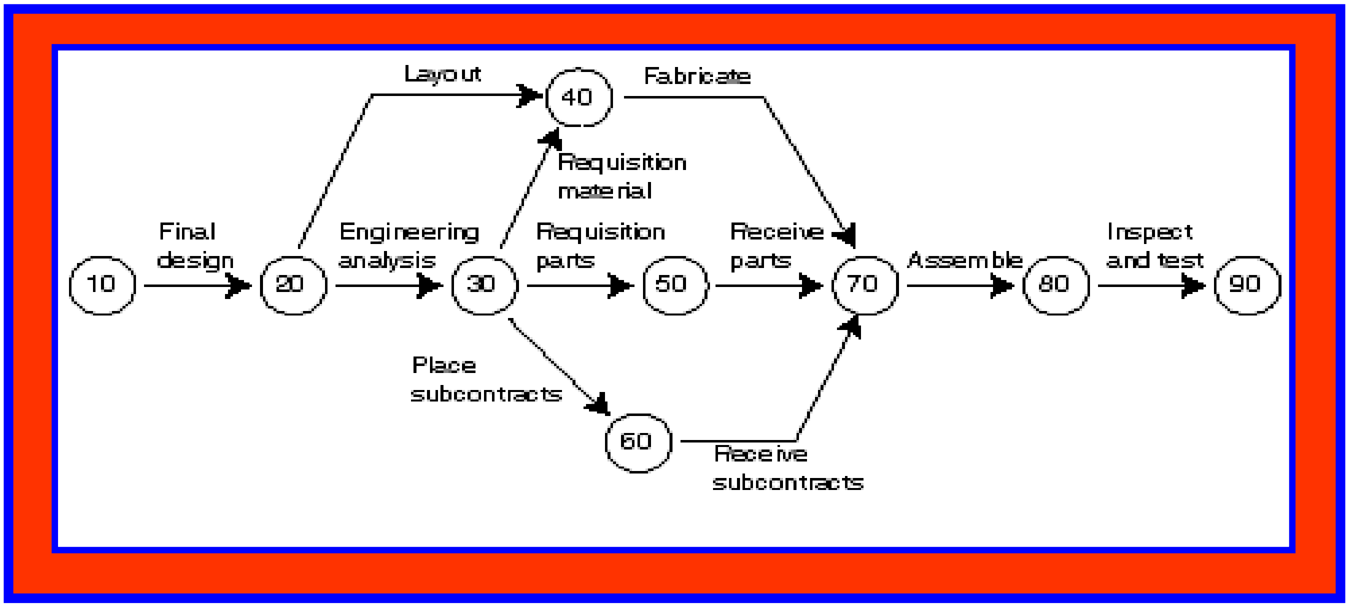
Critical Path Mapping with Activity Network Diagrams

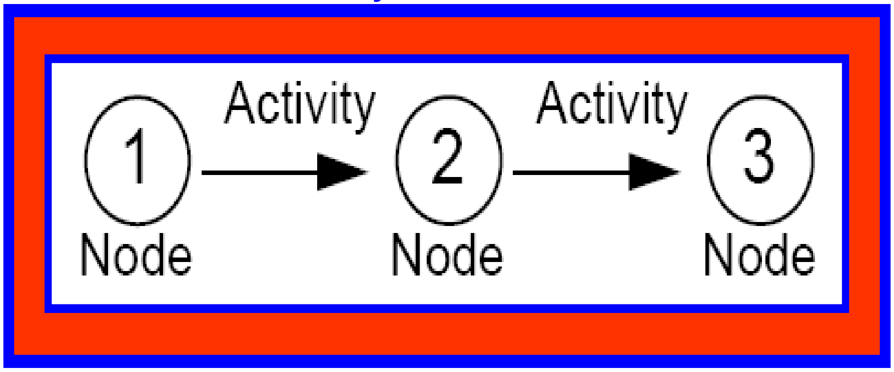


The activity network diagram is a method of displaying the timelines of all the various subtasks that are involved in any project. By doing this, the total task duration and the earliest and latest start and finish times for each task are also calculated and displayed.

In addition to showing which subtasks are critical to on-time task completion, the activity network diagram can help determine where extra effort to speed a subtask will have the greatest payoff to overall speed.

The activity network diagram has had a relatively long history, dating back to the 1930s. In the 1950s, the technique emerged as the Program Evaluation Research Technique (PERT) and as the Critical Path Method (CPM). There are several ways to represent the output of the PERT/CPM process.

Activity on arrows



The method called the activity-on-arrow or, more simply, the arrow diagram will be reviewed in this article. An arrow diagram treats numbered nodes as instantaneous stop/start points for activities. The activities themselves are considered to take place on the arrows connecting the nodes.

What can it do for you?

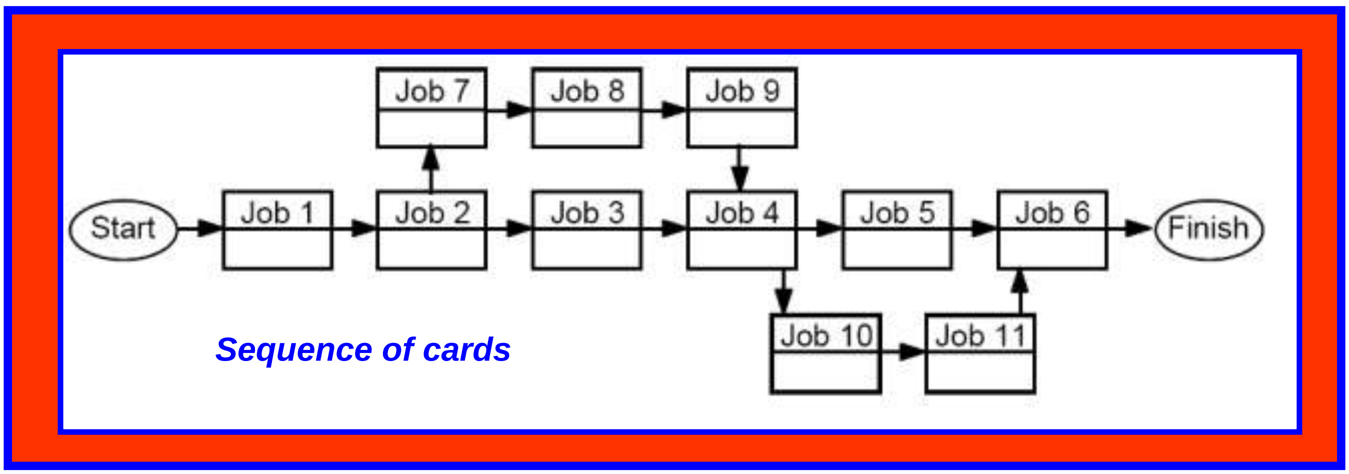
An activity network diagram can show you which activities or which series of activities is critical to the timing of a more complex collection of interactive activities. This can be very helpful in deciding where and when to apply extra energy to keep projects on time. Creating an activity network diagram is time-consuming, however, so you should consider these questions before you decide to create one:

1. Is the task a complex one with simultaneous paths that must be coordinated? Creating a diagram for a relatively simple task may be a waste of time.

2. Are the durations of the subtasks known with relative certainty? If the actual timing of events is markedly different from diagram times, it will have little value, and people will dismiss the diagram as a useless exercise.

3. Are the task and the timing of the task completion critical to the organization? The effort involved in creating a diagram should be applied to tasks that have little margin for timing error and have either serious consequences if completion of the overall task is delayed or large rewards if completion can be speeded.

Critical path mapping can be especially valuable in project bounding and in the measure and improve phases of the Lean Six Sigma methodology.



How do you do it?

1. Assemble the right team. The team must have either personal knowledge of the timing of all the subtasks involved or connection to that information. The team should include managers and other employees as close to the actual situation as possible.

2. Identify all of the subtasks necessary to complete the overall task. You might use brainstorming techniques or begin with a list of tasks from a previous project. Record the tasks so that you can rearrange them. A good way to do this is to write each job on the top half of a 3x5 card or Post-It™ note. (The bottom half of the card will be used for timing data later in the process.)

3. Put the activity cards in the sequence in which they must be performed to complete the overall task. To do this, create paths or strings of tasks that follow one after the other.

These strings will often describe sequences of activities that occur in parallel with each other. After all the activities are in some string or path of activities, create the overall sequence by connecting the paths. These connections will show where jobs or tasks require input from parallel sequences before the next task can begin. Feel free to add new cards for missing tasks or to remove duplicates.

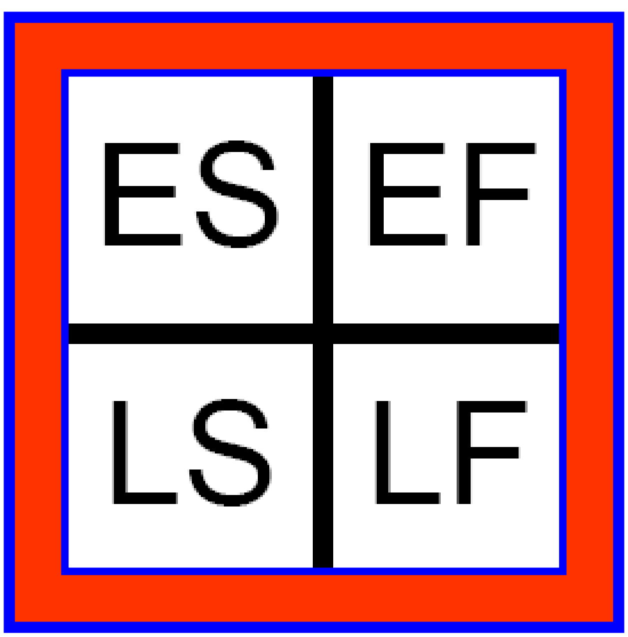
4. Assign time duration to each task or job. Write it on the bottom half of the card. Since you will be adding these times, keep the numbers consistent. For instance, do not have some cards showing days for completion, some showing hours and some showing minutes. Select the Lowest Common Denominator.

5. Calculate the shortest possible time within which the overall task can be completed by adding the times of each subtask to find the path of the longest cumulative duration. This is the critical path. Knowing the critical path is important because this will tell if the time objectives of the project are attainable. The critical path identifies those jobs or tasks that have no slack. Each must be done on time if the project is to stay on schedule. The critical path also identifies targets for improvement to increase speed. (If tasks on the critical path can be speeded, the overall time to complete the project may be able to be shortened. Remember, however, that if a task on the critical path is speeded up, a different path may become the critical path.)

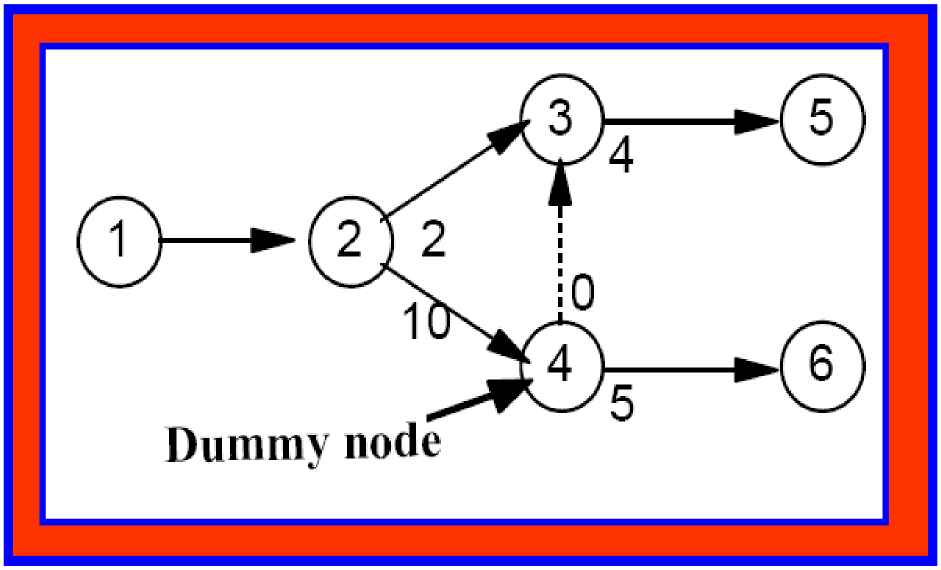
6. Calculate the earliest starting and finishing times and the latest starting and finishing times for each job or subtask in the project. Begin at the start of the diagram. The earliest start time for each job is the cumulative duration of all the previous jobs on that path.

The earliest finish time is the earliest start time plus the duration of that task. Repeat this process for each job on each path until you reach the finish point.

Next calculate the latest start and finish times. Begin with the earliest finish time at the end of the diagram. This is also the latest start and finish times is in a box like this:

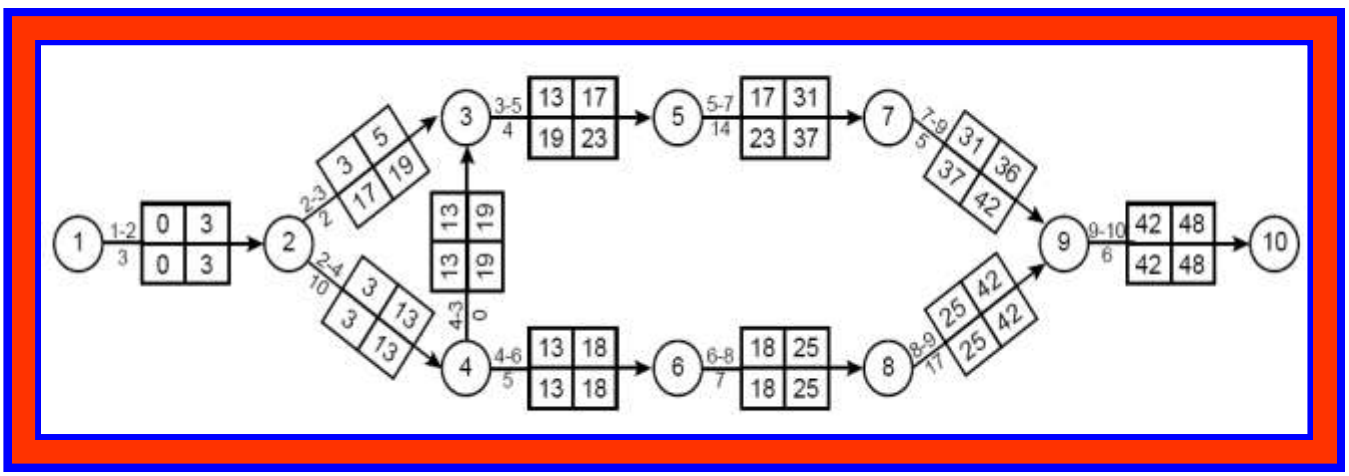


To calculate the slack time for any job or task, subtract the earliest start time from the latest start time. All of the jobs on the critical path, by definition, will have zero slack time. Remember that slack time is dependent on the time of completion of the previous job or task. If some of the slack time in a path other than the critical path is used in an early task, the slack times for the remaining tasks in that path will each be reduced by that amount.)



Note: *A dummy is an extra node symbol used to clarify an activity network diagram if one node has more than one job or task feeding into it from one other node. Since the diagram cannot show two activities coming from one node and going to another, a dummy node is created, with zero as the job duration shown on the arrow connecting them.*

7. Review the completed activity network diagram with the people who will be doing the work described by it. Consider any feedback. Expand or modify the diagram as necessary to fit the actual situation.



Now what?

As a tool, the activity network diagram is like a time-map of any time-sensitive project. As you are proceeding down the paths of the project, the map will help keep you on track. If you should falter or wander off the path, the map can be used to help get you back on the critical path. This description of the activity network diagram will help you to manually calculate and construct a process map.

Automated tools, such as SigmaFlow, are also available. SigmaFlow produces other valuable scheduling information, as well. Computer scheduling programs like SigmaFlow are able to easily deal with complex processes, recalculating times whenever you modify the data.

A critical path map can help uncover opportunities for increasing speed. Used in this fashion, critical path mapping is another tool to make the Lean Six Sigma method work smoothly. It is important to remember, however, that these diagrams, whether produced manually or by computer, are not intended to drive you, but to signal you if something is wrong.

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CPM/PERT

Project

- *"A project is a series of activities directed to accomplishment of a desired objective."*

Plan your work first.....then work your plan

Network analysis

Introduction

Network analysis is the general name given to certain specific techniques which can be used for the planning, management and control of projects.

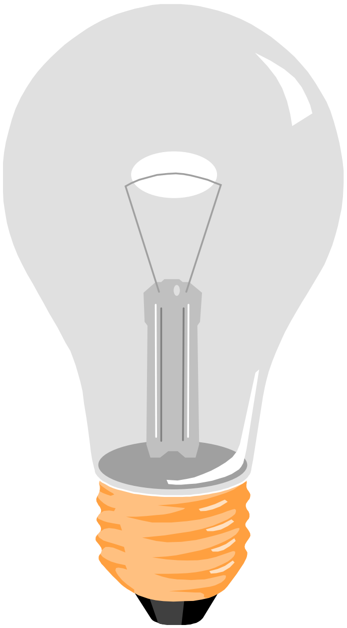
One definition of a project:

“A project is a temporary endeavour undertaken to create a "unique" product or service”

History

- Developed in 1950's
- CPM by DuPont for chemical plants
- PERT by U.S. Navy for Polaris missile

CPM was developed by Du Pont and the emphasis was on the trade-off between the cost of the project and its overall completion time (e.g. for certain activities it may be possible to decrease their completion times by spending more money - how does this affect the overall completion time of the project?)



PERT was developed by the US Navy for the planning and control of the Polaris missile program and the emphasis was on completing the program in the shortest possible time. In addition PERT had the ability to cope with uncertain activity completion times (e.g. for a particular activity the most likely completion time is 4 weeks but it could be anywhere between 3 weeks and 8 weeks).

CPM - Critical Path Method

- Definition: In **CPM** activities are shown as a network of precedence relationships using activity-on-node network construction
  - Single estimate of activity time
  - Deterministic activity times

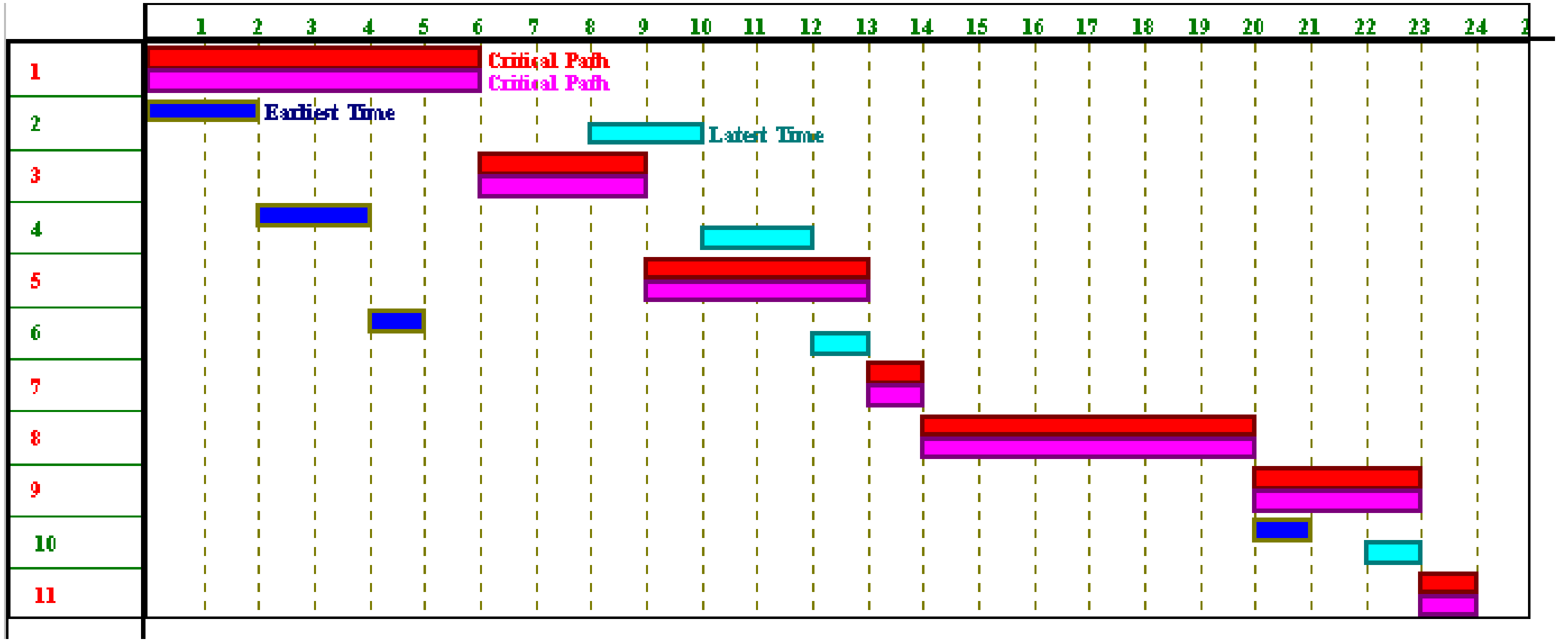
USED IN : Production management - for the jobs of repetitive in nature where the activity time estimates can be predicted with considerable certainty due to the existence of past experience.

PERT - Project Evaluation & Review Techniques

- Definition: In **PERT** activities are shown as a network of precedence relationships using activity-on-arrow network construction
  - Multiple time estimates
  - Probabilistic activity times

USED IN : Project management - for non-repetitive jobs (research and development work), where the time and cost estimates tend to be quite uncertain. This technique uses probabilistic time estimates.

Gantt chart



Originated by H.L.Gantt in 1918

Advantages

- Gantt charts are quite commonly used. They provide an easy graphical representation of when activities (might) take place.

Limitations

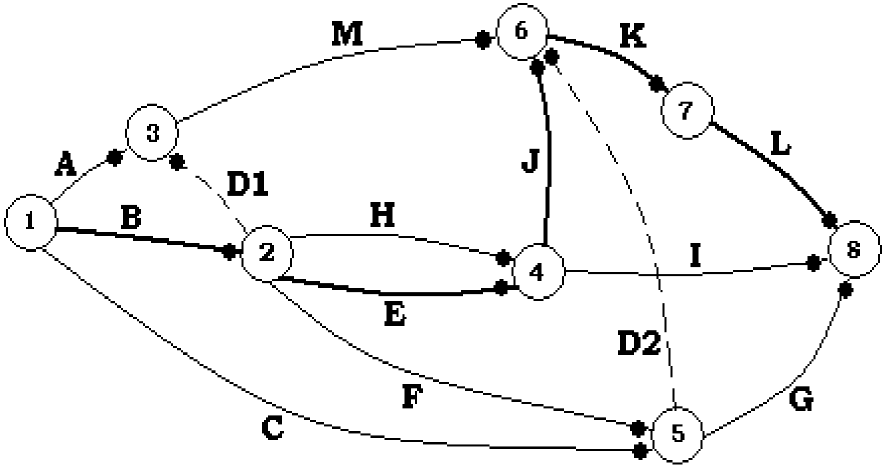
- Do not clearly indicate details regarding the progress of activities

- Do not give a clear indication of interrelation ship between the separate activities

CPM/PERT

These deficiencies can be eliminated to a large extent by showing the interdependence of various activities by means of connecting arrows called network technique.

- Overtime CPM and PERT became one technique
- ADVANTAGES:
  - Precedence relationships
  - large projects
  - more efficient



The Project Network

- Use of nodes and arrows

Arrows ➔ An arrow leads from tail to head directionally

– Indicate ACTIVITY, a time consuming effort that is required to perform a part of the work.

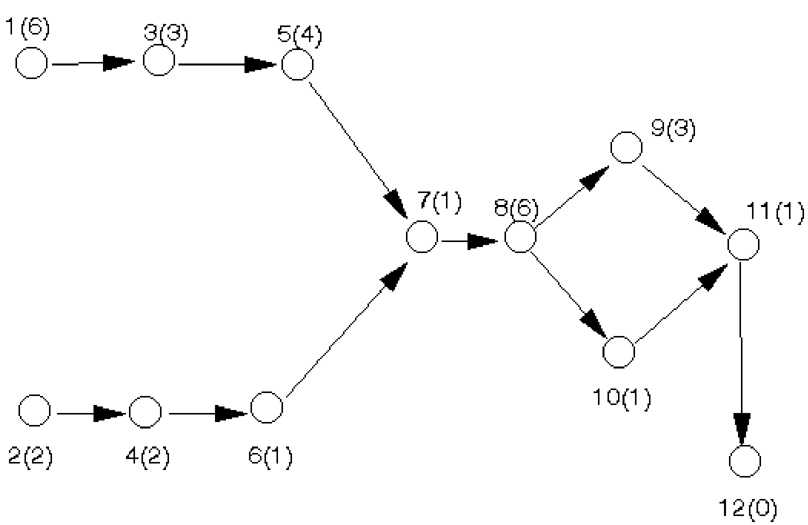
Nodes ● A node is represented by a circle

- Indicate EVENT, a point in time where one or more activities start and/or finish.

Activity on Node & Activity on Arrow

Activity on Node

- A completion of an activity is represented by a node



Activity on Arrow

- An arrow represents a task, while a node is the completion of a task
- Arrows represent order of events

Activity Slack

Each event has two important times associated with it :

- Earliest time , **Te** , which is a calendar time when a event can occur when all the predecessor events completed at the earliest possible times
- Latest time , **TL ,** which is the latest time the event can occur with out delaying the subsequent events and completion of project.

- Difference between the latest time and the earliest time of an event is the slack time for that event

Positive slack : Slack is the amount of time an event can be delayed without delaying the project completion

Critical Path

- Is that the sequence of activities and events where there is no “slack” i.e.. Zero slack

- Longest path through a network
- minimum project completion time

Benefits of CPM/PERT

- Useful at many stages of project management
- Mathematically simple
- Give critical path and slack time
- Provide project documentation
- Useful in monitoring costs

Questions Answered by CPM & PERT

- Completion date?
- On Schedule?
- Within Budget?
- Critical Activities?
- How can the project be finished early at the least cost?

example

Illustration of network analysis of a minor redesign of a product and its associated packaging.

The key question is: How long will it take to complete this project ?

Activity number		Completion time (weeks)
1	Redesign product	6
2	Redesign packaging	2
3	Order and receive components for redesigned product	3
4	Order and receive material for redesigned packaging	2
5	Assemble products	4
6	Make up packaging	1
7	Package redesigned product	1
8	Test market redesigned product	6
9	Revise redesigned product	3
10	Revise redesigned packaging	1
11	Present results to the Board	1

For clarity, this list is kept to a minimum by specifying only immediate relationships, that is relationships involving activities that "occur near to each other in time".

Activity number		Activity number	
1	must be finished before	3	can start
2		4	
3		5	
4		6	
5,6		7	
7		8	
8		9	
8		10	
9,10		11	

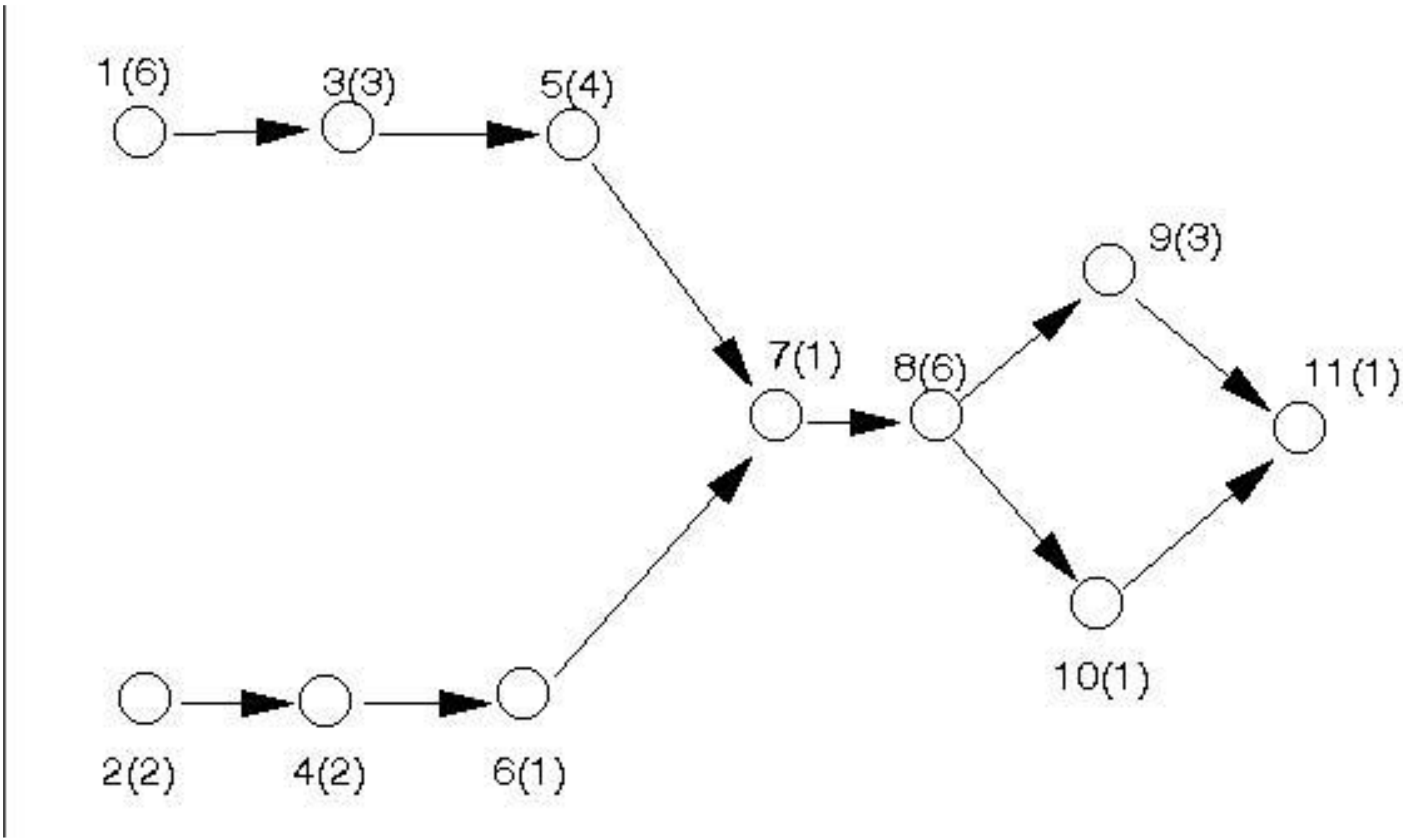
Before starting any of the above activity, the questions asked would be

- "What activities must be finished before this activity can start"
- could we complete this project in 30 weeks?
- could we complete this project in 2 weeks?

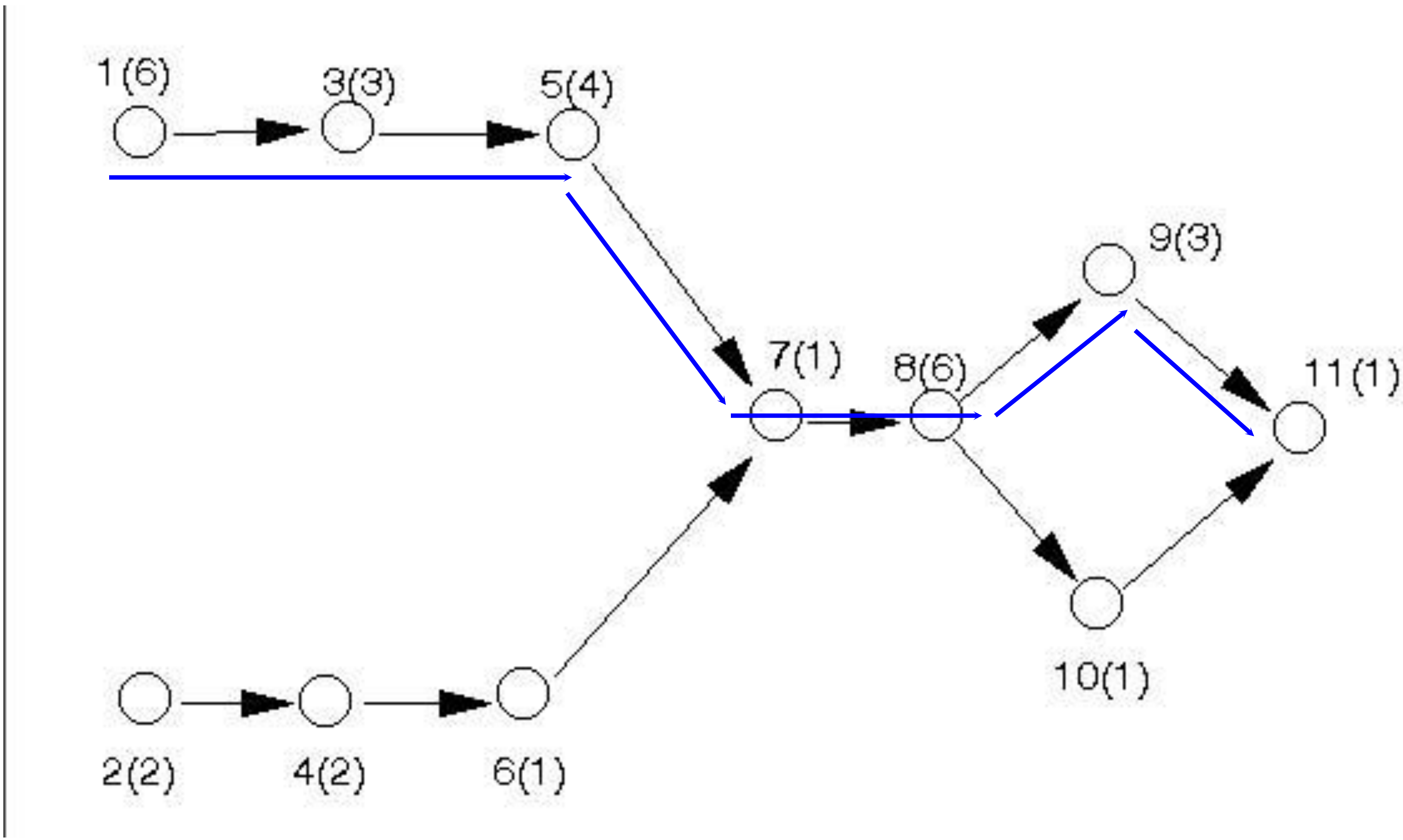
One answer could be, if we first do activity 1, then activity 2, then activity 3, ..., then activity 10, then activity 11 and the project would then take the sum of the activity completion times, 30 weeks.

“What is the minimum possible time in which we can complete this project ? “

We shall see below how the network analysis diagram/picture we construct helps us to answer this question.



CRITICAL PATH TAKES 24 WEEKS FOR THE COMPLETION OF THE PROJECT



Limitations to CPM/PERT

- Clearly defined, independent and stable activities
- Specified precedence relationships
- Over emphasis on critical paths