Operations Management

Dr. Inderdeep Singh
Department of Mechanical & Industrial Engineering
Indian Institute of Technology, Roorkee

Lecture - 32
Network Diagrams

[FL] friends welcome to session 32 in our course on Operations Management and in week 7; our focus is on project scheduling, CPM and pert. In pert, we will be discussing in week 8; so, in week 7 focus will primarily be on learning the project scheduling and the project management using the concept of networks network diagrams as well as CPM.

If you remember in the first session that we discussed in this week, we have taken into account the importance of network diagrams, we have tried to understand the importance of a project, we have seen the definition of a project. Also we have identified that for scheduling any project; there are three important things that have to be taken into account. And the first one is the cost; then the resources and third one is the risk involved.

So, the cost, time, resources can be in terms of times; the resources can be in terms of manpower. So, primarily focus when we talk of scheduling is on time; so, we say cost, time and the risk and we try to optimise all these three in order to complete our project by the deadline.

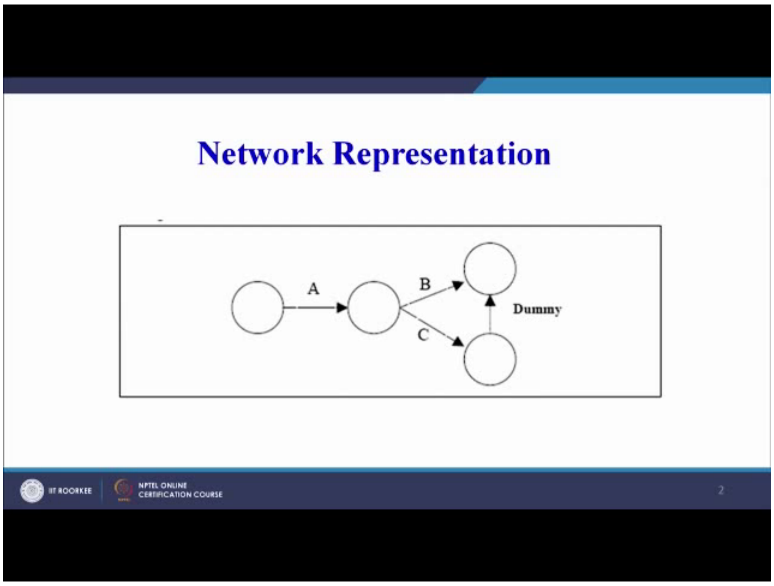
So, also I have emphasized that project scheduling or project networking or project management is not only related to activities on the shop floor, but is universal in nature. Even software industry, works in the project management mode; even the construction industry works in the project management mode; even the government also works in a project management mode. So, this is universal in nature; so for that sake all of us must know that how to define a project? What makes a project? What are the various ingredients constituents of a project? So, that we have highlighted in the previous session.

Today our focus will be that; how to represent a project in the form of a diagram? How the project representation can be successfully done in the form of networks? In the last session, if you remember we have seen a Gantt chart which is also a representation of a project, but it only shows the time domain; the cost, the manpower involved is not represented there.

So, only we have time domain which activity? When it is starting? When it is ending? Also it is not able to show the inter relationships among the various activities, the precedence relationship among the various activities. Therefore, networks offer maybe of broader scope to project management.

And therefore, we are going to learn that how the projects can be represented in the form of networks? What calculations we can do based on the networks? And how these calculations can be used for decision making by the managers or the engineers? And that is why today our focus is on network diagrams, we will see that how to represent a project in the form of a network? And how this network can be used for certain calculations? So, let us start our discussion with the network diagrams.

(Refer Slide Time: 03:46)



On your screen; you see a very simple form of a network There are three activities here and the fourth one is a dummy activity, which is represented here. We will try to see what is the importance of the dummy activity in due course of time, but prior to that; let us see how a project has been represented in the form of a network here?

Now this project consists primarily of three activities; the activities are activity A, activity B, and activity C. As we have seen in the previous session; on the last slide, we have seen that there is a activity or a task, then there is an event and there is a network. So, network is a broader picture; it is representing the various activities and the events. The events mentioned here are the circles, this is the first event which is representing the beginning of activity A. So, this may be day 0; when the project is starting or initialising.

So, this is the start of the project; then activity A is taking place; definitely it will require some time and resources. This event; second event circle represents the completion of activity A and the beginning of activity B and activity C. And this particular node is the last node because from here; no other activity is emanating or starting.

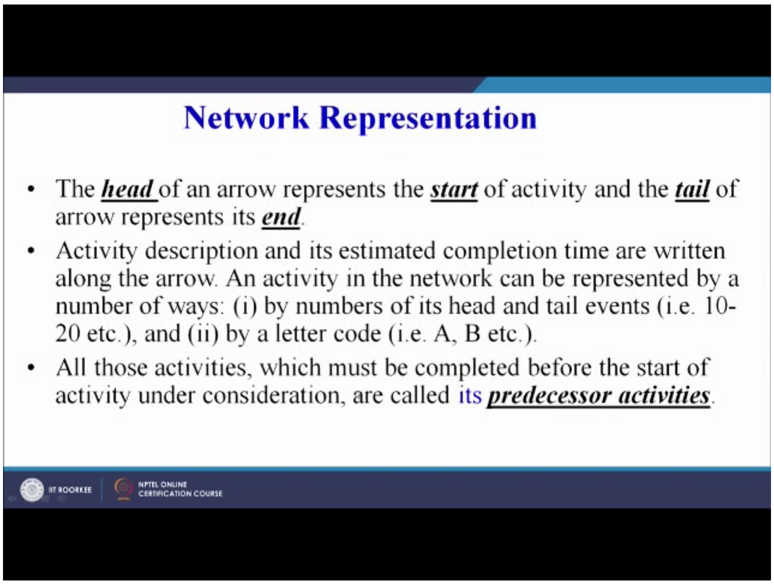
So, this circle usually is called as the node; so there are 4 nodes; N O D E S; 4 nodes in this network; node 1, node 2, node 3 and node 4. Some of you may be wondering that why I am calling this as node 3 and this as node 4? Why not this is 3 and this is 4? Absolutely right question that has come to your mind; so, we will try to answer this question also today with the help of Fulkerson's rule for the numbering of nodes.

So, first thing that we must learn is that; where is the activity? And where is the event? So, the circles are representing the events and the arrows are representing the activities. So, here we see activity A; this is a start node or start event for activity A, this is the finish node for activity A, this is the beginning node for activity B and activity C and this is the finishing node for activities C, and this is the finishing node for activity B; as well as activity C, through this dummy activity. We will try to understand why dummy activity is used? And what is basically a dummy activity?

So, this is the representation of the project network and we will be focusing on these types of network in our discussion on CPM as well as on pert. So, it is very important that all learners acquaint themselves with the basic terminology of nodes and activities. So, this representation is the; arrows are representing the activities or in the other way, we can see the activities are on the arrows and the nodes represents the events.

So, arrows represents the activities A A and the nodes represents the events; with this let us just read whatever I have already told. This is the start of activity, this is the end of activity. So, the tail of the arrow represents the start and the head of the arrow represents the finish.

(Refer Slide Time: 07:58)



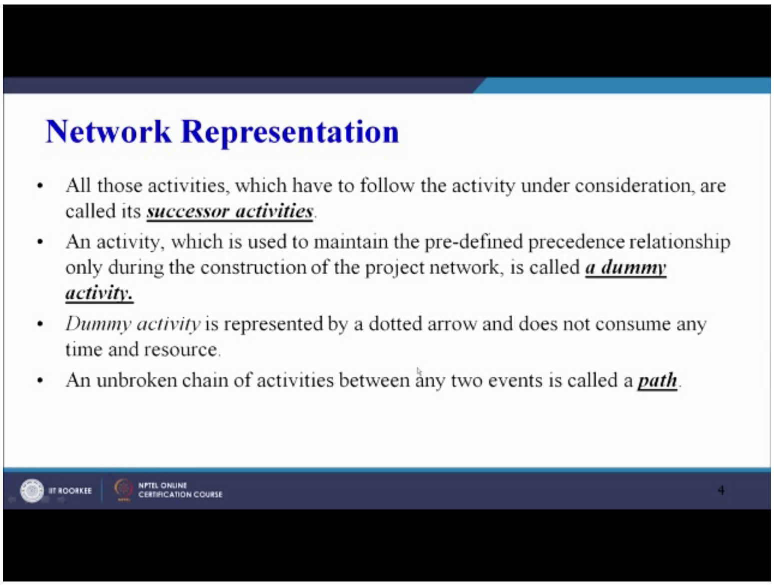
So, let us see the head and the start; the head of the arrow represents the start of the activity and tail of the arrow represent; its end. so, head and tail maybe I have used in the opposite manner. So, in the network we can see may be the sentence may not be correct, but this is the start of the activity and this is the end of the activity A; this much we must remember.

Then activity description and its estimated completion time are written along the arrow. In our network we have not represented the time, but in the networks that will follow in our discussion; we will definitely be representing the name of the activity like in our case there were A, B and C activity. We will be representing the activities with the alphabets as well as the time will also be represented on top of the arrow.

So, activity, description and its estimated completion time are written along the arrow. And activity in the network can be represented by a number of ways. So, we can represent an activity like in our case our activities are represented as alphabets A, B and C and we can also represent by the number of the node. So, suppose we are numbering our node as 1, 2, 3 and 4. So, one activity can be 1, 2; so, 1, 2 in our case was activity A; 2, 3 can be activity B; 2, 4 can be activity C.

So, we can represent an activity by the start and the end node also or by a letter code as I have already told the alphabets A, B and C can be used for representing the activities. Now all those activities which must be completed before the start of an activity under consideration are called its predecessor activities. Now, if we see the previous network here; in this network activity A must be completed before the start of activity B and activities C; therefore, activity A is a predecessor for activity B and activity C.

(Refer Slide Time: 10:09)



All those activities which have to follow the activity under consideration are called its successor activities. Now A is a predecessor activity for activity B and activities C, similarly B and C are successor activities to activity A. So, all these terms must be known to all the learners because we will be drawing a complicated network also. So, we must know that what is the predecessor activity? And what is a success activity?

Now predecessor activity in our network was A because A must be completed before B and C can start, but for A; B and C are the success activities that; after A will be completed B and C will start.

So, predecessor and successor has to be known to all the learners and activity which is used to maintain the predefined precedence relationship only during the construction of the project network is called a dummy activity. So, we have seen in the network there was a dummy activity; this is the dummy activity which is represented here. So, the dummy activity represents an activity which will not consume any time, it will not consume any resource, but it is represented in the network in order to present some logic.

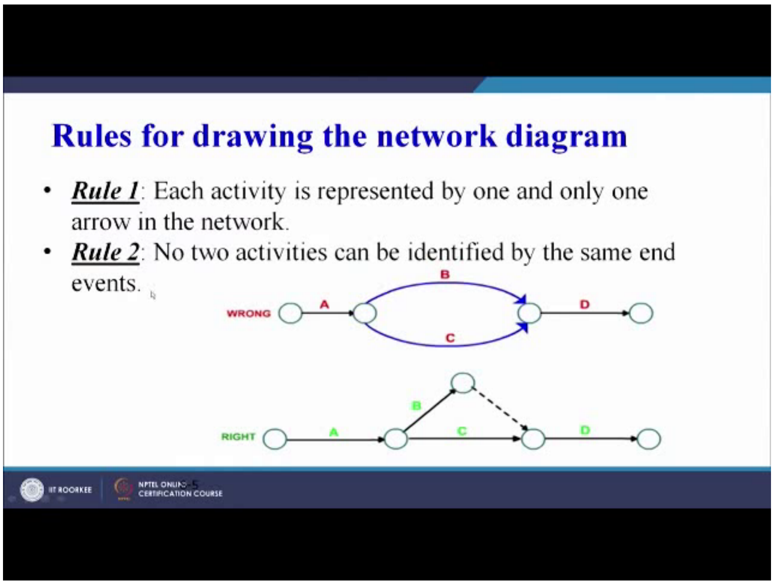
So, the logic can be a precedence relationship; the relationship of the form of predecessor and successor that this activity must be completed, then only these activities will start. So, that type of logic can be established with the help of dummy activities and we will try to see that with the help of an example in the subsequent slide. So, we have tried to define the dummy activity also; dummy activities represented by a dotted arrow and does not consume any time and resources.

So, dummy activity is we can identify when we look at a network; it will be easy to identify the dummy activity. Because it will be represented by a dotted lines; all other activities will be represented by the solid lines; so just by looking at the network, you can have a idea that this is specifically the dummy activity. And why this has been drawn? When you will analyse the network, you will see that a dummy activity has been drawn in order to establish a precedence relationship among the various activities.

So, an unbroken chain of activities between any two events is called a path. So, in our network we have seen A, B can be one path; A C and D was a dummy activity, so we can say d 1 is a dummy activity. So, our network has two paths; if we see that network that we have seen. Again I will go to the network, in the network if you see we have two paths here; one path is A and B; this is one path unbroken path of activities. And another one is A C and suppose we call the dummy activity d 1; so, A C and d 1 is another path and A B is one path in the networks. So, again I will read how to define a path; an unbroken chain of activities between any two events is called a path.

Now, let us see what are the important rules for drawing the network diagram? Rule 1.

(Refer Slide Time: 13:33)



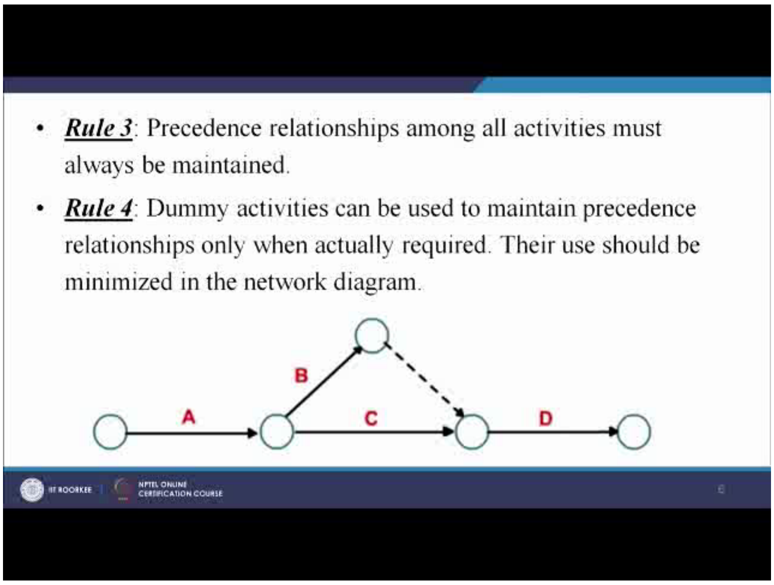
Each activity is represented by one and only one arrow in the network. So, this is very important that every activity has to be represented by one arrow only; it must not happen that activity A we are representing with three different arrows. A means one start node, one end node and on the arrow we have to write activity A.

Rule 2; no two activities can be identified by the same end events and this has been a explained with the help of a diagram also. You can see this is wrong; red colour defects wrong here A, B, C and D; so this network has 4 activities activity; A, B, C and D and B and C have same start node, same start event and same end event which is wrong from the network representation point of view.

And therefore, how we can represent this network? This is the right network here, we have incorporated a dummy activity here which is represented by this dotted line. So, this is now actual representation; which is correct from the network description or network representation point of view.

So, we can see one use of a dummy activity here that no two activities can have a same start and end node. So, a dummy activity will help us to resolve this issue.

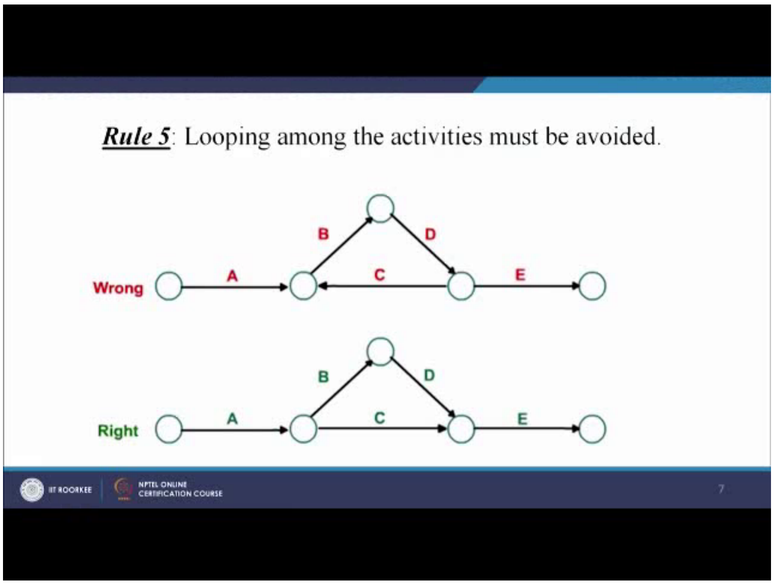
(Refer Slide Time: 15:02)



Rule 3; precedence relationships among all activities must always be maintained. We have to ensure that the predecessor successor relationship always has to be maintained. Rule 4 dummy activities can be used to maintain the precedence relationship only when actually required; their use should be minimised in the network diagram.

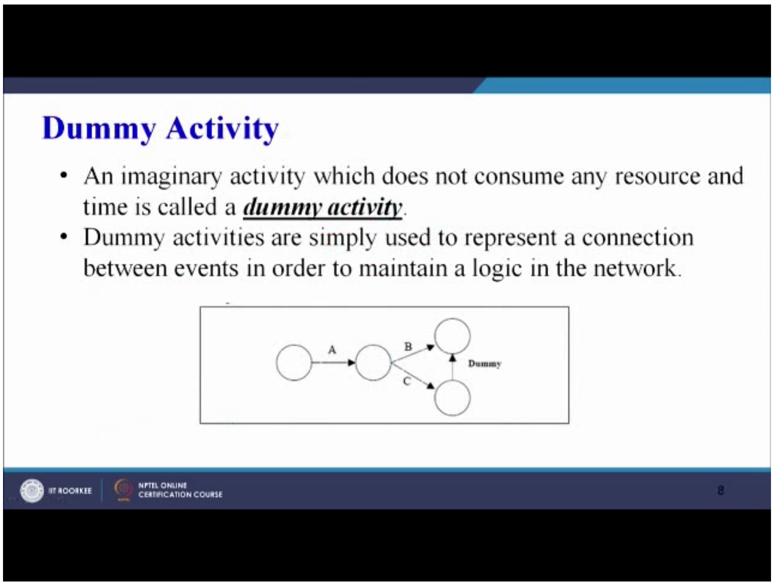
Many times; I have seen the learners will make very liberal use of the dummy activities which is not allowed or which is not maybe right from the calculations point of you; also if we are using a software for doing these calculations, it may take more time if we have been very liberal with the use of dummy activities. So, the use of dummy activities must only be restricted to establishment of precedence relationship among the various activities only. So, we should not use dummy activity just at the throw of the hat.

(Refer Slide Time: 16:05)



Looping among the activities must be avoided; so, here you can see rule 5 looping among the activities. So, here there is a loop which is created here, which is not correct you can see this has 5 activities activity A, B, C, D and E, but there is a loop between B D and C; this is arrow B, D and C. So, this type of loop has to be avoided because this is not going to help us to reach the last node and right way is A, B, D, C and E. So, the looping must be avoided will create problems when we will do the calculations for finding out the critical path.

(Refer Slide Time: 16:48)



Now, let us see the dummy activity; again we have come to the same diagram. So, by now we have seen the general rule for drawing a network, we have try to understand what is an activity? How it is represented? What is an event? How it is represented with the help of a node?

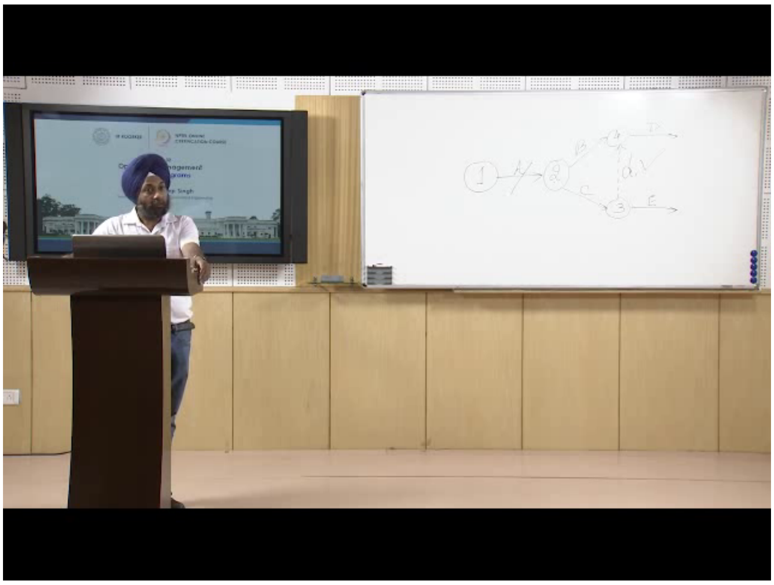
So, at least now if we have a list of activities and precedence relationship for each activity; we can try to construct a network, but before going to the actual construction of the network; let us try to understand the use of dummy activity and try to understand what a dummy activity actually is?

Dummy activity actually is an imaginary activity which does not consume any resource and time and it is called dummy activity; is usually represented by a dotted line in the networks. So, dummy activities are simply used to represent a connection between events in order to maintain a logic in the network. Now here, we see the use of the dummy activity; in this network let us try to understand from a different point of view that how dummy activity is important?

Now in this network, suppose there are two more activities; currently we have three actual activities A, B and C and there is a dummy activity d 1. Suppose, we have two more activities which we call as D and E; D has predecessor, that is B only and E has predecessor that is C only.

Just again I am repeating D has a predecessor B and E has a predecessor C; now your D can start from the network, I think I will try to draw this and try to explain this network.

(Refer Slide Time: 18:45)



Now, this is my start node then I have A; this is not sorry A; this is an event here and the nodes can be numbered as 1, 2 and this is my dummy activity here 1, 2, 3 and 4. I think this is a network that we have here A, B, C and then a dummy activity there. Now suppose there is activity D, which is only dependent on activity B. So, the activity D will start from here and the predecessor is B and there is an activity E; which has only predecessor as C.

So, here we can see; if we do not use this dummy activity and we directly take C here; so, D and E have will emanate from that node 4 or in that case node 3, if we do not use this dummy activity. So, B and C cannot go directly into node 3 or 4; as per our rule that no two activities can have same start and the end node, so they have to be separated. Then the successor activities are also having different predecessors; D is having a predecessor B and E is having a predecessor C.

So, we have to see if we combine the two together, if we combine; if you do not use this dummy activity d 1; what will happen? We are not able to establish this precedence relationship of activity D and activity E. Because we both starting from the same node means E is also dependent on B, which is not true.

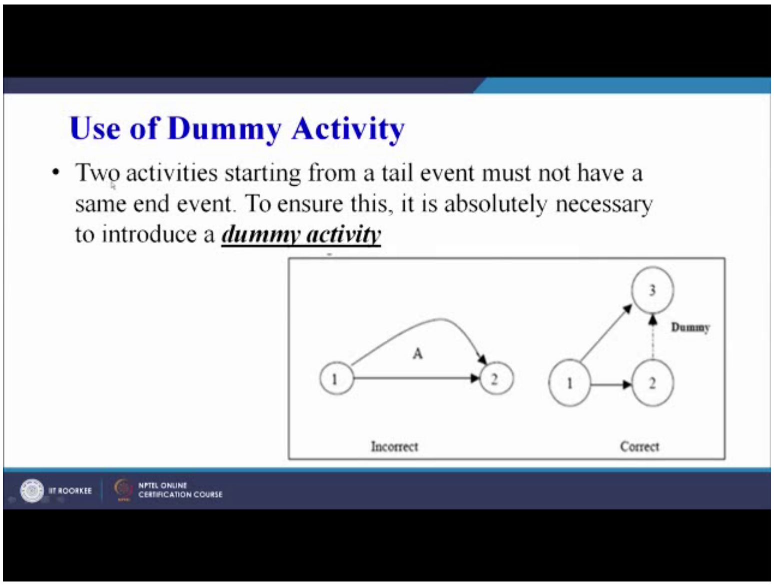
So, therefore, the use of dummy activity has helped us to establish this precedence relationship that C is the predecessor of E and E can only start, when C has finished.

Similarly D can only start, when B has finished; this logic has been established only been made possible with the use of this dummy activities.

So, similar type of situations may arise when we are using the networks and these networks are maybe representation of the project and this project definitely would be requiring us to calculate the times required for the project. And if the representation is not correct, we may not be able to get the right time for completion of the project.

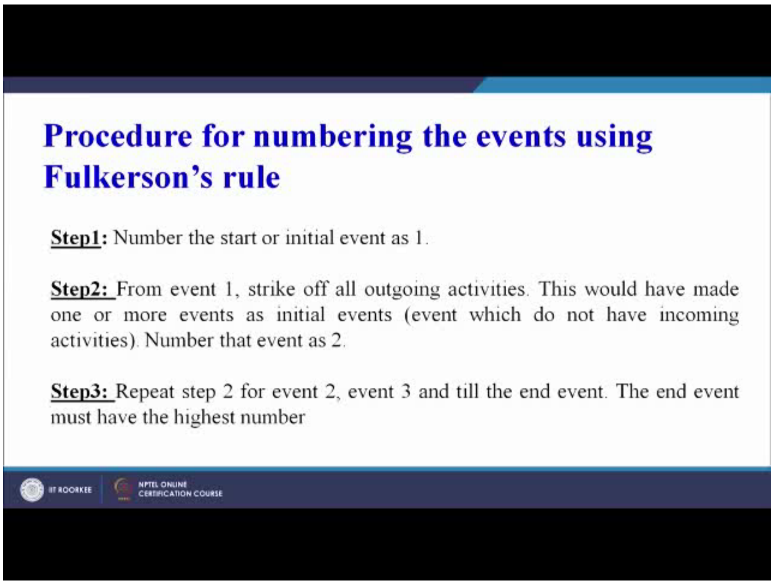
So, I think I have tried to explain the use of dummy activity and we have an example also which will show the use of dummy activity.

(Refer Slide Time: 21:59)



Two activities starting from the tail event must not have a same end events; to ensure this, this is absolutely necessary to use a or introduce a dummy activity. So, 1 or 2 activity A here and there is another activity B which is incorrect. So, correct way is that we must use a dummy activity here and from successor predecessor relation point of view, I have tried to explain there; that in order to satisfy the exact logic of the network, we must use the dummy activity.

(Refer Slide Time: 22:31)



Now, the next part of the network representation is the numbering of the nodes. So, here you see I have numbered the nodes as 1, 2, 3 and 4. So, the nodes are representing the events in the network; so here I have used them because we keep on drawing this networks, when we go to the class and teaching the class; it has become our habit to number the nodes and maybe we are most of the time correct, when we draw them.

But there is a rule that has to be followed for numbering of node and the rule is mentioned on your screen. You can see the procedure for numbering the events using Fulkerson's rule; step 1, number the start or the initial event as 1. So, you see initial event is marked as 1 here; how we can find out that which is the start node?

If you see a network; one is by intuitively we can look that this is seems to be the start, we can say this is our first node or first event. But we can see that there will be a node in the network; in which there is no arrow entering, but only arrows coming out.

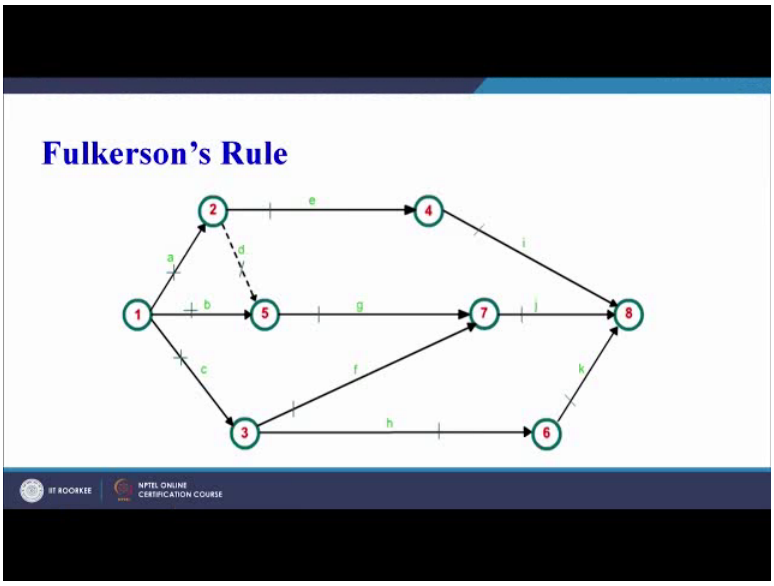
So, if we see in this network only there is one event; where there is no entry of any arrow only one arrow is coming out; that is our activity A. So, that is the identification of our start node which we are going to number as 1; from event 1, strike of all out going activities. So, you strike off the activities; we can see strike off this activity and then try to figure out that which is the node; which has no arrow entering into the node or events and only arrows emanating or coming out.

So, we see this is the node in which only arrows are coming out; 2 arrows are coming, 2 activities are starting from this events, but no arrow entering into this. So, we number this has 2; so, from event 1, strike off all outgoing activities. This would have made one or more events as initial events, event which do not have incoming activities; number that even or node as 2.

Repeat steps 2 and for event 2; event 3, repeat the step 2; the step 2 means striking off of the activities or the arrows coming out of the events; you repeat that step sequentially and every time you will get at least 1 event or 2 events in which, there is no arrows entering, but only the arrows are coming out or the activities are only starting from that event and keep on numbering those events maybe in a serial manner.

So, repeat step 2 for event 2, event 3 and till the end; the end event must have the highest number. So, serially we have to number the events; which are representing the network. So, let us now try to see an example on your screen.

(Refer Slide Time: 25:40)



So, we can see here I have tried to explain on the white board. So, one is on your screen which has no activity entering only three activities are coming or starting from this event one; so, that is a, b and c. Now you strike of a, b and c and try to see a node in which there is no activity entering, but only the activities coming out or the arrows coming out from that events.

Now this is one; this we have already deleted from here we see that and all three have been deleted from here. So, from here e and d are coming out; d is a dummy activity here, from 5 g is coming out and from 3 your f and h are coming out. Now, here from maybe this node even after deleting this activity b; d is still there. So, a, b and c goes in the first step; so, we get 2 and 3 here.

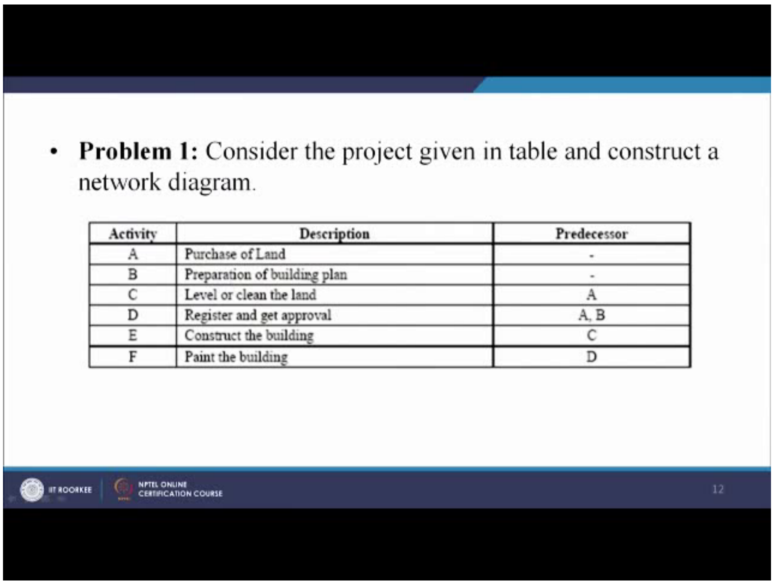
So, normally it is a practice that the top one; we will give the lower number and the lower one, we will give the larger number. So, 1 then this is 2 and this is 3 and this we are not numbering as 4 right now here; because d is coming out from 2 and entering here. So, this has two entry points here; so, even after striking off this, there is another activity that is entering here.

So, once 2 and 3 are numbered; then we will cut all activities coming out from 2 and 3. So, this is cut and from 3; this one and this one is cut then we will try to figure out which one is the next higher number that we can give. So, 1 is numbered, 2 is numbered, 3 is numbered then 4 and 5 come into picture; because 4 is on top so, we will represent it as 4.

And then the 5 activity and similarly we will keep on striking off the activities that are coming out from a particular event and will keep on numbering. So, you can practice this and in case of any conflict; the top representing event is given the lower number and the bottom is given the higher number as in case of 2 and 3; similarly 4 and 5. So, this is a; may be a rule for numbering of the nodes.

Now, towards the end of today session; let us try to see one problem.

(Refer Slide Time: 28:24)



Activity	Description	Predecessor
A	Purchase of Land	-
B	Preparation of building plan	-
C	Level or clean the land	A
D	Register and get approval	A, B
E	Construct the building	C
F	Paint the building	D

Consider the project given in the table and construct a network diagram. So this is the way the problem will be mentioned; so, we have activity description as we have seen activities can be represented by alphabets A, B, C or they can be represented by the start and the end note for the activity, but currently we are focusing on the alphabets as the representation of the activity.

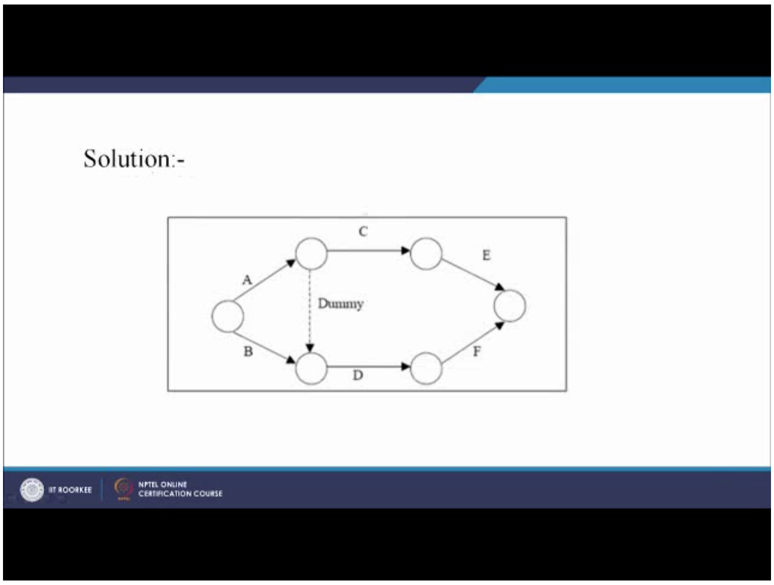
So, there we have activities A to F; that 6 activities, A, B, C, D, E, f and the description is also given purchase of land, preparation of building plan, level or clean the land, register and get approval, construct the building, paint the building. So, this is just for construction of a house; the overall maybe work has been divided into 6 activities and here we see there is a predecessor or a precedence relationship.

Purchase of land has no predecessor, preparation of building plan has no predecessor, level or clean the land has got a predecessor A. You can only level or clean the land; once you have purchased that land. Similarly register and get approval; A and B are must, you must have purchased the land and the preparation of the building plan has to be ready when you get registered and get the approval.

Now, for constructing the building; levelling or cleaning of land is necessary. So, E can only be done; when C has been completed, paint the building when the construction of the building has been done. So, maybe one precedence relationship is given; here I think in place of D, we should have C here; maybe C must be the predecessor for F, when the building has been constructed, we can paint it; so E has to be here.

Paint the building; when after the construction of the buildings, instead of D; I think we must have E, this is my logic that goes for the project, but the purpose of showing this diagram is that how to represent the network? We can leave the description part also; we can leave this description, we have a set of activities; we have the predecessor relations and relationship and then we have to represent the network.

(Refer Slide Time: 30:43)



So, here we can see this is the representation of the network. So, A and B there is no predecessor, C can only start when A has been completed, D can only start; when A and B have been completed. So, D can only start when A and B; so, we use a dummy activity here to represent the network and here we can see the use of dummy.

C is only dependent on A, but D is dependent on both A and B. So, we therefore, we require the dummy activity here because C is dependent only on A, D is dependent both on A and B. then E is dependent on C and F is dependent on D. So, F can only start when D is completed; so, we can see F can only start, when D is completed.

So, this is the way in which we can represent our project in the form of a network diagram. And in our next session, we will see that how and what type of calculations can be done based on this network? So, we have finished two sessions on project scheduling and networks. And in first session our target was just to understand the importance of the network diagrams and just to understand the definition of a project and project scheduling objectives of project scheduling.

In today's session we have seen the rules that one must be kept in mind, while drawing a network we have try to understand the use of the dummy activity. And finally, we have seen one problem of construction of a house; that how the different activities can be listed, what is the precedence relationship among the activities? And finally, how a project network will actually look like; in the next session, we will see the calculations based on this network.

Thank you.