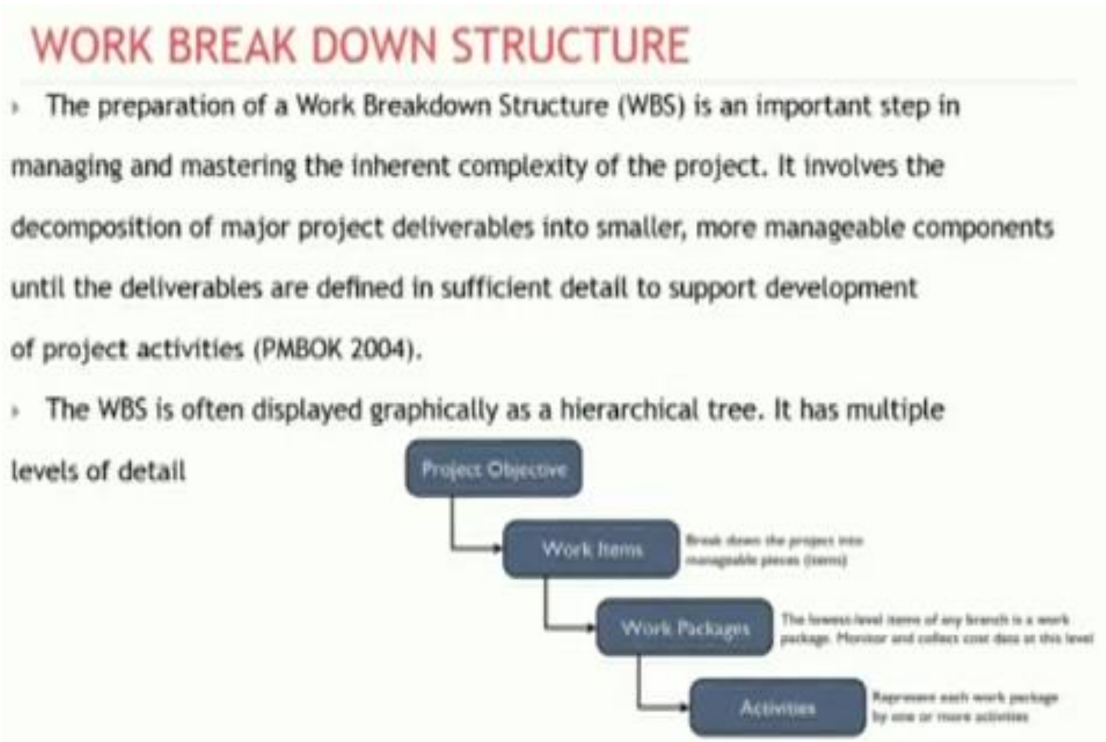
Construction and Project Management
Lecture 4

Network Analysis 1



Project objective is construction of a building. Work item is electrical works. In electrical works, lots of sub-divisions can be done. They are divided into work packages, like external electrical works, internal electrification works, etc.

Interior electrical work: This is a work package on its own and there are many sub activities in it -- wiring works, conduit works and light fixing works. These are minor activities. We have broken down the overall project into simpler activities for easier understanding and working. For smaller activities like installation of light fixtures, we can ascertain its duration. So, I would require a week to fix all the lights for a particular house and two months to complete the electrical conduit work. If work packages are split into activities, it is easier to allocate time for that particular activity as well as resources. For example, two not so efficient electricians can fix all the light fixtures. I ascertain the time, equipment, materials, manpower and everything that is required for a particular activity by breaking down the overall complex project into simpler activities, which is work breakdown structure.

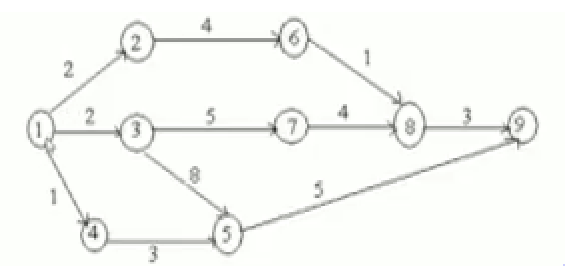
NETWORK ANALYSIS

- The purpose of analysis:
    1. to find critical path i.e. the sequence of activities with the longest duration.
    2. to find the float associated with each non critical activity.

<u>Non critical activity</u>: It is the activity which could be relaxed a little bit. For example, internal painting is not a critical activity. If the painter doesn't turn up one day, I can wait for the next day to start the activity. This particular painting activity is a non-critical activity. If the same activity is a critical activity, even a day could not be spared. For example, installation of lift is a critical activity.This has to be installed in a week. The person who fixes the lift needs to be in the place and install the lift so that the project is completed in the committed date.

- SYSTEMATIC ANALYSIS
    1. Calculate the time schedule of each activity
    2. Calculate the time schedule for the completion of entire project
    3. Identify critical activities
    4. Determine the critical path for the network

While doing network analysis, we must first ascertain the project activity duration. Each activity will have its own duration. But, the project on the whole will have a duration. Depending on the dependencies of each activity like the predecessor and successor, we find out the duration of the project. Here, we note that:

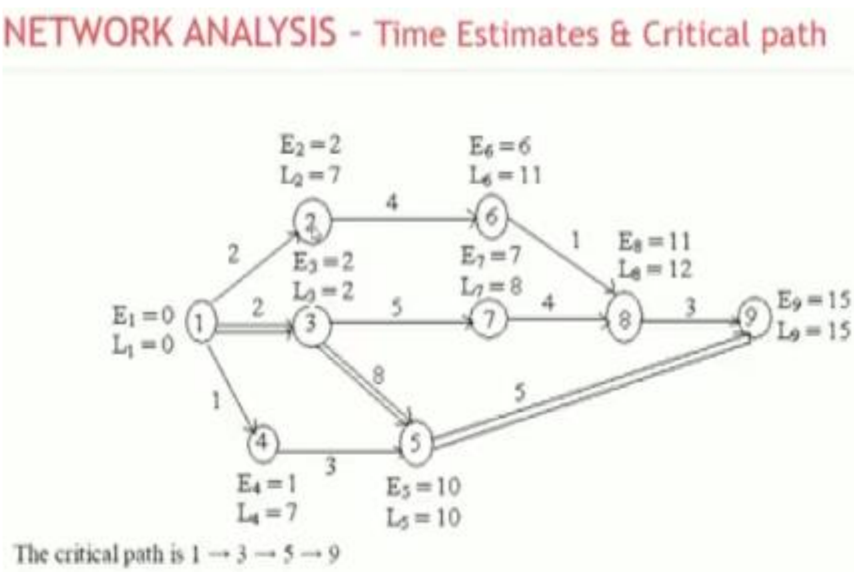


There are 2 ways to calculate the duration of the project -- forward pass and backward pass.

Forward pass is tracing the project from start to end, that is from node 1, we go on adding the duration of the project and we find out the complete duration when we reach node 9 as given in the above diagram.

Early start time: In the above diagram, activity 6 will start after completion of activity 1 and activity 2, which means it will start only after 2+4=6 days. Activity 7, with 4 days duration, can start only after the completion of activity 1→3→ 7, which will take 2 + 5 days, which is 7. So, the early start of activity 7 is seven days. Likewise, we need to find the early start and early finish for all the activities. For activity 5, from 1 to 3 to 5, we have 2 + 8 = 10 days for the activity to start and from 1 to 4 to 5, it’s 1 + 3 = 4 days. So, this particular activity’s early start will be 10 days and not 4 days. This is how early start and early finish dates are computed.

Another way of doing the calculation of time is backward pass. In the above diagram, backward pass is calculating the duration from node 9 and ending at node 1.



Event 1 will have early start of zero and early completion of zero. But, activity 2 takes a time of 2 days, so its early start is 2. For node 6, it is 2 + 4 = 6 days. For node 8 through 1 to 2 to 6 to 8, it is 2 + 4 + 1 = 7 days and through 1 to 3 to 7 to 8, it is 2 + 5 + 4 = 11. Activity 9 (from node 8) with a duration of 3 days can start only after the completion of 11 days, because it needs to wait for both activities mentioned above (both paths from node 1 to node 8) to get completed. So, here the early start is only 11. Likewise, early start and early finish should be computed for all individual nodes. Similarly, the backward pass is also done for latest start and latest finish of all events. If you see, node 1 to 3 to 5 to 9, all have the same late finish time and early finish time. Those events are called as critical events where even a day cannot be delayed and the path 1 to 3 to 5 to 9 is called the critical path.

Once the critical path is known, the focus will be on completing the project in 15 days. To complete the project in 15 days, even a single day or resource must not be wasted for the path from 1 to 3 to 5 to 9. If any of the event like event 5 (node 5) gets delayed by 2 days, then the whole project will take 17 days to complete. So, this particular path is more critical in determining the total project duration.

Activity float and slack:

The activities 1, 3, 5, 9 are called critical activities and activities/nodes 2, 6, 7, 8 and 4 are called non-critical activities. In the case of non-critical activity, it can be delayed by some duration without affecting the total project duration because they have breathing time. Activity 8 will get started only after the completion of 1 or 4 days, i.e. two paths from 1 to 2 to 6 to 8 which is 2 + 4 + 1 = 7 days and 1 to 3 to 7 to 8 which is 2 + 5 + 4 = 11 days. So, the activity path 1 to 2 to 6 to 8 with durations of 1, 4, and 2 days can be delayed by 4 days and still the project duration will not be altered, but maintained at 15 days. It is called as float in the case of an activity and when the same flexibility is extended to an event, it is called as slack.

Network Analysis 2

Non critical activities have some flexibility i.e. these activities can be delayed for some time without affecting the project duration.

This flexibility is called as slack in case of an event and as float in case of an activity.

Slack time for an event: Difference between latest event time and the earliest event time.

Let us see how late or how early a particular event can start. In this case, the particular event 5 (path 1 to 3 to 5), can start only after 10 days because the event with 2 days duration and 8 days duration should get completed. However, the same event 5 with the path 1 to 4 to 5, with one day and 3 days duration respectively, will get over in 4 days. So, event 5 will have a slack of 10 – 4 = 6 days. Generally in CPM, we work on arrow method of networking. Our general focus will be on the calculation of float, so that we know where we have some breathing time and where resources, equipment can be diverted to ensure that the critical path is not altered and project duration is not disturbed. Now, we will see about various types of float and calculation of float.

- **Total float** of an activity: Difference between earliest and latest start / finish time for an activity.

TF_{ij} = LST-EST or TF_{ij} = LFT-EFT

Amount of time by which the actual completion of an activity can exceed its earliest expected completion time without causing any delay in the project duration.

The particular activity 5 to 9 in the path 1 to 3 to 5 to 9, which has a duration of 5 days, can start only after 10 days. Activities 1 to 3 with a duration of 2 days and 3 to 5 with a duration of 8 days have to be completed, before this activity with a duration of 5 days is started. Though it can be started in 4 days through the path 1 to 4 to 5, it needs to wait for the activity with 8 days to get completed. Only then the particular activity 5 to 9 can start, i.e. only after 10 days. This is the rule of the network, i.e. all preceding activities should get completed before starting an activity. The early start of this activity is 4 days and late start is 10 days. So, late start (10 days) minus early start (4 days) gives the total float for this activity (6 days).

It is, therefore, the amount of time by which the actual completion of an activity can exceed its earliest expected completion time, without causing any change in the project duration. So, even if activity 5 gets delayed by 6 days, there would not be any problem as the same project duration can be maintained. This is called the total float. The project duration will not get altered because of the total float provided for any particular activity.

- **Free float** of an activity: Determined by subtracting the head event slack from the total float of an activity.

$FF_{ij} = TF_{ij}$ - (slack of the event j)

Free float indicated the value by which an activity in question can be delayed beyond the earliest starting point without affecting the earliest start.

Independent Float: Determined by subtracting the tail event slack from the free float of an activity.

$IF_{ij} = FF_{ij}$ - (slack of the event i)

Independent float can t be a negative value.

Interfering float: Utilization of float in an activity can affect the float of the subsequent activity in the network. Thus interfering float can be defined as that part of the total float which causes a reduction in float of the successor activity.

Difference between the latest finish of the current activity and the earliest start of the following activity, or zero which ever is larger

Free float of an activity: Determined by subtracting the head event slack from the total float of an activity.

Event 5 has a slack of 6 days, as we saw earlier. So, this particular activity 5→9 with a duration of 5 days will have a free float, which is nothing but head event slack (6 days) minus the total float of this particular event. This particular event will have a total float of zero days and hence the free float is 6 days.

Free float indicated the value by which an activity in question can be delayed beyond the earliest starting point without affecting the earliest start.

Event 5 has a slack of 6 days. Here, 4→5 with a duration of 3 days has an early start of one day. So, even if the event carrying 3 days duration is pushed by another 5 days, event 5 will start at the 10^{th} day, thus not affecting the project duration or the start of activity 5. Though I delay this activity by 3 or 4 days, activity 5 will start on the same day without affecting the project duration. This is called as free float.

Independent Float: Determined by subtracting the tail even slack from the free float of an activity.

Free float is nothing, but the superseding activity start date not getting affected. Independent float is irrespective of any activity duration, though the duration is altered, the overall project duration doesn’t get altered.

Interfering Float: Utilization of float in an activity can affect the float of the subsequence activity in the network. Thus interfacing float can be defined as that part of the total float which causes a reduction in float of the successor activity.

If the activity is delayed by 10 days or so, it affects the start of the succeeding activity. In that case, the float type is called interfering float. It is better to have interfering float as zero to ensure that the project is completed on time.

<u>Examples for all types of floats:</u>

Suppose, finishing work is underway in an apartment, with the flooring being laid, painting and door fixing being done. These are the major activities taken up in the project. When the doors are fixed, flooring should not be affected. Likewise, when internal painting is done, the door frames/door shutters shouldn’t be affected by the paint stains. So, firstly, the door frames are fixed and covered and then flooring work is started. Once the flooring is laid, wrap the floor with all the protection and do the internal painting work. After these activities are completed, the door shutters are fixed so that they are not wasted. This is the sequence in which the network is being worked and this is how the relationships are. Door frame fixing is the starting activity, followed by flooring, followed by painting and then fixing of door shutters.

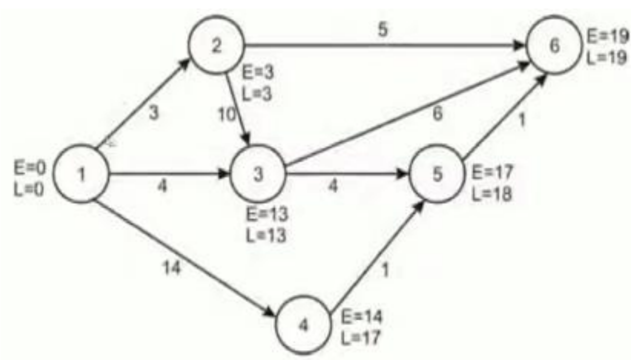
Fixing of door frames takes a time of 10 days, but I encounter a problem in the work and the time gets delayed by 3 days. So, the total duration becomes 13 days, but it doesn’t affect the other works’ duration as the door frame fixing and flooring works are taken up simultaneously in this particular room. This particular float of 3 days corresponding to the activity of door frame fixing is called as the total float.

If fixing the door frame activity is getting completed and flooring activity is getting started, this is like a free float. It doesn't wait for the previous activity to get completed. This is the free float we give for any activity.

Independent float is nothing, but the painting activity and fixing of door shutters where no work delay can cause a delay of other activities.

Interfering float needs to be maintained at zero to ensure that the project duration does not get affected.

Example:



We need to find early start date, early finish date, late start date, late finish date and the float for each activity.

Network Analysis Table

Activity	Duration	Start		Finish		Float			
		E	L	E	L	Total	Free	Ind	Interfering
1-2	3	0	0	3	3	0	0	0	0
1-3	4	0	9	4	13	9	9	9	0
1-4	14	0	3	14	17	3	0	0	3
2-3	10	3	3	13	13	0	0	0	0
2-6	5	3	14	8	19	11	11	11	0
3-5	4	13	14	17	18	1	0	0	1
3-6	6	13	13	19	19	0	0	0	0
4-5	1	14	17	15	18	3	2	0	1
5-6	1	17	18	18	19	1	1	0	0

Interfering float has to be maintained at 0, if it is 3 as in the case of activity 1-4, then it will affect the project duration.

Update CPM Diagram

As the project progresses, the actual task completion times will be known and the network diagram can be updated to include this information. A new critical path may emerge, and structural changes may be made in the network if projects requirements change.

Then, CPM is done. What is CPM diagram? It is updating the network on a timely basis so that delay and lag are found out and rectified.

CPM Benefits:

- Provides a graphical view of the project
- Predicts the time required to complete the project
- Shows which activities are critical to maintaining the schedule and which are not

CPM Limitations

- While CPM is easy to understand and use, it does not consider the time variations that can have a great impact on the completion time of a complex project. CPM was developed for complex but fairly routine projects with minimum uncertainty in the project completion times. For less routine projects there is more uncertainty in the completion times, and this uncertainty limits its usefulness.

The limitation is that CPM works on projects, for which the duration is known like, for example, construction of a house. Casting of a slab takes 7 days and block wall raising takes 8 days with more labourers. So, the duration of the project and how much resources need to be allocated are known. For such activities, CPM is used. For activities for which duration is not known, network cannot be done with CPM. For example, time is not known when a research will be successful.