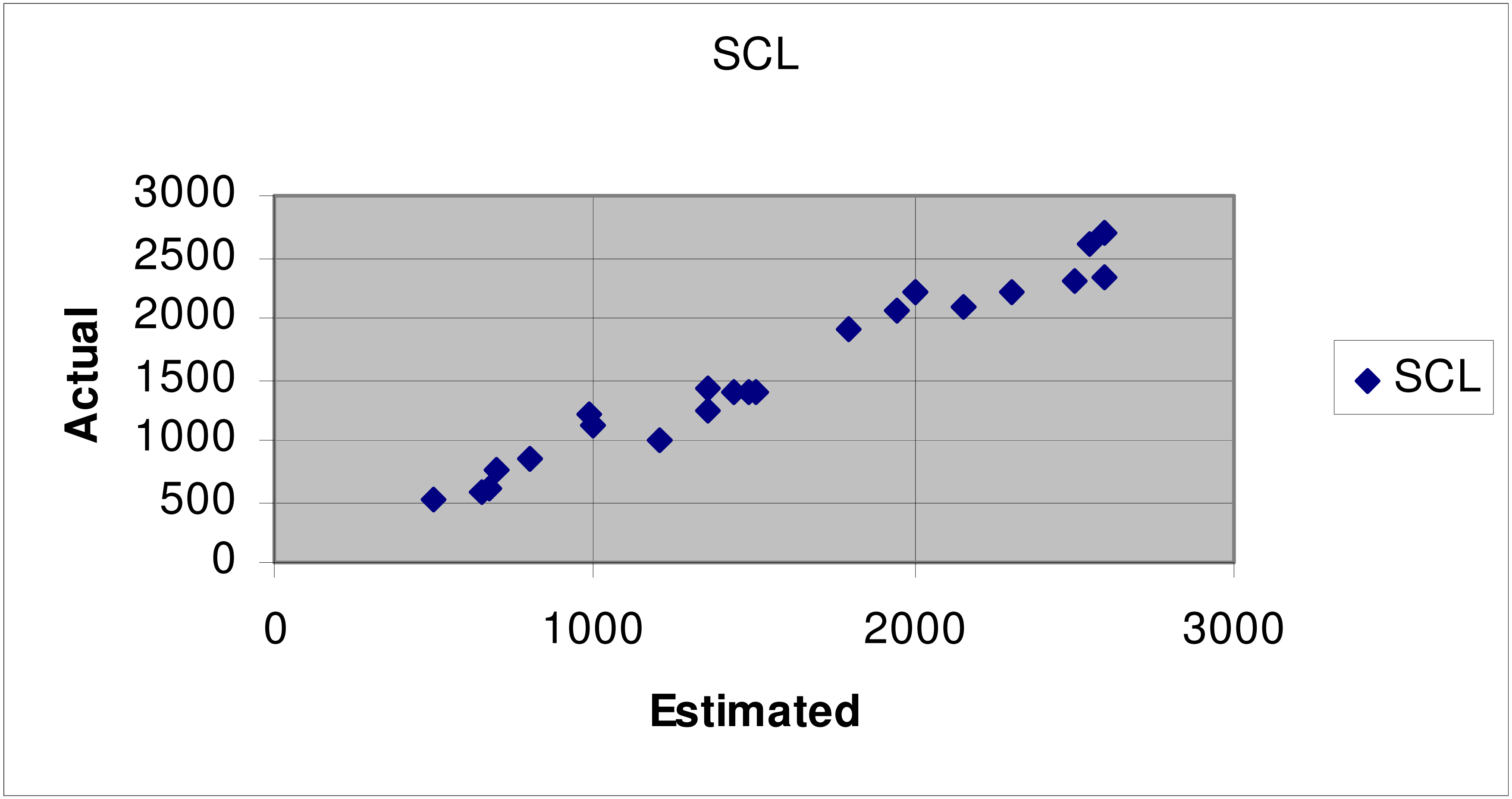
Estimate Activity Duration, Resource Requirements, and Cost

Duration

- What is the duration? The duration of a project is the elapsed time in business working days, not including weekends, holidays, or other nonworking days.

- Duration is different from work effort. Work effort is labor required to complete an activity. That labor can be consecutive or nonconsecutive hours.

Actual versus Estimated Effort



- 50% of the project are within 25% of the estimated effort
- On average, the actual effort is 25% higher than the estimate

Duration

- When we talk about estimates and duration, there are two types of time that are not the same:
  - Labor Time
  - Clock time

For examples, if we estimate that a task would require 40 hours of labor to complete, then in a normal business setting we need at least 50 business hours, ***Why?***

Duration

- Your average business day may include few of the following activities or perhaps a number of each:
  - Meetings
  - Phone calls
  - E-mails
  - Coffee breaks
  - Friendly chat with you teammates

- The duration of the activity is the clock time or “Elapsed” time” that we want to estimate.

Resource Loading vs. Activity Duration

- Assume that you have a system that is composed of 2 modules each has 500 SCL, “the smallest workable unit”, let us look at the following resources
  - If the average developer productivity is 100 SCL per Day, then
    - One developer will work on the system for 10 days
    - Or two developers will work on the system for 5 days
    - But can we have three developers? NO, because we reached the crashpoint of the activity.
    - **Remember the one door + one chair story where the productivity gains will diminish if we assign more than 2 people for this task, one would carry the chair the other would open the door**

    The crashpoint is the point by which returns will diminish when adding more resources to certain activity

Variation in Activity Duration

- Since We cannot know what factors will be effective when work is underway on an activity, we cannot know exactly how long it will take.
- One of the goals in estimating the activity duration is to define the activity to a level of granularity that estimates have a narrow variance; the estimate is as good as you can get it at the planning stages of the project.
- There are several causes of variation in the actual activity duration :

Causes of Variation in the Actual Activity Duration

1. **Varying skill levels**. Our estimate of the activity duration is based on average skilled engineer. We may get a higher or lower skilled engineer assigned to the activity, causing the actual duration to vary from the planned duration.
2. **Unexpected events**. Random acts of nature, vendor delays, traffic jams, power failures, etc.

Causes of Variation in the Actual Activity Duration

3. **Efficiency of work time**. Every time a worker is interrupted it takes more time to get up to the level of productivity prior to the time of the interruption. These interruptions may have little or substantial impact on the worker's productivity
4. **Mistakes and Misunderstandings**. In organizations that have a document process, rework may have its toll on the actual activity duration.

Six Methods for Estimating Activity Duration

- Estimating activity duration relies on best effort approach; no 100% guarantees.
- In many projects the estimate will be improved as you learn more about the deliverables that are completed as part of the project work.
- Re-estimation and re-planning are common.

Six Methods for Estimating Activity Duration

- Six techniques for initial planning estimates:
  - Historical data
  - Similarity to other activities
  - Expert advice
  - Delphi technique
  - Three-point technique
  - Wide-band Delphi technique

Six Methods for Estimating Activity Duration

1. **Historical Data :**
   - As part of the project development process there will be quality record that saved in a common document repository of the estimated and actual activity duration.
   - This historical record can be used in other projects.
   - The recorded data become your knowledge base for estimating activity duration.
   - This differs from the ***Similarity to Other activity*** technique in that it uses a record, rather than depending on memory

Six Methods for Estimating Activity Duration

2. Similarity to Other activity:

- Rely on your personal experience or your peers' experience to estimate the activity duration

- This technique doesn't rely on official documentation of the referenced experience

3. Expert Advice:

- When the project involves a technology that is being used for the first time in the organization, and the lack of skilled engineers in that technology within the organization.
- Rely on outside sources for advice and consultation; mainly the vendors and high-tech consulting firms.

Six Methods for Estimating Activity Duration

4. Delphi Technique:

- The Delphi technique is used to produce good estimates in the absence of expert advice.
- This technique relies on the knowledge of the group to arrive at an estimate.
- After the group is briefed on the project and the nature of the activity, each individual in the group is asked to make his or her best guess of the activity duration.
- The results are presented, to the group in a histogram labeled ***First Pass***. Those participants whose estimates fall in the outer quartiles are asked to share the reason for their guess.
- After listening to the arguments, each group member is asked to guess again. The results are presented as a histogram labeled ***Second Pass***, and again the other quartile estimates are defended. A third guess is made, and the histogram plotted is labeled ***Third Pass***.
- The ***average of the third guess*** is used as the group's estimate.
- The technique has been demonstrated to be effective in the absence of expert advice.

Six Methods for Estimating Activity Duration

5. Three-Point Technique:

- This method depends on three estimates of activity duration: optimistic, pessimistic, and most likely.
- The optimistic time is defined as the shortest duration one might expect to experience given that everything happens as expected.
- The pessimistic time is that duration that would be experienced if everything go wrong and yet the activity was completed.
- The most likely time is that time usually experienced. For this method you are calling on the collective memory of professionals who have worked on similar activities but for which there is no recorded history.
- The Estimate : $E = \dfrac{O + 4M + p}{6}$

Six Methods for Estimating Activity Duration

6. Wide-Band Delphi Technique :

- Combining the Delphi and the three-point methods results in the wide-band Delphi technique.
- It involves a panel, as in the Delphi technique, but rather than a single estimate that the panel members are asked to give at each iteration, they are asked to give their optimistic, pessimistic, and most likely estimates for the duration of the chosen activity at each iteration.
- The results are compiled, and any extreme estimates are removed. Averages are computed for each of the three estimates, and the averages are used as the optimistic, pessimistic, and most likely estimates of activity duration.

$$E = \frac{O + 4M + p}{6}$$

- Finally, you apply the formula :

Project Resources

- The previous estimation techniques can be used to estimate the resource requirements for any project.

- But lets see the types of resources that a project may include:

Project Resources

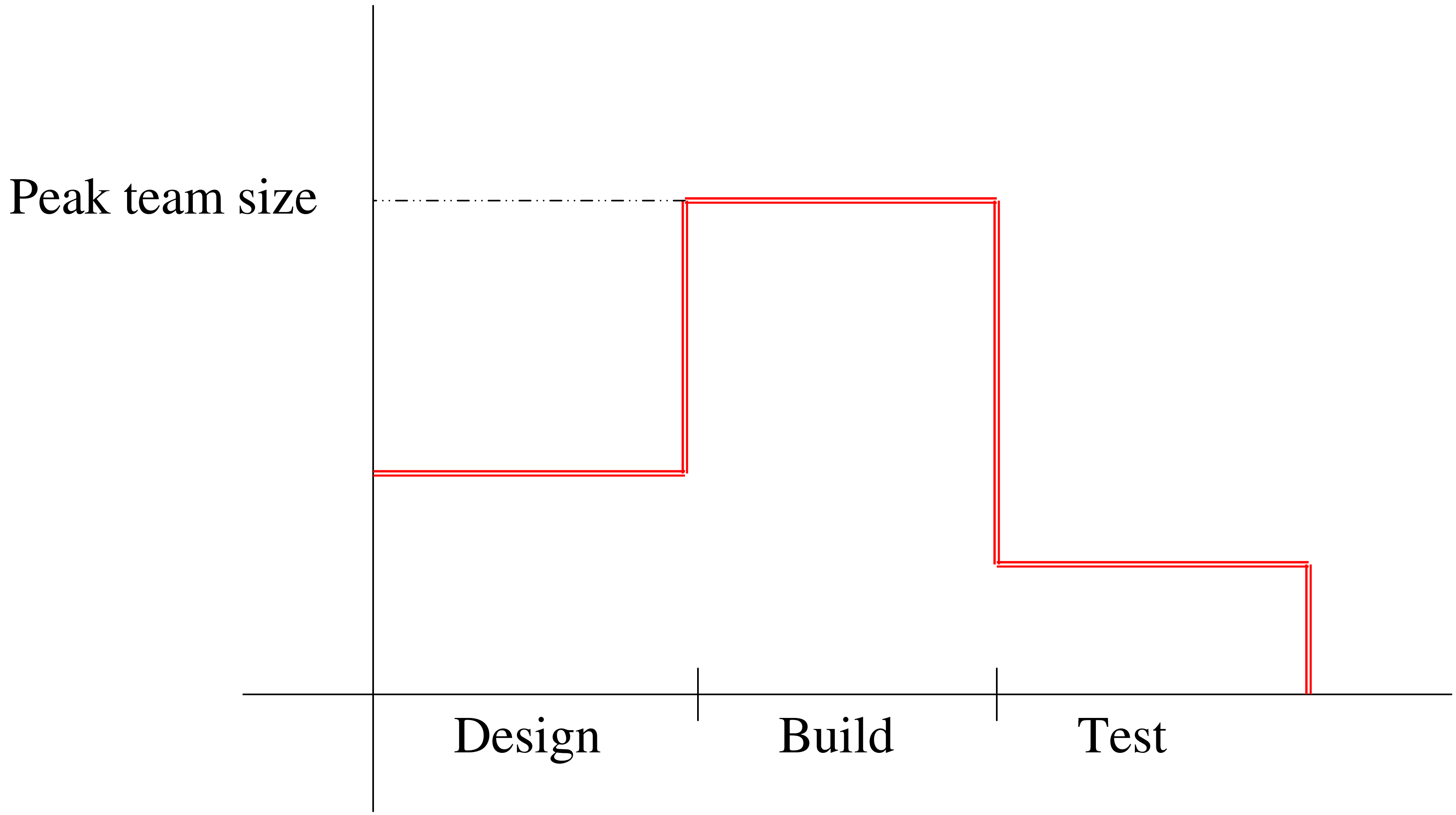
- **People**. The most difficult type of resource to schedule.
- **Facilities**. Project work takes place in different locations at different times. Conference rooms, Labs are examples of facilities that projects require. You need to know what is needed, when it is needed, and for how long.
- **Equipment :** What is needed and when.

Project Resources

- **Money :** Project expenses typically include travel, tools, supplies, etc shall be accounted for in the budget

- **Material (Hardware/Software components):** Parts to be used in the fabrication of products and other physical deliverables are often part of the project work, too. For example, the materials needed to build a bicycle might include nuts, bolts, washers, and spacers.

Manpower ramp-up in a typical project



People as Resources

- We often depend on the term “skills” to identify technical people who are appropriate for the project.

- From the project’s point of view:
  - ***Skill Category***: We need to now what skills are needed
  - ***Skill Level***: Who posses these skills in the organization and in what level: expert, knowledgeable, novice.
  - ***Skill Source***: Some organization deploys the concept of resource and skill pools OR through training
  - ***Skill Amount***: the number of technical people to do the work of activities.

Estimating Duration as a Function of Resource Availability

- Three variables influence the duration estimate of an activity:
  - The Activity duration itself
  - The total amount of work, as in person hours / days, that will be done on the activity by a resource
  - The percent per day of his or her time that the resource can devote to working on it

Estimating Duration as a Function of Resource Availability

- There are four ways to approach the calculation of duration, total effort, and percent/day:
  1. Assigns as a total work and constant percent/ day
  2. Assign as a duration and total work effort
  3. Assign as a duration and percent / day
  4. Assign as a profile

Assigns as a total work and constant percent/day

- If we have an activity that requires 40 hours and the resource that we have can devote only 50% of his/her time to the project activity work, then the real duration to complete the activity will be 80 hours.
- The formula : 40hours/.50 = 80 hours

Assign as a Duration and Total Work Effort

- Estimate the duration based on history. Then the total work could be averaged over that duration, yielding the percent per day value. Using the same values as above, the formula would look like: 5 person days / 10 days=.5

- This method is just another way to look at the previous number

Assign as a Duration and Percent/Day

- The third method is to estimate the duration as previously described and assign the percent per day. This will calculate the total effort. The formula works like this: 10 days x .50 = 5 person days
- Note a person day is meant to have 8 hours
- Of the three methods this is the least used.

Assign as a Profile

- The three duration estimating and resource assignment methods all assumed that the resource is going to work at the same percent per day for each day of the activity.
- There will be cases where the technical headcount will not have the same productivity rate due to some other commitments.
- In such cases, the duration is estimated first and then the work is assigned at different percents over the 40-hour window.
- Examples: We may assign the worker 75% of 40 hours or 25% of 40 hours

Estimating Cost

- Estimating cost begins at the activity level.
- Once costs at the activity level have been determined, they are aggregated to the project level.
- Generally, We categorize costs as ***labor costs*** or ***material costs***.
- Material costs will be priced on a per-use or per-time-unit basis.
- Labor costs are people resources. In order to estimate people costs for an activity,
  - you need to know the rate of pay for a time unit of labor.
  - The time unit can be hourly or daily.
  - Because you know the resource requirement by skill or job classification for an activity, you can easily calculate the total labor cost for an activity.
  - The variable here is the activity duration over which the labor costs are accrued; needed for cost/schedule control purposes.

WBS and Estimating Cost

- Most WBS structures are project specific and cross-project comparison are usually difficult. Nevertheless, we can learn from the answers to the following questions:
  - What is the ratio of productive activities (design, implement, etc.) to overhead activities (management, environment)
  - What is the percentage of effort expended in rework activity.
  - What is the cost of release N compared to release N-1?
  - To produce 1 SCL may cost $1, but to rework 1SCL may cost $3, ***Why?***

The Project Network Diagram

The Project Network Diagram

- From the WBS we identify the activities and then the duration for each one of these activities
- The planning team will then start identify the order in which these activities to be executed.
- The activities and the activity duration are the basic building blocks needed to construct a network diagram of the project.
- This diagram provides you with two additional pieces of schedule information about the project:
  - The ***earliest*** time at which work can ***start*** on every activity that makes up the project
  - The ***earliest*** expected ***completion*** date of the project

The Project Network Diagram

- The project network diagram is a pictorial representation of the sequence in which the project work can be done.

- There are a few simple rules that you need to follow to build the project network diagram.

- The relationships between the activities in the project are represented in a flow diagram called the network diagram

The Project Network Diagram

- From its definition, the project is a sequence of ***interconnected activities***.
- You could perform the activities one at a time until they are all complete.
- This approach would not result in an acceptable completion date. It results in the longest time to complete the project.
- Any ordering that allows one pair of activities to be worked on concurrently would result in a shorter project completion date.

How to Build the Project Schedule

- There are two ways to build a project schedule:
  - Gantt chart
  - Network diagram

Gantt Chart

- **Gantt chart** is the oldest of the two and is used effectively in simple, short-duration types of projects.
- To build a Gantt chart
  - the project manager begins by associating a rectangular bar with every activity.
  - The length of the bar corresponds to the duration of the activity.
  - The project manager then places the bars horizontally along a timeline in the order in which the activities should be completed.
  - There can be instances in which activities are located in parallel on the timeline so that they are worked on concurrent with other activities..

Gantt Chart

- Two drawbacks for the Gantt chart:
  1. Because of its simplicity; the Gantt chart does not contain detailed information. It shows the order by which the activities will be executed.
  2. The Gantt chart does not tell the project manager whether the schedule that results from the Gantt chart completes the project in the shortest possible time or even uses the resources most effectively. The Gantt chart only reflects when the manager would like to have the work done.

Network Diagram

- **Network Diagrams** can be used for detailed project planning, during implementation as a tool for analyzing scheduling alternatives, and as a control tool.

Network Benefits to Network-Based Scheduling

- **Planning**:
  - the project network gives a clear graphical picture of the relationships between project activities.
  - It is a high-level and detailed-level view of the project.
  - Members of the planning team can use the network diagram for scheduling decisions. the network diagram is very useful during the JPP session.

Network Benefits to Network-Based Scheduling

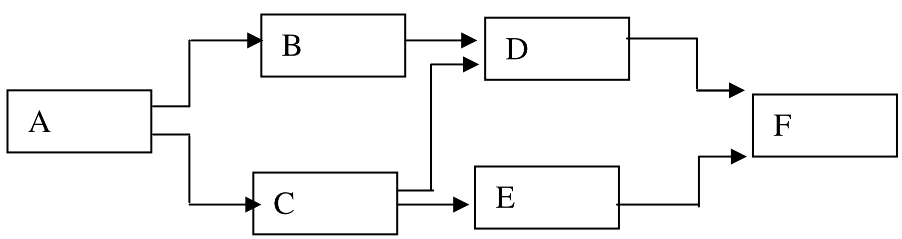
- **Implementation:**
  - If you use automated project management and software tools, you will update the project file with activity status and estimate-to-completion data. The network diagram is then automatically updated and can printed or viewed.
  - The need for rescheduling and resource reallocation decisions can be determined form the network diagram.

Network Benefits to Network-Based Scheduling

- **Control:** the network diagram retains the status of all activities, and the best graphical report for monitoring and controlling project work will be the Gantt chart view of the network diagram.
- This Gantt chart cannot be used for control purposes unless you have done network scheduling or incorporated the logic into the Gantt chart.
- Comparing the planned schedule with the actual schedule, the project manager will discover variances.

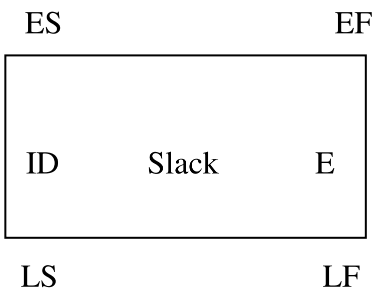
Building the Network Diagram Using the PDM

- PDM : The Precedence Diagramming Method.
- The basic unit of analysis in a network diagram is the activity.
- Each activity in the network diagram is represented by a rectangle that is called an activity node.
- Arrows represent the predecessor/successor relationships between activities; the following is an example of a network diagram in PDM format



Building the Network Diagram Using the PDM

- Every activity in the project will have its own activity node as shown below.



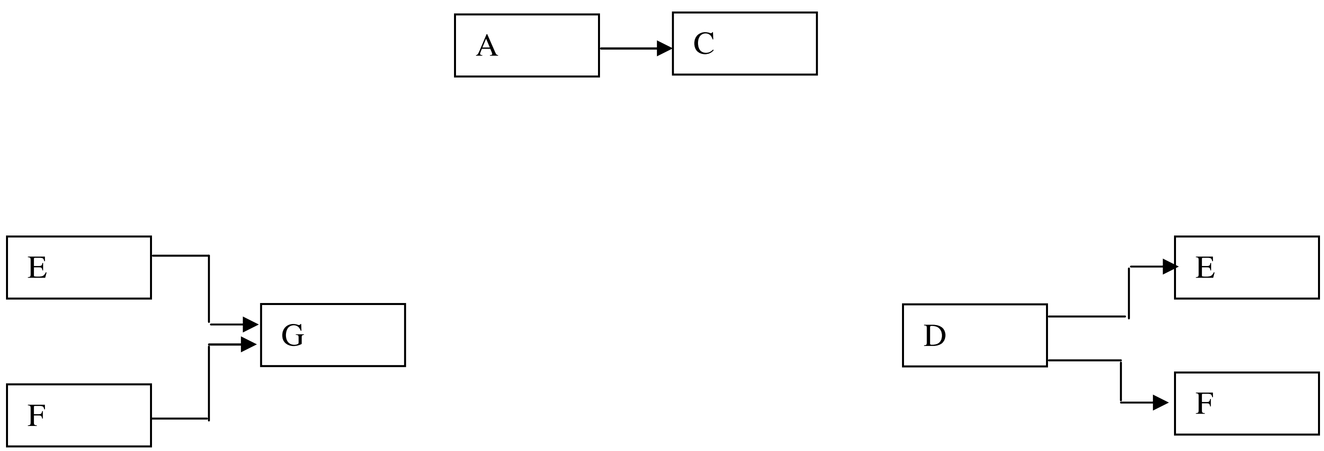
- The entries in the activity node describe the time-related properties of the activity.
- Some of the entries describe characteristics of the activity such as its expected duration (E), while others describe calculated values (ES, EF, LS, LF) associated with that activity; E=earliest, F=Finish, S=Start

Building the Network Diagram Using the PDM

- The network diagram is logically sequenced to be read from left to right.
- Every activity in the network, except the begin and end activities, must have at least one activity that comes before it (its immediate predecessor) and one activity that comes after it (its immediate successor).
- An activity begins when its predecessors have been completed. The start activity has no predecessor and the end activity has no successor.

Building the Network Diagram Using the PDM

- The following figures give examples of how the variety of relationships that might exist between two or more activities can be diagrammed.

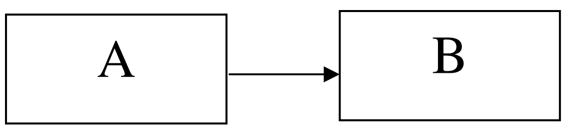


Dependencies

- A dependency is simply a relationship that exists between two pairs of activities.
- To say that activity A depends on activity B means that activity B produces a deliverable that is needed in order to do the work associated with activity A.
- There are four types of activity dependencies:

Finish to Start

- The finish to start (FS) dependency says that activity A must be complete before activity B can begin.
- The FS dependency is recommended in the initial project planning session. The finish to start dependency is displayed with an arrow emanating form the right edge of the predecessor activity and leading to the left edge of the successor activity.

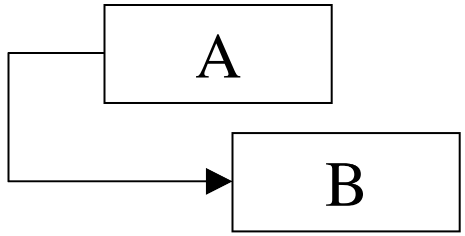


FS: When A finishes, B may start

Start to Start

- The start to start (SS) dependency says that activity B may begin once activity A has begun.
- A and B could both start at the same time, but B can't start earlier than A
- The start to start dependency is displayed with an arrow emanating from the left edge of the predecessor (A) and leading to the left edge of the successor (B).
- This dependency relationship is very useful in schedule compression strategies.

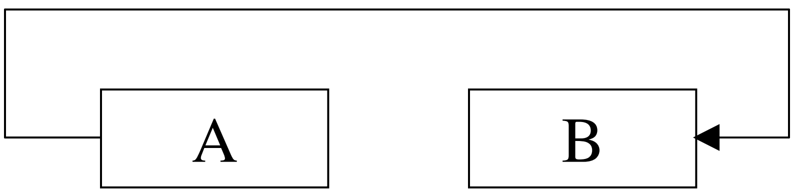
SS: When A starts, B may start



Start to Finish

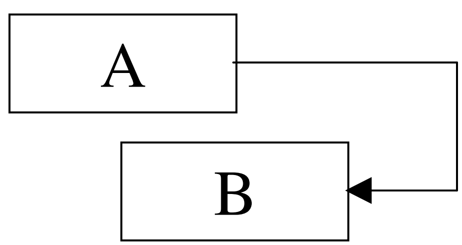
- In the SF, activity B can not be finished sooner than activity A has started.
- For example, suppose you have built a new information system. You don't want to eliminate the legacy system until the new system is operable.
- When the new system starts to work (activity A) the old system can be discontinued (activity B). The start to finish dependency is displayed with an arrow emanating from the left edge of activity A to the right edge of activity B.

SF: When A starts, B may Finish



Finish to Finish

- The finish to finish (FF) dependency states that activity B cannot finish sooner than activity A.
- For example, Testing (activity B) cannot finish until Implementation (activity A) has finished. In this case, activity A and B have a finish to finish dependency. The finish to finish dependency is displayed with an arrow emanating from the right edge of activity A to the right edge of activity B.



FF: When A finishes, B may finish

Constraints & Activities Relationships

- The type of dependency that describes the relationship between activities is determined based on the constraints that may exist between the activities.
- Each type of constraint can generate any one of the four dependency relationships.
- Four types of constraints that may affect the sequencing of project activities and hence the dependency relations between activities:
  1. Technical constraints
  2. Management constraints
  3. Interproject constraints
  4. Date constraints

Technical constraints

- Technical dependencies between activities are those that arise because one activity (the successor) requires output from another (the predecessor) before work can begin on it. In the simplest case, the predecessor must be completed before the successor can begin.
- Within the category of technical constraints **four related situations** should be accounted for:

Technical constraints

- **Discretionary constraints**. judgment calls, based on personal feeling or thinking, by the project manager that result in the introduction of dependencies.
- **Best-practices constraints**. past experiences that have worked well for the project manager
- **Logical constraints**. like discretionary constraints but based on past practices and common sense we may prefer to sequence activities in a certain way.
- **Unique requirements**. This constraint occurs in situations where a critical resource, say an irreplaceable expert or a one-of-a-kind piece of equipment is involved on several project activities.

Management Constraints

- Suppose that the product manager on a software developmental project is aware that a competitor is soon to introduce a new product that will have similar features to theirs.

- Rather than following the concurrent design-build strategy, the product manager wants to ensure that the design of the new software will yield a product that can compete with the competitor's new product.

Interproject Constraints

- Interproject constraints result when deliverables from one project are needed by another project. Such constraints result in dependencies between the activities that produce the deliverable in one project and the activities in another project that require the use of those deliverables.
- Interproject constraints arise when a very large is decomposed into smaller, more manageable projects.
- For example, the construction of the Boeing 777 took place in a variety of geographically dispersed manufacturing facilities.
- There were activities in the final assembly project that depended on deliverables from other subassembly projects.

Date Constraints

- Date constraints impose start or finish dates on an activity that force it to occur according to a particular schedule.

- These constraints generally conflict with the schedule that is calculated and driven by the dependency relationships between activities.

- It has very limited applicability.

Creating an Initial Project Network Schedule

- To create the project schedule, we need to prepare two schedules: the early schedule, which we calculate using the forward pass, and the late schedule, which we calculate using the backward pass.

- The ***early schedule*** consists of the earliest times at which an activity can start and finish. These are calculated numbers that are derived from the dependencies between all the activities in the project.

- The ***late schedule*** consists of the latest times at which an activity can start and finish without delaying the completion date of the project. These are also calculated numbers that are derived form the dependencies between all of the activities in the project

Creating an Initial Project Network Schedule

- The combination of these two schedules gives us two additional pieces of information about the project schedule:
  1. The window of time within which each activity must be started and finished in order for the project to complete on schedule
  2. The sequence of activities that determine the project completion date

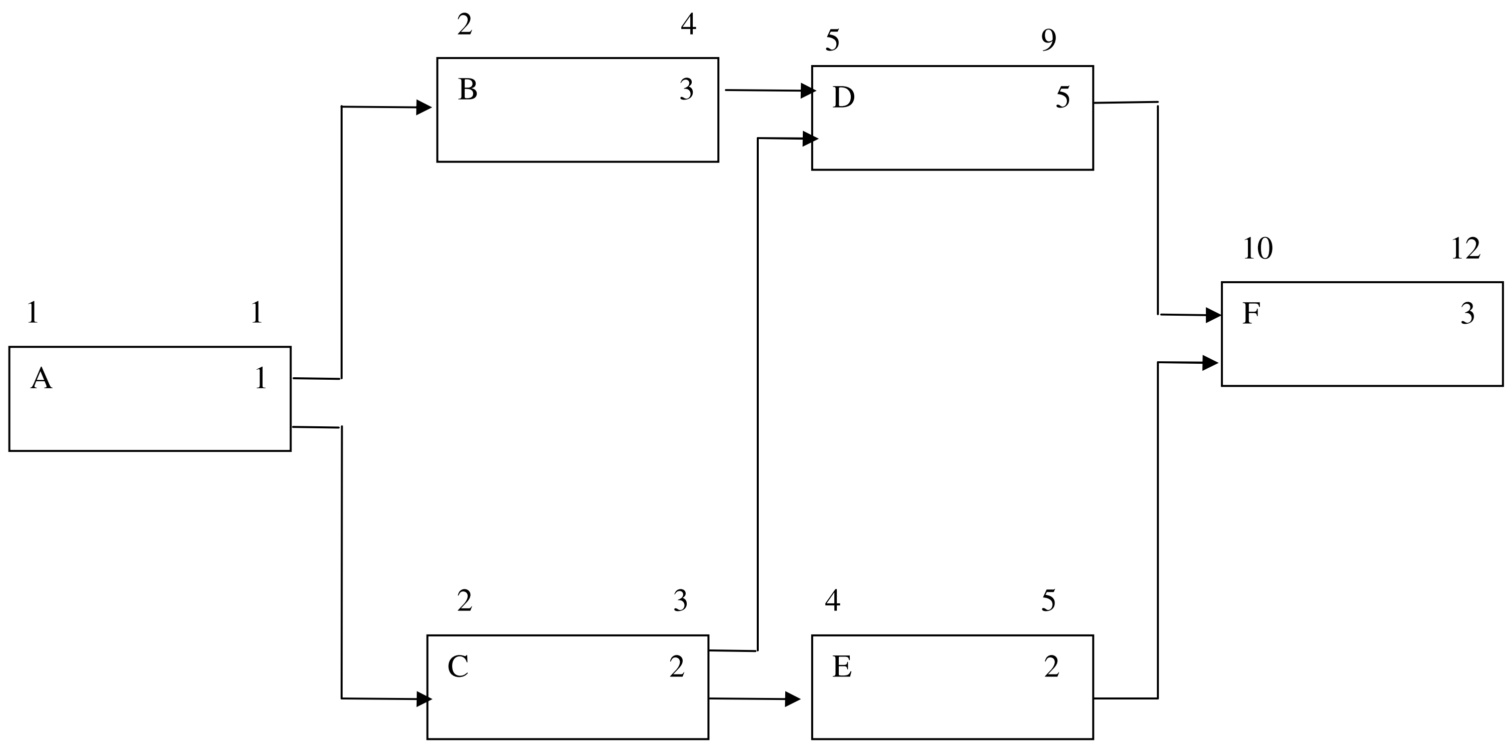
Creating an Initial Project Network Schedule

- The sequence of activities that determine the project completion date is called the ***critical path***. The critical path can be defined in several ways:
  – It is the longest duration path in the network diagram
  – It is the sequence of activities whose early schedule and late schedule are the same
  – It is the sequence of activities with zero slack or float

Creating an Initial Project Network Schedule

- The activities that form the critical path are called the ***critical path activities***
- The ***earliest starts (ES)*** time for an activity is the earliest time at which all of its predecessor activities have been completed and the subject activity can begin.
- The ES time for an activity that has no predecessor is set to 1.
- The ES time for an activity with one predecessor is determined from the EF of its predecessor
- The ES time for an activity with two or more predecessors is determined from the latest of the EF times.
- The EF time = ES + duration – 1
- A one day activity starts/ends on the same day; start at the beginning of the day.

Creating an Initial Project Network Schedule



- C is the predecessor of E
- The EF for C is end of day 3
- The ES for E is the beginning of day 4
- D has 2 predecessors, B and C. And its ES is the maximum of of the ES times for B and C

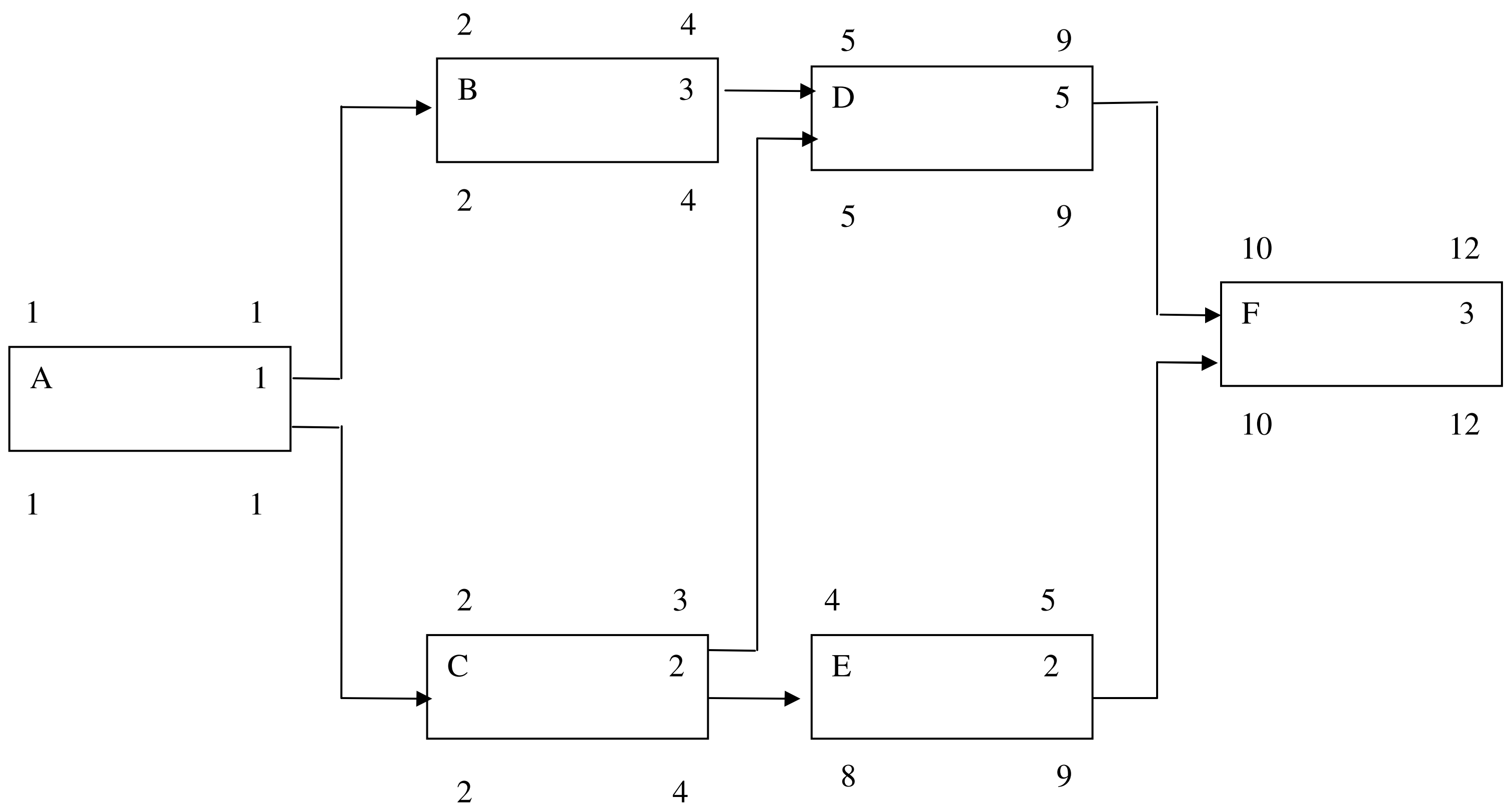
Creating an Initial Project Network Schedule

- The The Latest start (LS) and latest finish (LF) times of an activity are the latest times at which the activity can start or complete without causing any delays on the final completion date of the project.
- To calculate these times, we work backward in the network:
  - First set the LF time of the last activity to be its EF time
  - Set LS = LF – duration + 1
  - The LF time of all immediate predecessor activities is the minimum of the LS-1 times of all activities for which it is the predecessor.

Creating an Initial Project Network Schedule

- What is the late schedule for activity E?
  - Its successor F, has LS date of day 10
  - Therefore the LF date for E, will be the end of day 9
  - The LS date for E is equal to 9-2+1
- What is the late schedule for activity C?
  - It has D and E as successors
  - LS for C = minimum of the LS for D and E= min(5,7)=5
  - So the LF for C is end of day 4.

Creating an Initial Project Network Schedule



Late Schedule : Backward pass calculations

Critical Path Calculation

- The critical path calculation is the longest path or sequence of activities in terms of activity duration through the network diagram.

- The critical path drives the completion date of the project. Any delay in the completion of any one of the activities in the sequence will delay the completion of the project.

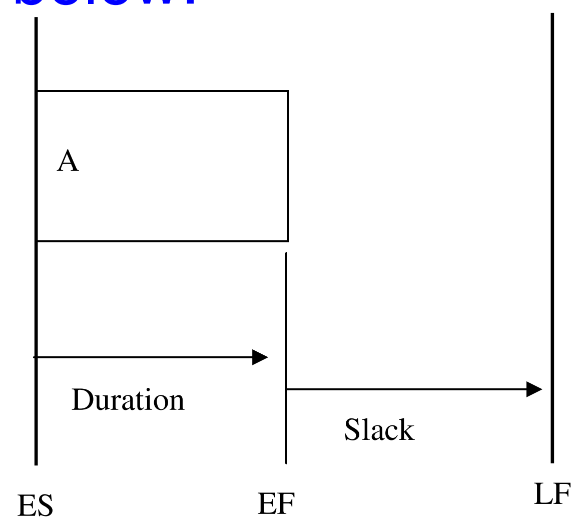
- The project manager uses the critical path to calculate the early schedule and the late schedule

Critical Path Calculation

- Two methods to find the critical path:
  - First method to identify the critical path in the network diagram is to find all possible paths through the network diagram and add up the durations of the activities for each path. Then the path the longest duration time is the critical path. and add up the durations of the activities that lie along those paths. This method is not effective for mid-large size projects; number of nodes in the network is 100+ nodes.For projects of any size this method is not feasible, and we have to resort to the second method of finding the critical path-computing the slack time of an activity
  - Second method relies on the use of ***Slack Time***.

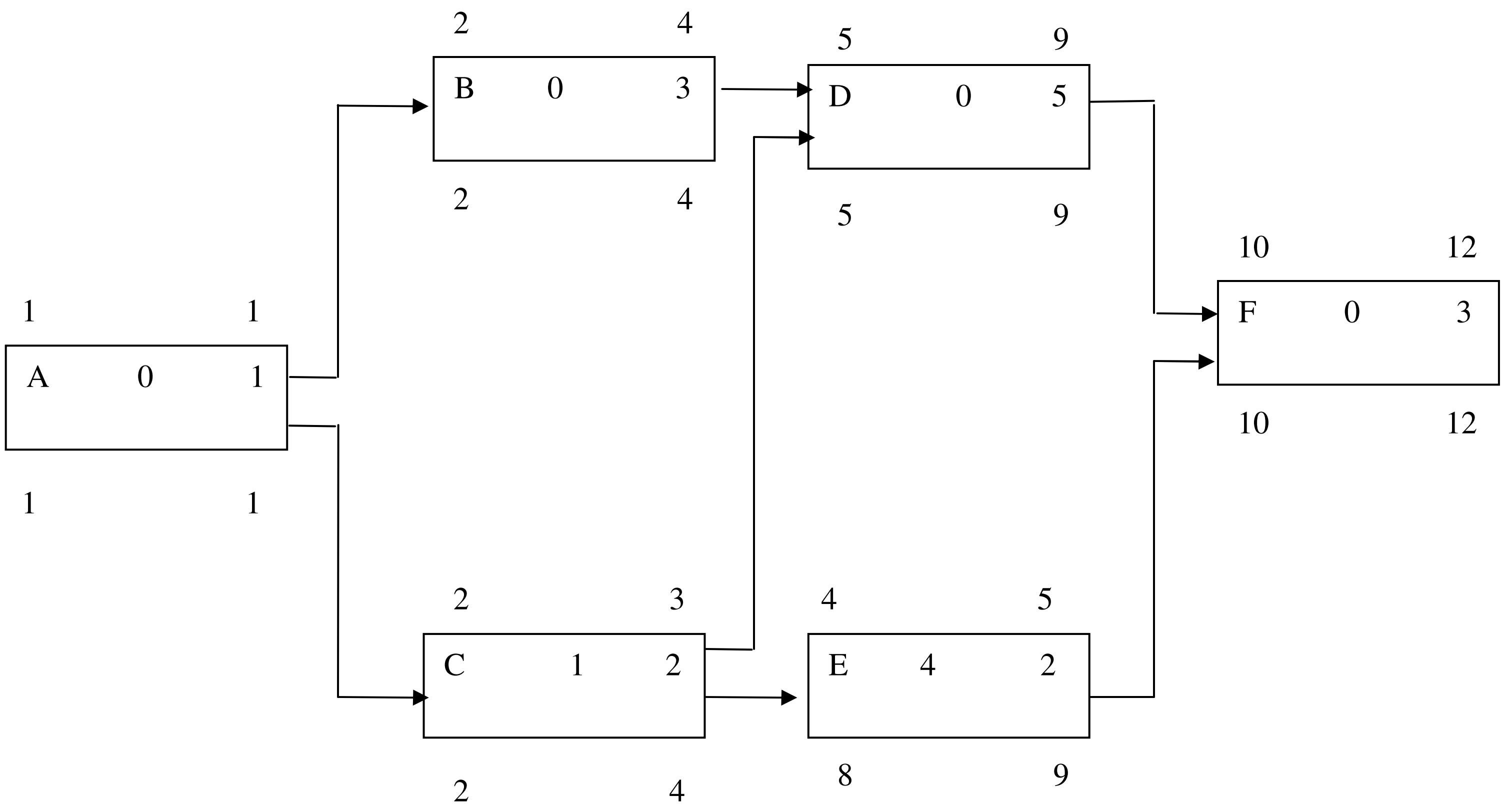
Slack Time

- Slack time, also known as float, is the amount of delay expressed in units of time that could be tolerated in the starting time or completion time of an activity without causing a delay in the completion of the project.
- Slack time is the difference between the late finish and the early finish (LF-EF). If the result is greater than zero, then the activity has a range of time in which it can start and finish without delaying the project completion date, as shown in the figure below:



Slack Time

- Example:



Slack Time

- If an activity has zero slack, it determines the project completion date. In other words, all the activities on the critical path must be done on their earliest schedule or the project completion date will suffer.
- If an activity with total slack greater than zero were to be delayed beyond its late finish date, it would become a critical path activity and cause the completion date to be delayed.
- The sequence of activities that has zero slack is defined as the critical path
- In general, the critical path is the path that has minimum slack.

Analyzing the Initial Project Network Diagram

- After creating the initial project network diagram, you will end up with 2 cases:
  - The initial project completion date meets the requested completion date.
  - The initial project completion date is later than the requested completion date; And we have to squeeze the project schedule.
- When we try to squeeze the project schedule we have to address two considerations:
  - the project completion date
  - resource availability under the revised project schedule.
  - For the time being, we proceed under the assumption that resources will be available to meet this compressed schedule. Later we will discuss the resource-scheduling problem.

Schedule Compression

- Generally, there will be huge potential for the initial project to result in completion date beyond the required completion date. The project planning team will be required to find ways to reduce the total duration of the project to meet the required date.

1. People are tempted to look at critical path activities that come early in the life of the project, but this usually is not a good strategy because in the early stage of a project the project team is little more than a group of people who have not worked together before. We should give them some time to become a real team. Therefore, we have to look downstream on the critical path for those compression opportunities.
2. A second factor to consider is to focus on activities that are partitionable. A partitionable activity is one whose work can be assigned to a more than one individual in parallel.

Schedule Compression

- How to compress a schedule?
  1. Look into the network diagram and the critical path to adjust dependencies.
  2. Replace the series (FS dependencies) with parallel (SS dependencies) sequences of activities, and the critical path may change to a new sequence of activities.

Management Reserve

- We usually like to pad our estimates for the project schedule.
- This way we give ourselves sometime in case something don’t go as planned.
- If there is a task that requires 40 hours worth of work, better we submit 50 hours because we tend to underestimate project activities. The extra 10 hours are padding.