Project Planning & Control

Prof. Koshy Varghese

Department of Civil Engineering

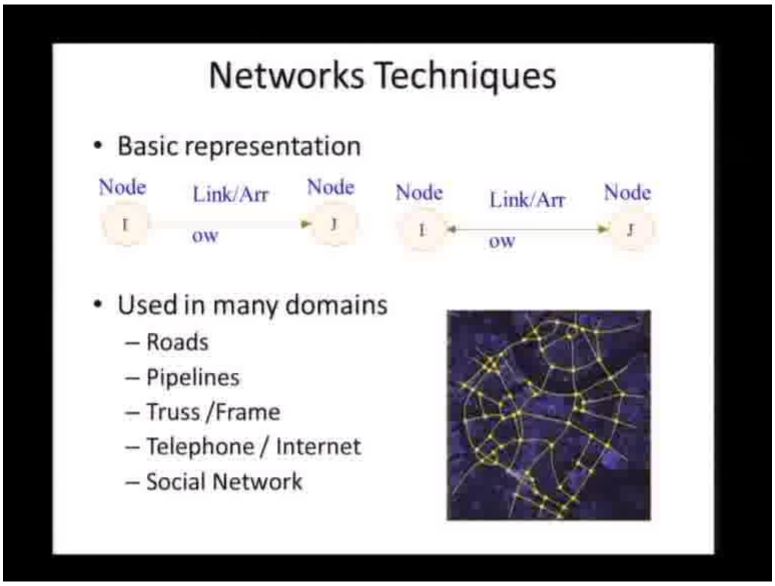
Indian Institute of Technology, Madras

Lecture – 17

Lesson – 05

Networks – Introduction, Techniques

(Refer Slide Time: 00:18)



When you get into networks, networks are a very, very how would I say it is a very active area of utilization and research; both computers science, mathematics and in many areas. So, something like a graph theory or network analysis, it is a whole domain on it is own and the fact that we choose to use networks to do our time management or time planning is itself quite an innovation. So, I am got this slide where I am showing you. Basically, I think when we talk about network all of us know what a network means.

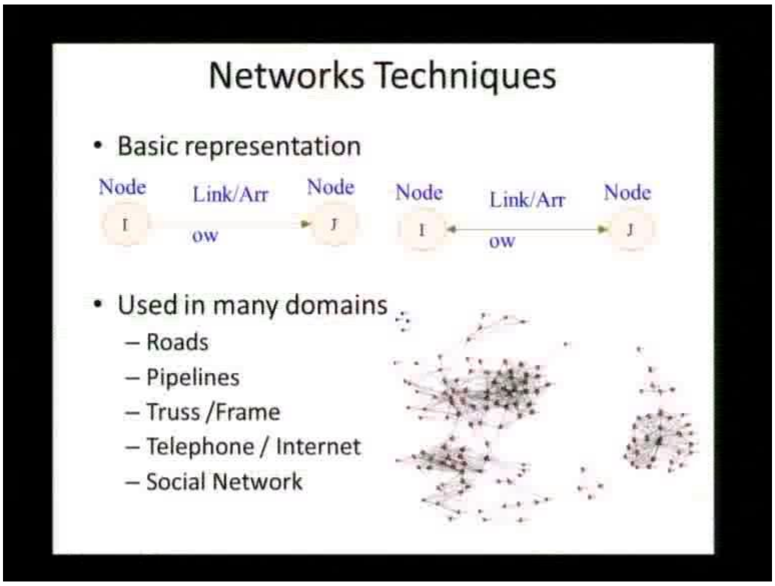
And we, I mean everyday context we talk about road networks, pipe networks, cable networks, the internet is a network there are so many kinds of networks. And when you start representing the network in the form I have shown here, which a network consists of a node and a link or an arrow. So, you have a, so here you have a single directional network, where the arrow goes only from I to J, or you can have bidirectional, you can have I to J, J to I.

Now, something like a road can be represented, this might be like a one-way street, this is a two-way street. Now, if you look like I said it has many domains so that you can have roads, for example, you can see this image here, where you can see nodes and links or nodes and arrows. So, these are, this is a network. Now, you can imagine, so what are the nodes consists of in a road?.

Student: Intersections.

Intersections, links are the road themselves; same thing in a pipeline, same thing in a truss or a frame. You talked about the telephone, if you have telephone networks, the internet all of these are networks, now you have a social network.

(Refer Slide Time: 02:21)



So, is a social network or physical network, is it physical really.

Student: ((Refer Time: 02:16))

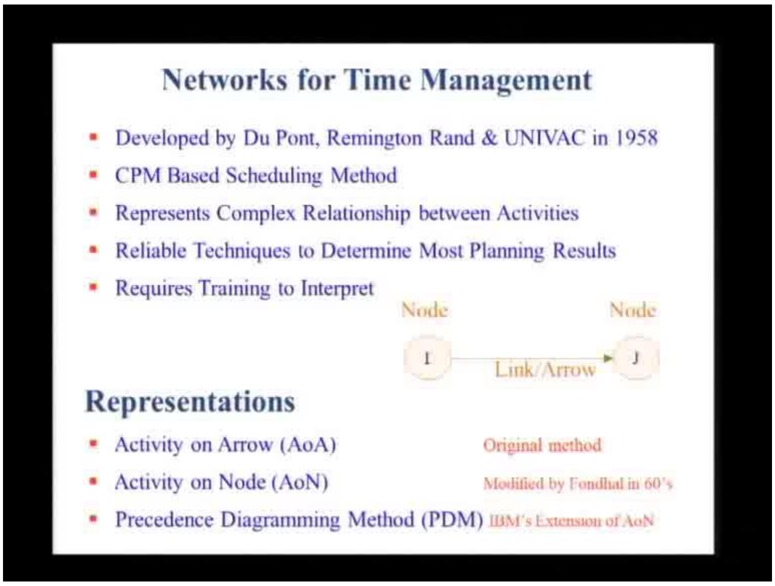
It is not really a physical, it is basically, sees what you see here. Basically, they are saying, so many people are linked to so many, what is who is on a network. So, in a way it is physical, but basically what you are saying is you are linked socially to somebody else, and the algorithms and techniques of network analysis can be applied to social networks also.

So, networks and graphs are a huge domain which is very, very of rich mathematically; we are only touching the tip of the iceberg in it is a utility for project time management. So, this is the kind of what we would call it probably when we look at a project, do you see a network in a project. Is it as natural as a road network?

Student: Certainly not.

Certainly not. It is not as intuitive as a road networking. So, if you take our network from a project perspective, it is more abstract than a road. We have to start representing the road as a network is, we can see the junctions we can see their links we represented it as a network. Representing a project as a network is not so intuitive. So, we really have to plot the people who thought of representing the project as a network, it is you know it is a higher level of abstraction, and this was something that came out in the 50's, and it was an effort by Du Pont Remington Rand & UNIVAC.

(Refer Slide Time: 03:43)



So, Du Pont needed construction and maintenance of it are works and things like that((Refer Time: 03:53)), Remington Rand was a management consulting group at that stage, and UNIVAC was the computer for and they got together and developed the CPM scheduling method. And network planning and though, at that time OR and graph theory and all go you know in the developmental stages and the team that got together really put you know very innovative to put this together and use it in the term for construction planning.

And they develop the critical path method, there is quite a bit of history to it, and I will give you some references at the end, where you can read as to as we know, how the terminology we use today is not necessarily the terminology that was originally used. But, the techniques are relatively the same, there is also a lot of debate on whether the original technique is actually more authentic for construction planning than some other techniques we used today, but some of this we will take on later in the class, we will go through the basics today.

Now, when you take CPM, the nice thing is that when you compare it with the Bar chart one of the limitations you remember was that we could not represent relationships. So, here you can represent the relationship between activities, number 2 is there is a certain mathematical background to the way CPM is done. The Bar chart, did you have any analysis from a Bar chart? No, it was a good communication tool, but more than that it did not give us any more results.

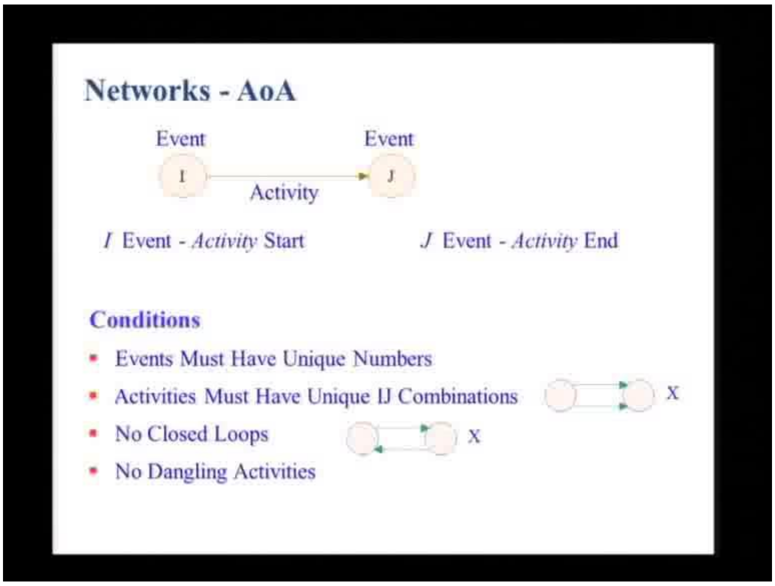
We could, once we applied our mind to the project and expressed it in the form of a Bar chart, it served as a good communication tool, you could update the Bar chart, you could use it in many ways, but it was mostly a visual communication tool. Visual communication and representation, a network offer more than that, and we will see some of that. One of the real limitations of the network is that it requires training to interpret. You could see something like a Bar chart; we can discuss it for half an hour or even less and someone can use it straight away.

But, when I come to CPM you would really need, you know quite a few hours of introduction and even then a lot of practice to be able to use it effectively on a project. Now, when we look at, so the first thing when you take a network, and you look at a project in terms of a network, what you have to understand is, how do we actually represent a project as a network. So, you know we got a clue so far, we are going to break a project into activities, you know we are taking those activities, we are sequencing the activities, and you know so on.

So, we certainly understand activity is one part of this network representation and you know the other part is the precedence relationship, the relationship between activities. So, in the original representation which is called activity on arrow AOA, the nodes represented the start and the end of the activity, and the arrow represented the activity itself. Now, you will do a small exercise on this problem for you to understand or for you to be able to see, why people like Fondhal came out with activity on the node.

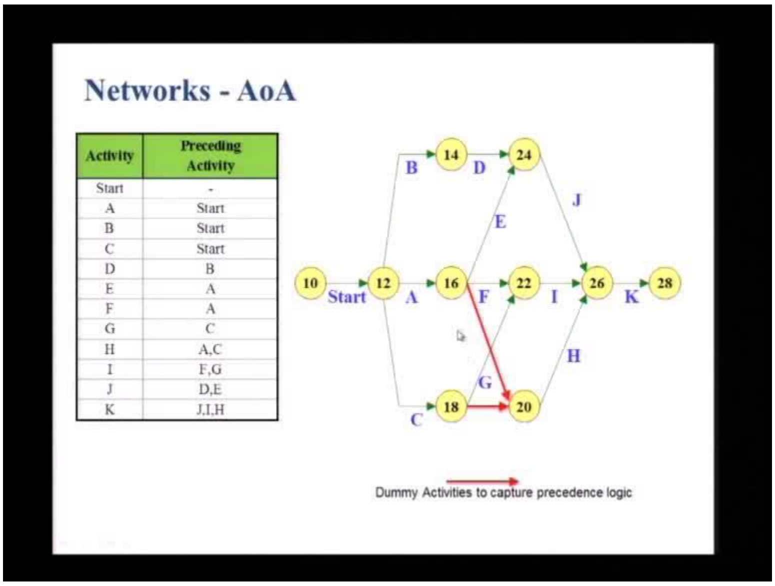
So, when you take activity on node you will find that the activities are represented by nodes and the relationships are represented by arrows. And then you have the precedence diagramming method, which was IBM's extension for activity on the node and this is, even more, offers more sophisticated features on activity on the node. So, what, we will cover today is a little bit of activity on the arrow, more on activity on the node, precedence diagramming gets it is own two sessions later on in the course.

(Refer Slide Time: 07:42)



So, like we talked activity on the arrow you have, you know that is an event I and event J, the event is a start of the activity and the end of the activity, activity is represented by the arrow. Now, there are some conditions one should follow, we should have all event should have unique numbers in this representation, activities must have unique I-J combinations. I cannot have two activities represented in this form; there is no question of having closed loops or dangling activities, so all activities have been ended with the node.

(Refer Slide Time: 08:21)



Now, if we take the inputs for a network what we have shown you here is a set of activities and a set of predecessors. So, when you take activity A, it means that only after the project starts we should be able to start, once you start yes, then only activity A starts. To do activity

D, activity B should finish; to do activity E, activity A should finish. So, this is called the relationship. So, for example, to start activity I, activity F and G should finish.

So, now, you have seen the rule for making activity on arrow diagrams. Do you think you can try to represent this logic through activity on arrow? Can you try it? Remember the arrow is the activity, done. We will just take a look at the network, and you can compare, what you had with what you, what is here. So, this is you can see the, there is a start, you have activity A, B, C succeeding the start, you can see activity D is after B, E, F. So, E is after A, F is also after A, F is this and activity G is after C. Now, activity H requires A and C as predecessors.

So, right now if I start activity H out of here, what happens; out of 18 to 26 if I join…

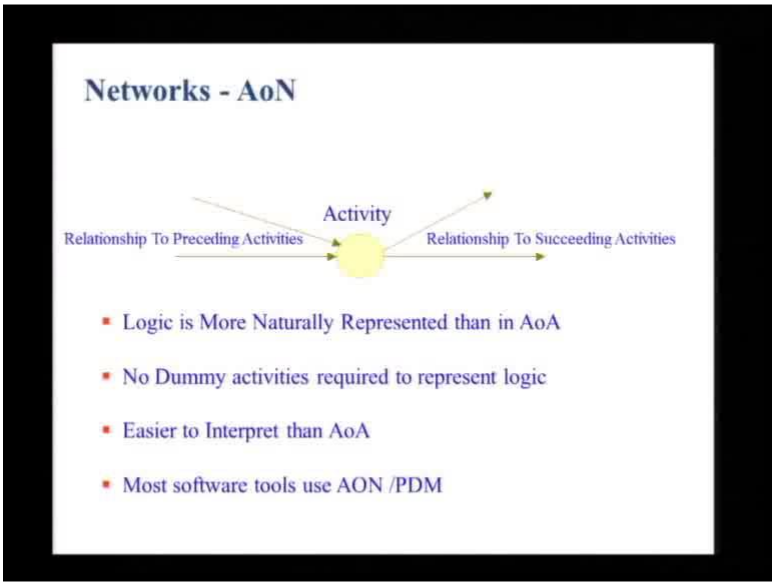
Student: It is no longer ((Refer Time: 10:23))

You know A is not included if I join from… So, what we do is I mean what AOA requires is the concept of dummy activities. So, we have two dummy activities which enable us to create this node and then, link 20 to 26 and make it H. So, it is not just the inclusion of dummy, you find that as even with representing E you might have some difficulty. You would have had, you know you would have started off with one loop and found there is the redundant activities coming in and things like that.

So, then you can follow the rest you will see J has got D and E as predecessors, K has J, H and I as predecessors. Now, this the word, I mean you experience a little bit of the difficulty of what AOA causes, which is this inclusion of dummy activities, and when activities are on the arrow, almost always it is very difficult to draw the network logic cleanly the first time. You will have to keep repeating because only the topology of the network will govern the logic and only as you do it in a couple of times, you can optimize it to the minimum number of nodes and arrows.

So, this was a challenge in the past and in the earlier programs which had activity on the arrow would have around of optimizing the network itself. So, that was one of the challenges. So, here we have what we called the dummy activity to capture the precedence logic. Now, so this, so a lot of activity on the arrow, the lot of the activities are also dummies, no duration only requirement to catch logic.

(Refer Slide Time: 12:09)

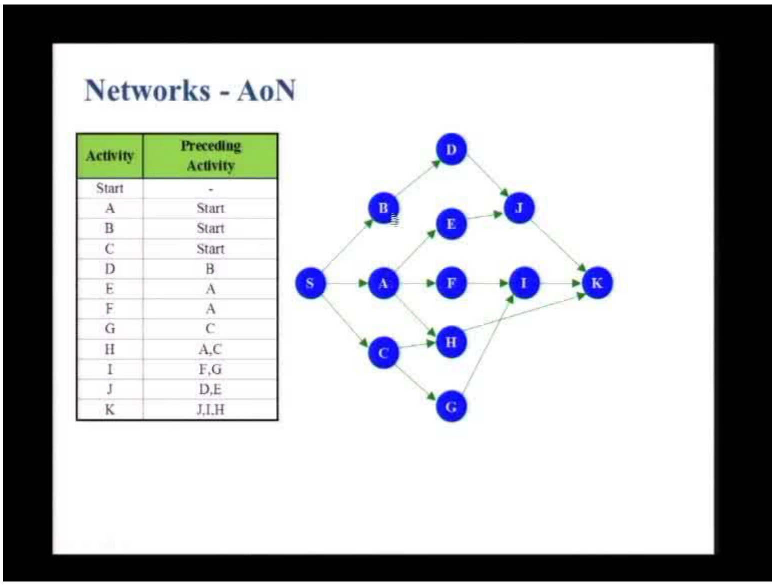


Now, let us move on to activity on the node, so the activity on node was proposed as a good way to do hand calculations for CPM. This is what Fondhal had written in this paper, it was some other work he did for the US Navy and he said, look you can now use a technique, which is activity on node and you can actually it is so, it is intuitive, so you can do hand calculations for that and activity on arrow really needed a… For large networks, it needed a computer program to do here, network representation and calculations. So, here you will find, you have to tell me.

So, let us, so basically what you have here is you have activity in the node, the relationships are represented by arrows. So, if an arrow goes from a node to another node, it means there is a succeeding activity otherwise it is a proceeding activity. Now, here I have made some statement, so no dummy activities are required is easier to interpret you know, and most software tools use AON than PDM last statement is true and that is one reason for the real you know usage of AON growing a lot.

But, I want you to see if this two are something which you can validate if especially the logic is one naturally represented.

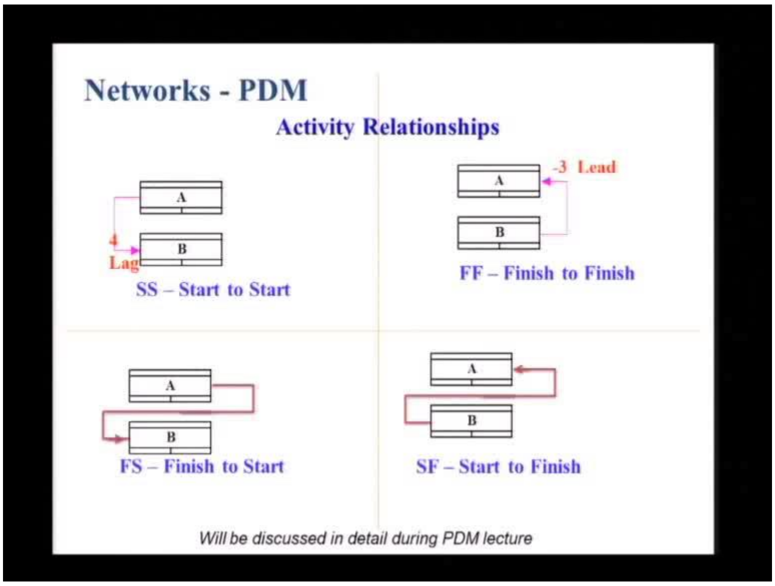
(Refer Slide Time: 13:29)



So, let us take the same problem and you try to do an AON, done one simpler the logic flows and you are able to go through the whole process without, I mean you might get a few arrows crossing, which sometimes cannot be avoided, but basically you can find here that their activities are on the nodes arrows represented relationships as you go through the network you start drawing your arrows putting your remaining nodes, and it flows thing.

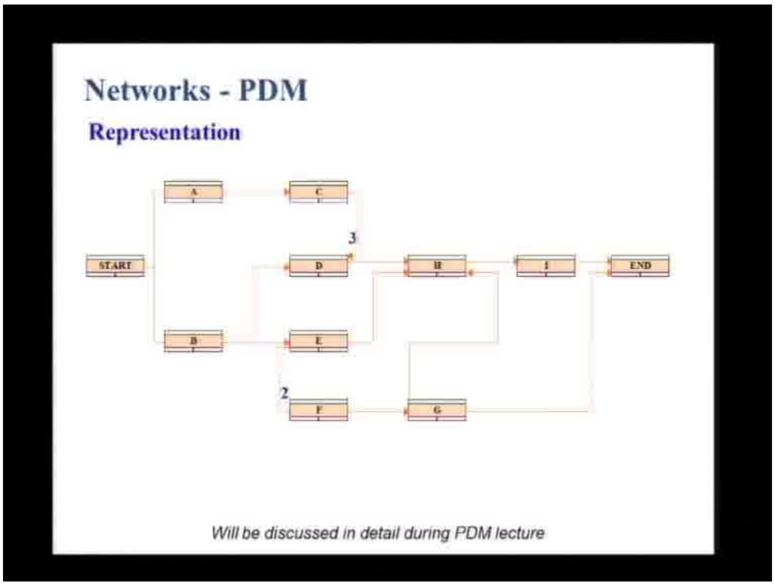
Now, this representation ((Refer Time: 14:05)) and this representation contain exactly the same information same topology ((Refer Time: 14:10)) from a human perspective this is much easier to interpret, and you will continue with this for the hand analysis when we go to precedence diagramming method you will find that it becomes as tricky as this in some ways.

(Refer Slide Time: 14:28)



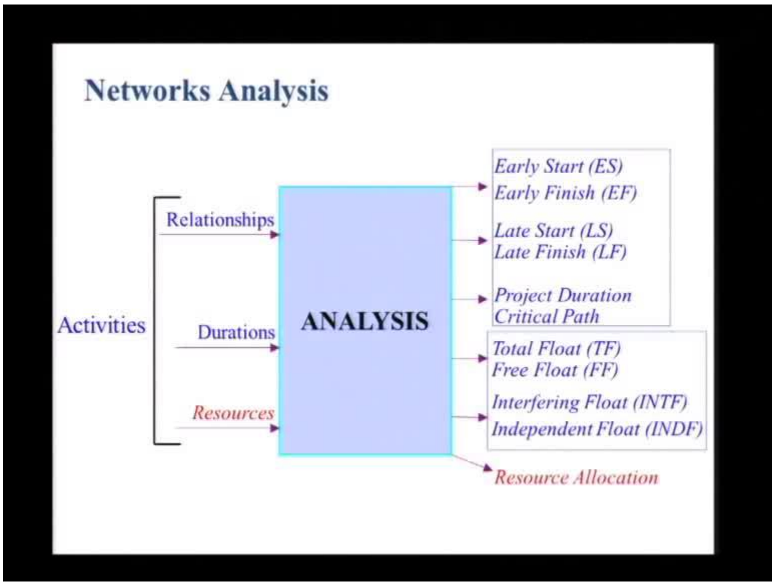
So, and the reason for PDM being tricky as this that, so for we have been talking in the in AON, AOA only talked about finish-start relationship that an activity should finish before the next starts; that is the only relationship we can represent when we go to a precedence diagramming method the key differences there are other relationships. So, you can see there is something like a start-start relationship which says that you know, and here I have included a lag also which says B can start only 4 days after A starts or a finish, finish relationship you can have the conventional finish-start relationship and a very kind of not, so much used start to finish relationship. We will take more of this during the lecture on PDM we have a few sessions on PDM will take more of it then.

(Refer Slide Time: 15:21)



And a PDM network will look something like this where you have the various relationships, which are shown and this can also get complicated to do by hand, because of the different types of relationships involved. But, again we will take this up later in the PDM lecture.

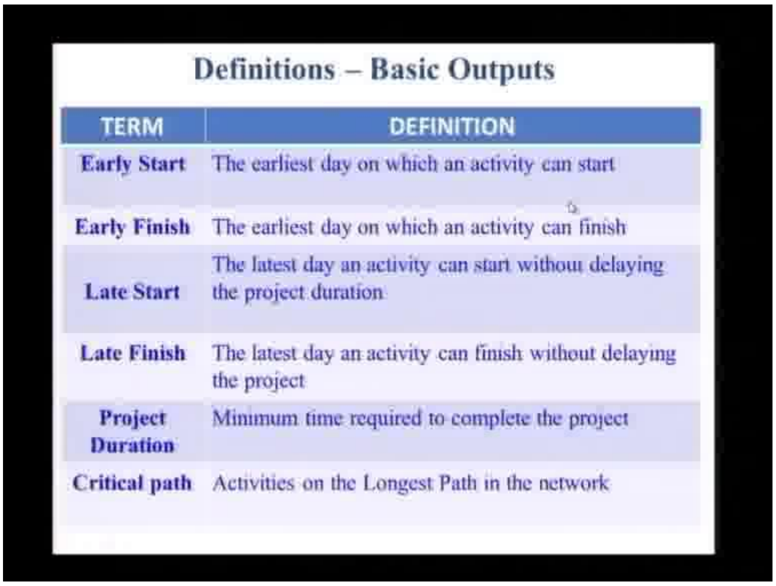
(Refer Slide Time: 15:42)



Now, we talked about network representation, so for and one thing which we have to recognize is we have, so right now I actually given you the relationships. Establishing those relationships can be tricky, and we will take more of those sequencing as we call it when we actually take up some cases. But, when we look at the analysis of a network you will find we talked about activities, we heard of finding the relationship between the activities, we talked about durations, will talk about resources later, we talked about resources with respect due do duration, but we have to have resource management which is a separate area on it is own and we will take this up a later in this in the course.

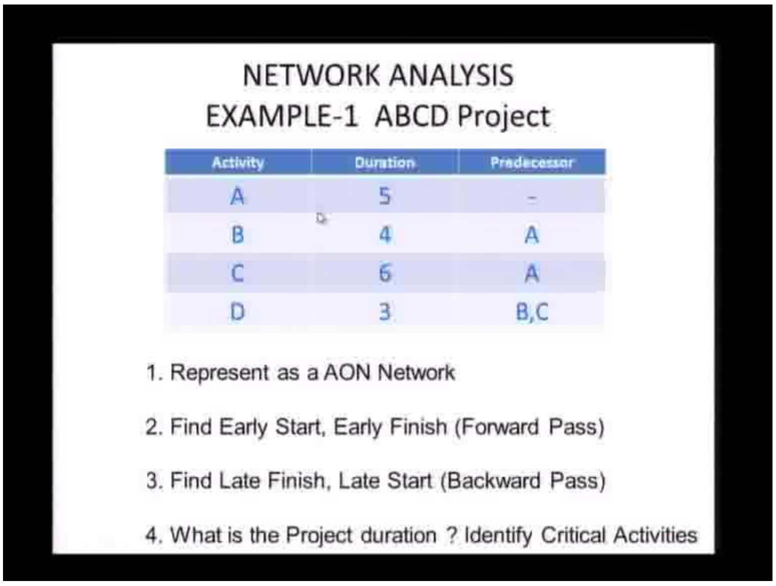
But, given relationships and durations these are the outputs we get from network analysis, what we call early start, early finish, late start, late finish, the project duration, the critical path, or critical activities we have a serious of floats are slacks, which we get which is total float, free float, interfering float and independent float. So, what we have to do or what we are going to cover a network analysis is to kind of illustrate, how what each of this mean and how they calculated. So, in this session, we will primarily talk about the times the early start the start the finish and the project duration of the critical path.

(Refer Slide Time: 17:09)



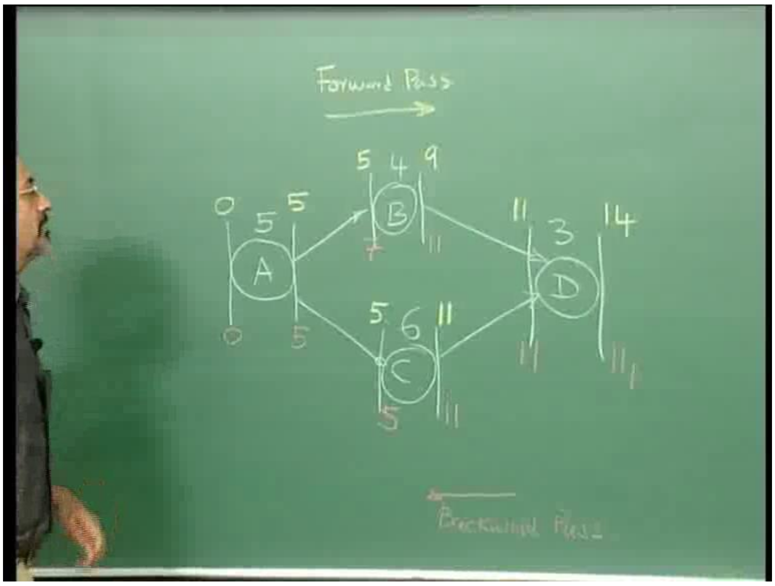
So, we take a little bit on the definitions you can see it here the early start is the earliest day, which on activity can start the early finish is the earliest day on which on activity can finish, late start is the latest day an activity can start without delaying the project duration we will illustrate this it will become clearer a late finish is late is latest and activity can finish without delaying the project, project duration is minimum time require to compute the complete project and the critical path is the activities on the longest path in the network. We will kind of illustrate these calculate these quantities through an illustration.

(Refer Slide Time: 17:46)



And this is the illustration which I would like to use first it is a very simple network you can see it has just got five activities four activities A B C D, and you have the durations given there, and you have the predecessor relationships I think all of you will be able to draw the network pretty easily.

(Refer Slide Time: 18:11)



So, let me take this as, so A has, so I am going to do the activity on node representation. So, A has no predecessor I have B and D. So; this gets a network through, so you can see D has B and C as a predecessor; now you have durations and in my notation, I like to put the duration on top of the activity. So, you have a duration of 5 B has a duration of 4 C has a duration of 6 and D has a duration of 3.

So, I like to keep the duration if and as far as we are concern the duration is constant it is fixed we are not changing the duration for this analysis, I like to make a notation in this form, which makes hand calculation easier to interpret and what we are going to do is, now do we are going to calculate of this is takes care of the first part which you are represented the activity on node network.

Now, we are going to the second part, which is called the forward pass we take the network from the left to right, and we use a certain terminology for time we say that this is starting on 0, which is actually the beginning of the first day we put 0 it is going to take 5 days we put 5 here, which is actually the end of the fifth day, because that is the 5 day duration. So, A starts beginning of the first day which is 0 end of the fifth day, now we have two activity, so when can B start.

So, we are putting five which is actually the beginning of 6 days. So, we are putting 5 and five we go to 9 we go to 11, so now, between 9 and 11 when can D start 11. So; obviously, it has to wait for B will finish by nine it has to wait for C to finish because it is a predecessor and only then it can start, and D can finish on 14. So, what we have calculated here is the early start, early finish of the all the activities of the network and ultimately landed up with the project duration.

So, this is network will take this project will take 14 days to complete and we found the early start and early finish through the forward pass, now what we do is we actually have to find out the late finish and late start. So, remember what was the late finish? Latest an activity can finish without delaying the project duration project, so our project is now fixed as 14 we cannot change. So, D can't we change 14 and when should D start to finish by 14, 11 it cannot. So, this becomes 14 minus three that is an 11 how late when we talking about late, now how late can B finish 11.

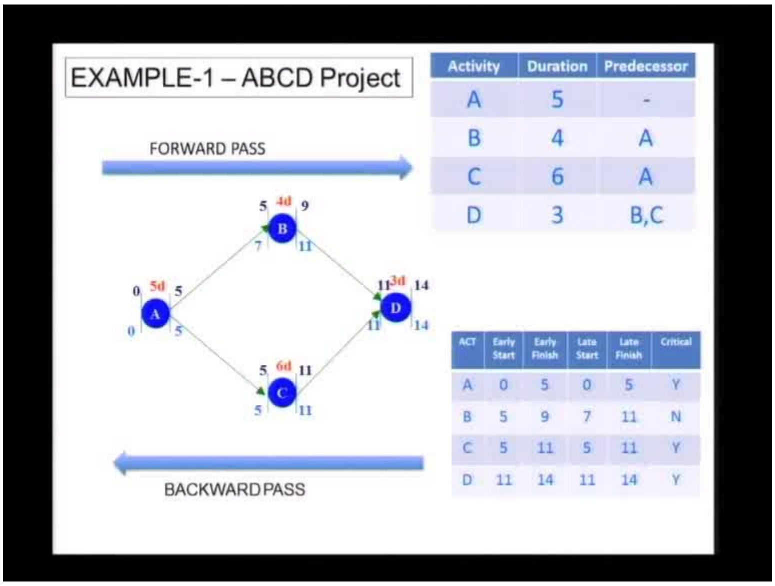
So, even if B finishes by 11 we are okay project is okay C 11 now C has to start later it can start is by 5 and what about B 7 yes. So, 11 it was four days and four is a constant. So, it comes to 7 we has the latest it can what happens if B starts on the 8th day yeah 8 days this goes to 12, which means D can only start on 12 and project goes to 15, So, this is 7, now I come to A, I have 5 what is the latest A can finish 5 if I finish after 5 what happens C gets delayed and 0. So, this is the backward pass we did the forward pass to find early start early finish the backward pass to find the late times now can you observe.

So, we have two paths one going A B D and other going A C D and you can see that is there any difference between any of the activities we can see in terms of time in terms of the relation 0 5 0 5 5 11 5 11 11 14 11 14 5 9 7 11 here the late times are different which means there is something different about B compare to C, and that is slack or float we will take that up later, but you can see that there is something different now what we talk as if I delay B by 1 day what happens it's okay as for as the project concern if I delay C 1 by day project gets delayed if I delay A by 1 day project it gets delay.

So, these activities are critical. So, activity A, C, and D are critical and it really the critical path does not mean as much as identifying the activities that are critical. So, if you want to draw the path you would say the critical path goes through. So, this was a simple example which illustrates basically how the network analysis is done and we are calculated all the parameters which we talked about the early start early finish late start late finish project duration and identify critical activities.

Now, we identified critical activities more because it is a simple network the actual algorithm to identify critical it certainly depends on the float and when we cover float in more detail we will come to that.

(Refer Slide Time: 25:07)



Now, the same network I can show it you in a brief animation it is exactly what we did by hand and these are the times now how would you like to see if you like to see the results like this, or do you like to see in some other form, what would be the best way to express the results.