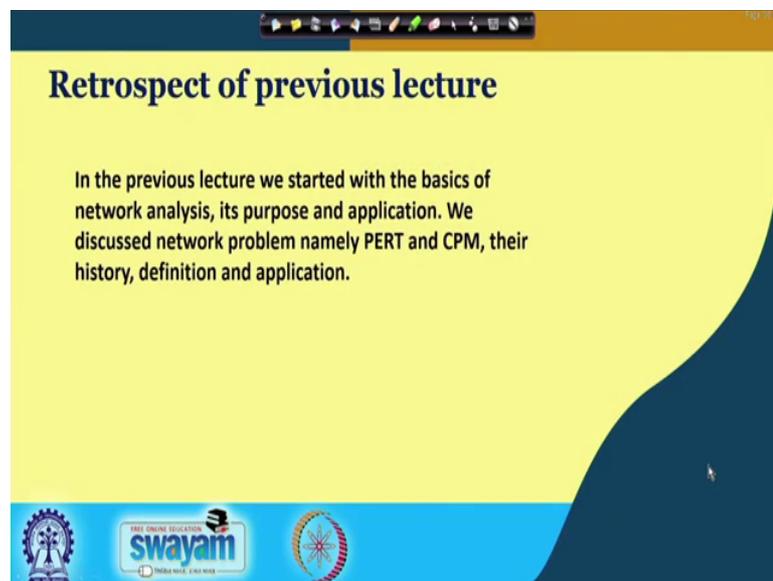


Network Analysis for Mines and Mineral Engineering
Prof. Kaushik Dey
Department of Mining Engineering
Indian Institute of Technology, Kharagpur

Lecture – 02
Introduction to network and some terminology

Let me welcome you to the second lecture of NPTEL online certification course Network Analysis for Mines and Mineral Engineering.

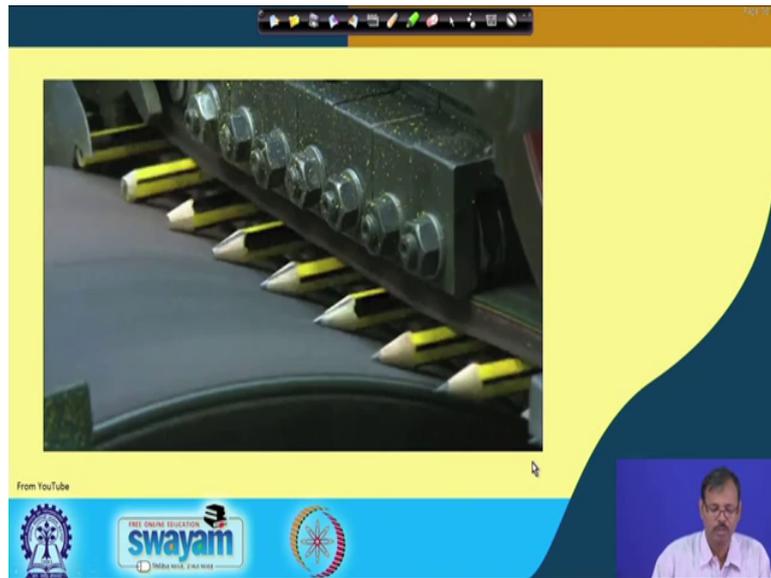
(Refer Slide Time: 00:32)



So, in the previous lecture we introduce our subject to you, now you know that basically network analysis is nothing, but analysis of the different unit activities carried out for achieving some manufacturing or for completion of a total process. So there are, there is a total process which comprises in number of unit activities network analysis is nothing, but presenting them in a network form.

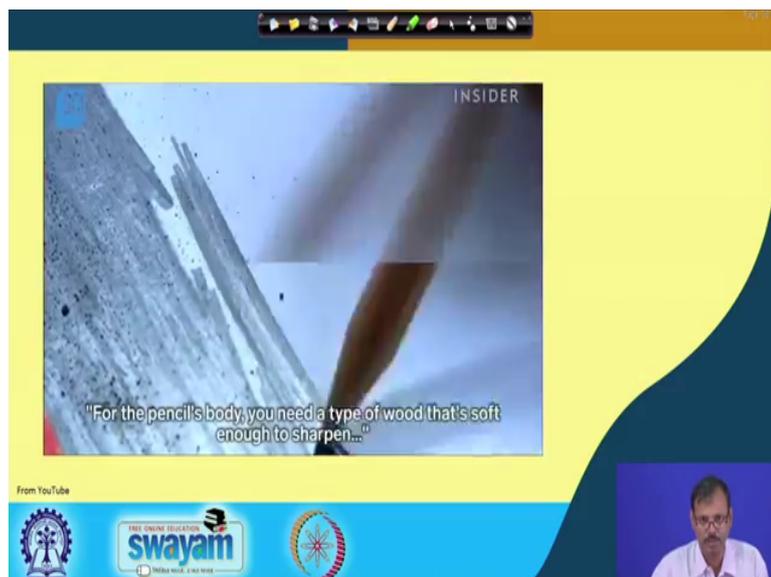
And that is required the analysis for its optimization either in terms of time or in terms of cost or in terms of the conservation of the material. You are also known that this approach may be divided in two part, one is the probabilistic approach another is the deterministic approach the probabilistic approach is called PERT P E R T Program Evaluation Review Technique and deterministic approach is called Critical Path Method or CPM. Their history of development definitions and applications are also discussed in the last class.

(Refer Slide Time: 01:41)



So, as last class also you have absorbed some videos, but I want you must see another video 18 basically gives you some good idea about the different manufacturing process. This is also taken from the YouTube which is nothing, but the pen nothing, but a pencil manufacturing process. So, in this what is happened, first the lead of the pencil is made which is nothing, but the mixture of the graphite of the black soil.

(Refer Slide Time: 02:14)



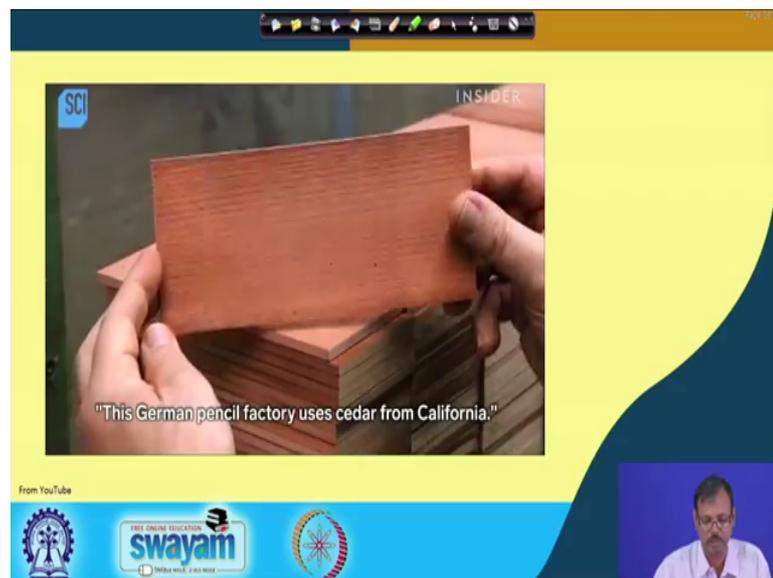
And then that pencil is fixed between two wooden pieces, you can see.

(Refer Slide Time: 02:19)



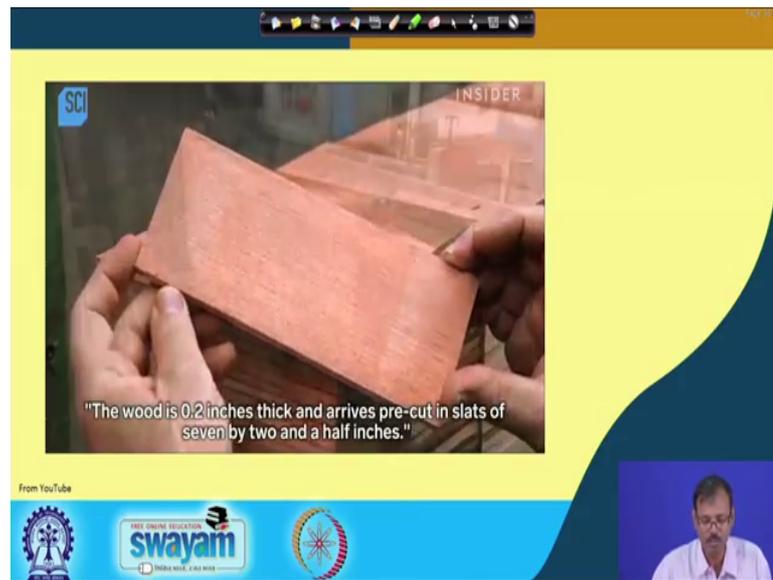
These are placed in this type of place.

(Refer Slide Time: 02:23)



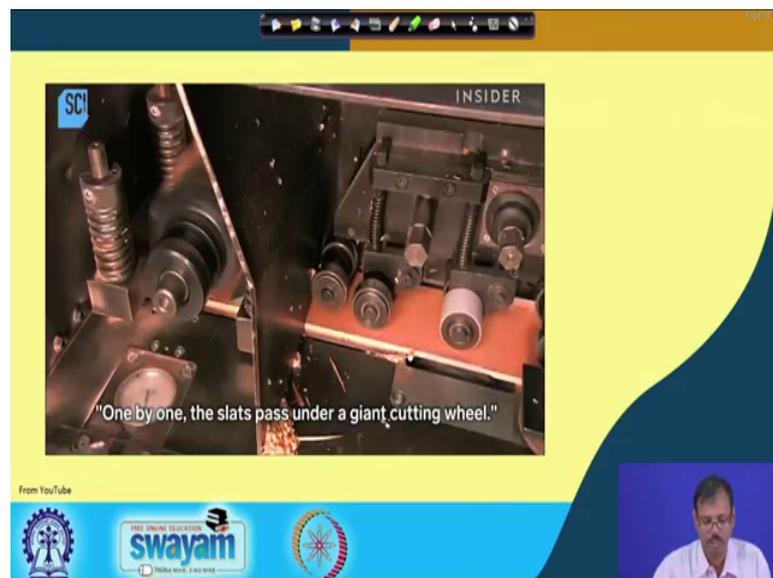
And you can see how these are made.

(Refer Slide Time: 02:26)



You see 0.2 inch thick wood pieces are cut here.

(Refer Slide Time: 02:32)



These are they are polished.

(Refer Slide Time: 02:38)



Then the groups are made into that wood piece.

(Refer Slide Time: 02:44)

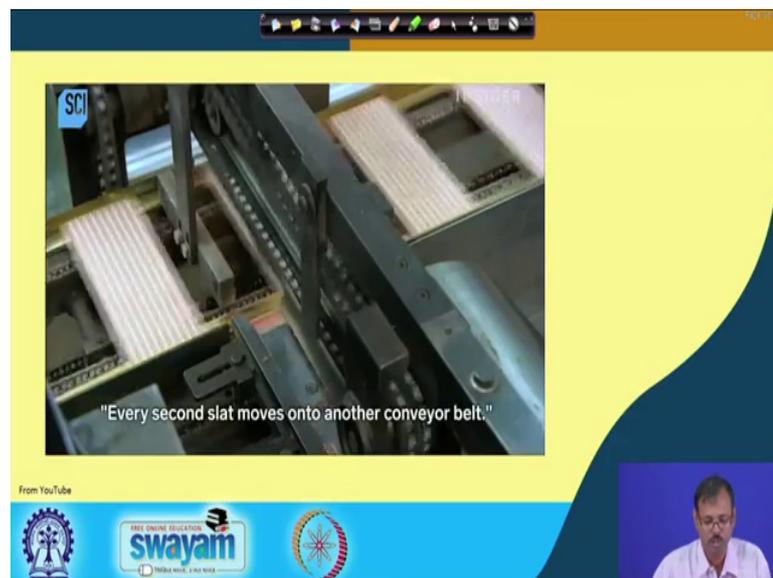


(Refer Slide Time: 02:49)



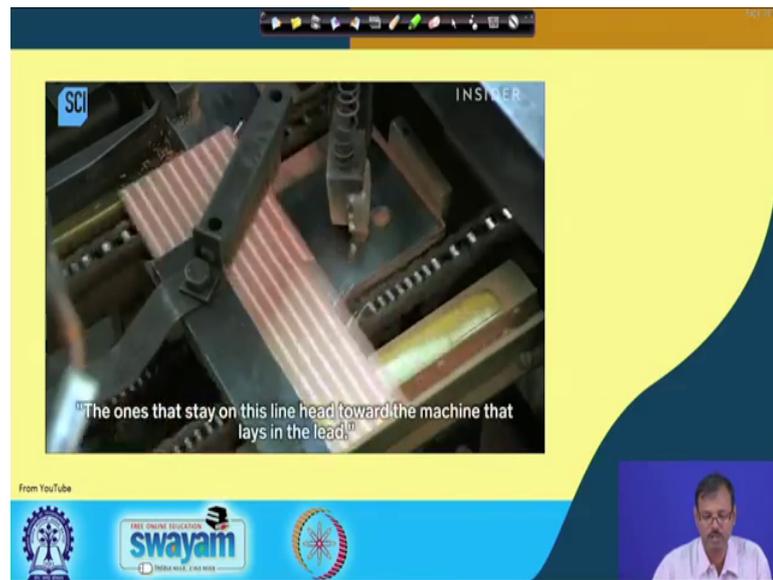
Then the glue is filled in those on those groups.

(Refer Slide Time: 02:57)



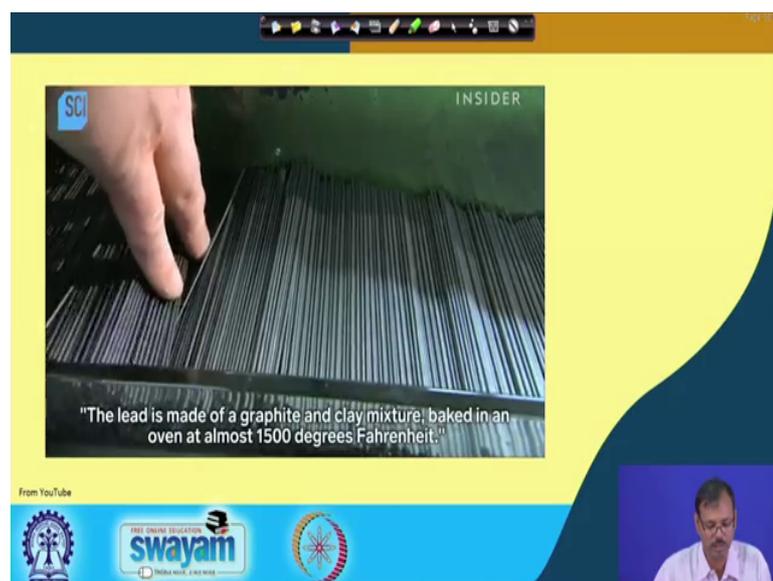
After pressing the glue, the lead which is already manufactured will be placed on that.

(Refer Slide Time: 03:01)



The screenshot shows a video player interface. The main video area displays a close-up of a manufacturing process where a red, ribbed lead pencil is being cut by a machine. A subtitle at the bottom of the video reads: "The ones that stay on this line head toward the machine that lays in the lead." The video player includes a toolbar at the top with various icons, a 'From YouTube' label, and logos for 'swayam' and 'INSIDER' at the bottom. A small inset video in the bottom right corner shows a man speaking.

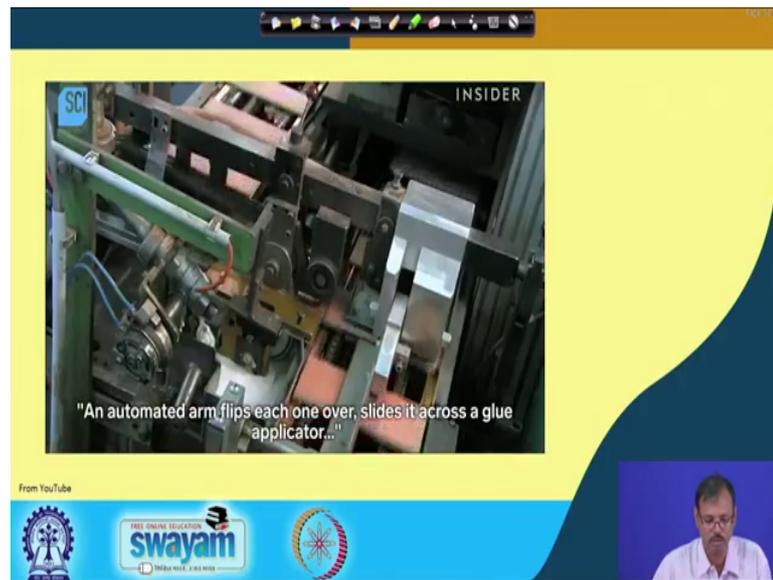
(Refer Slide Time: 03:07)



The screenshot shows a video player interface. The main video area displays a hand touching a stack of lead pencils. A subtitle at the bottom of the video reads: "The lead is made of a graphite and clay mixture, baked in an oven at almost 1500 degrees Fahrenheit." The video player includes a toolbar at the top with various icons, a 'From YouTube' label, and logos for 'swayam' and 'INSIDER' at the bottom. A small inset video in the bottom right corner shows a man speaking.

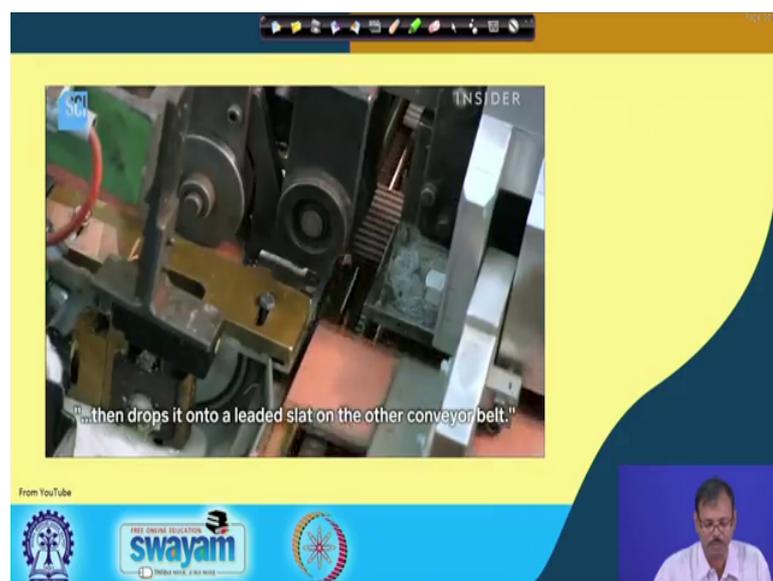
You see these are already manufactured graphite and clay mixture.

(Refer Slide Time: 03:24)



The screenshot shows a video player interface with a yellow background. The video content displays a complex industrial machine with various rollers and belts. A subtitle at the bottom of the video frame reads: "An automated arm flips each one over, slides it across a glue applicator...". The video player includes a toolbar at the top with navigation icons and a small inset video of a man in the bottom right corner. At the bottom of the slide, there are logos for 'swayam' and 'From YouTube'.

(Refer Slide Time: 03:29)



The screenshot shows a video player interface with a yellow background. The video content displays the same industrial machine as the previous slide, but from a slightly different angle. A subtitle at the bottom of the video frame reads: "...then drops it onto a leaded slat on the other conveyor belt.". The video player includes a toolbar at the top and a small inset video of a man in the bottom right corner. At the bottom of the slide, there are logos for 'swayam' and 'From YouTube'.

And then there is another a flip of wood will be placed on that.

(Refer Slide Time: 03:35)



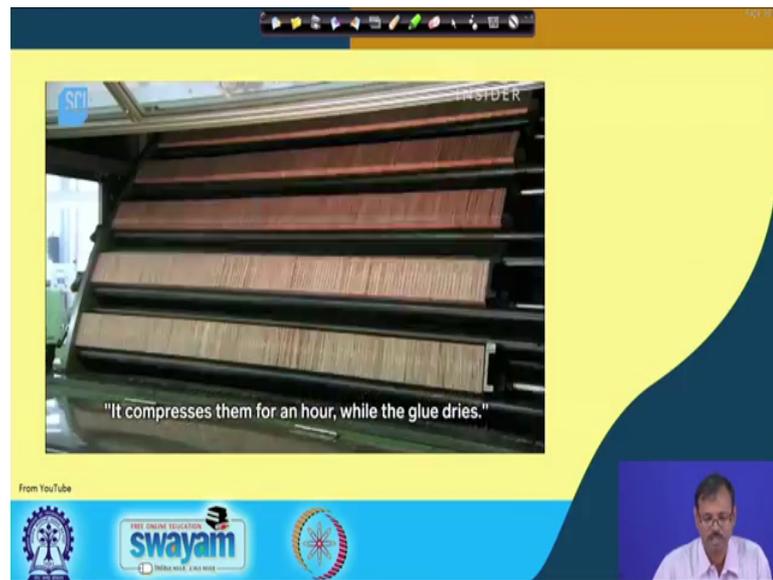
That and so these are lead covered with the another wooden piece.

(Refer Slide Time: 03:39)



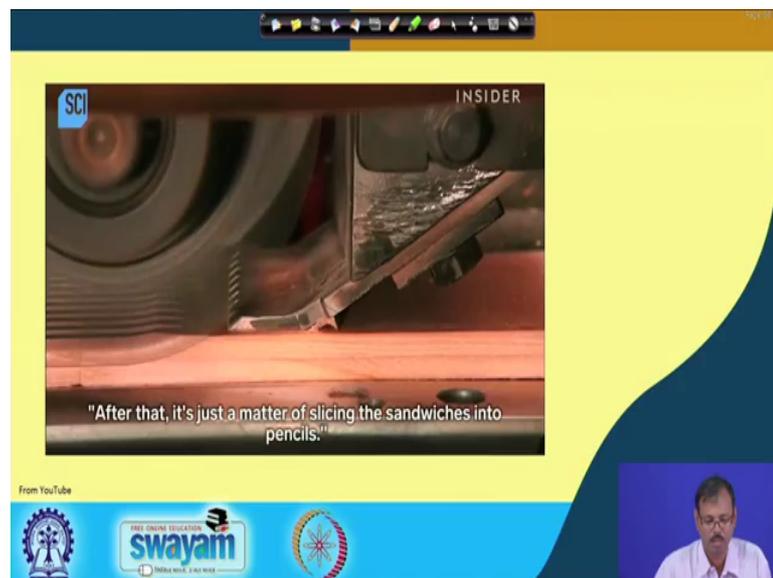
And finally, these are set like this.

(Refer Slide Time: 03:44)

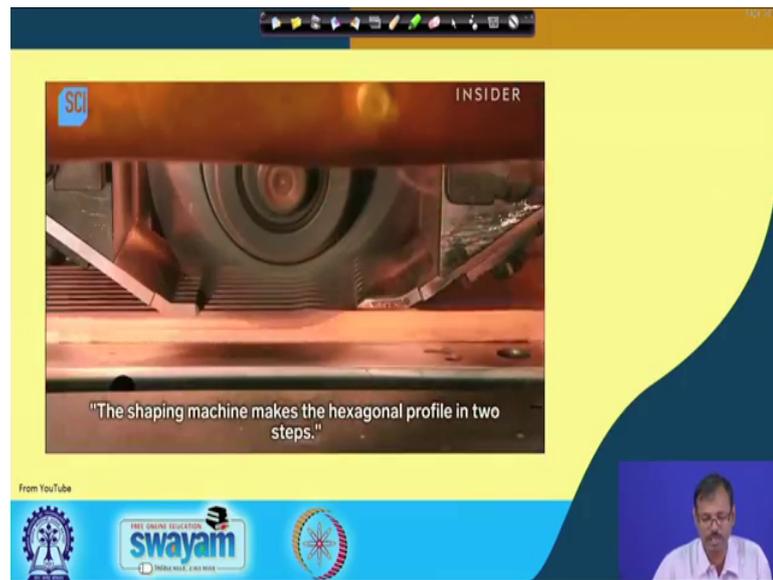


So, that a pencil can be formed.

(Refer Slide Time: 03:52)

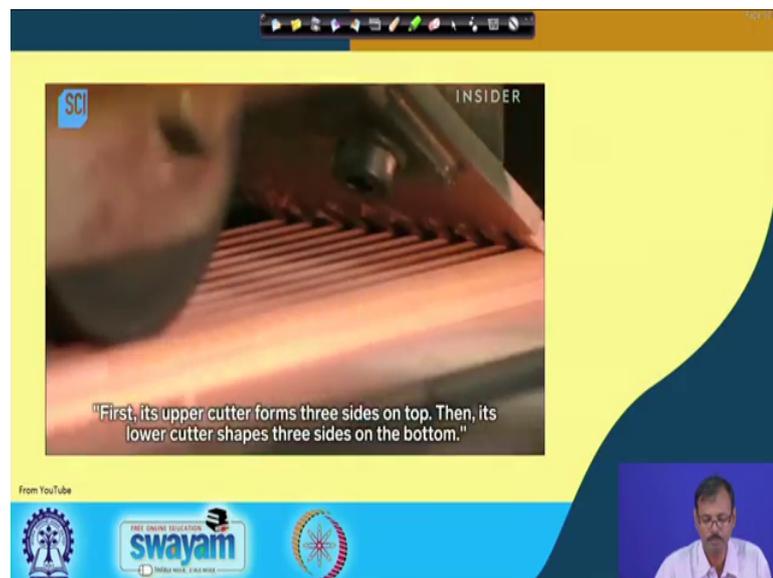


(Refer Slide Time: 03:67)

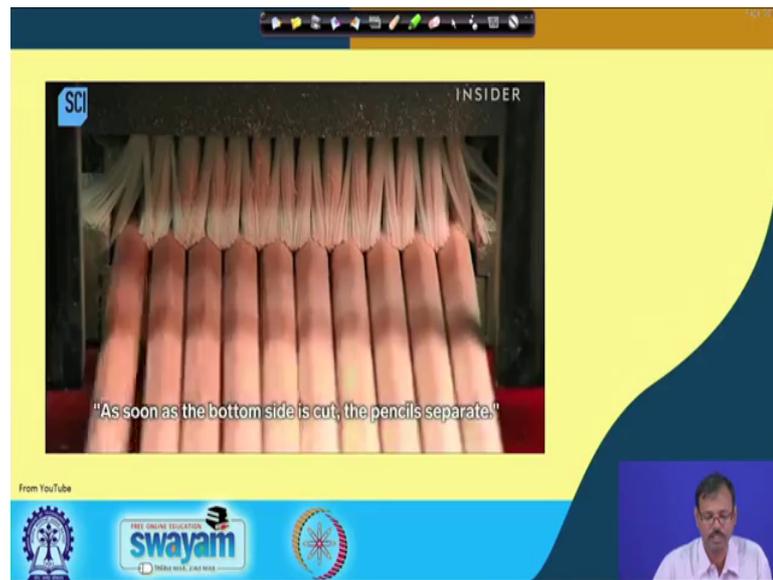


Then they will cut each pencil separately from that.

(Refer Slide Time: 04:00)

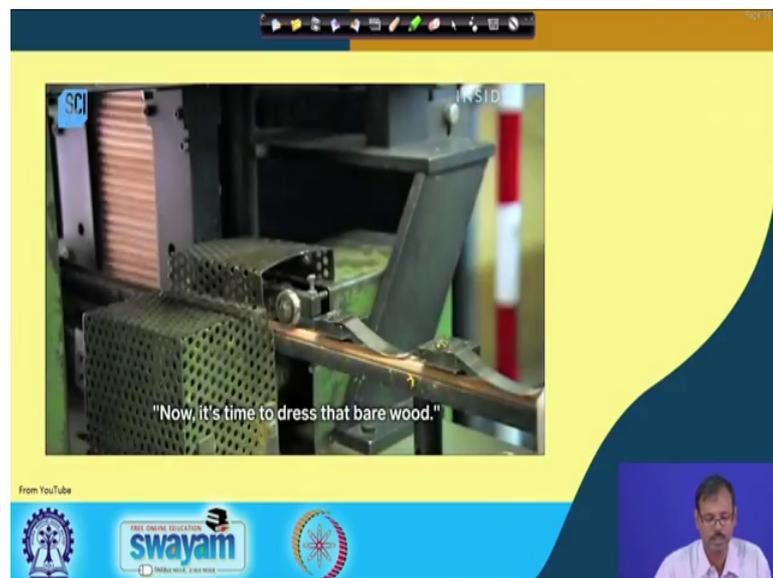


(Refer Slide Time: 04:06)



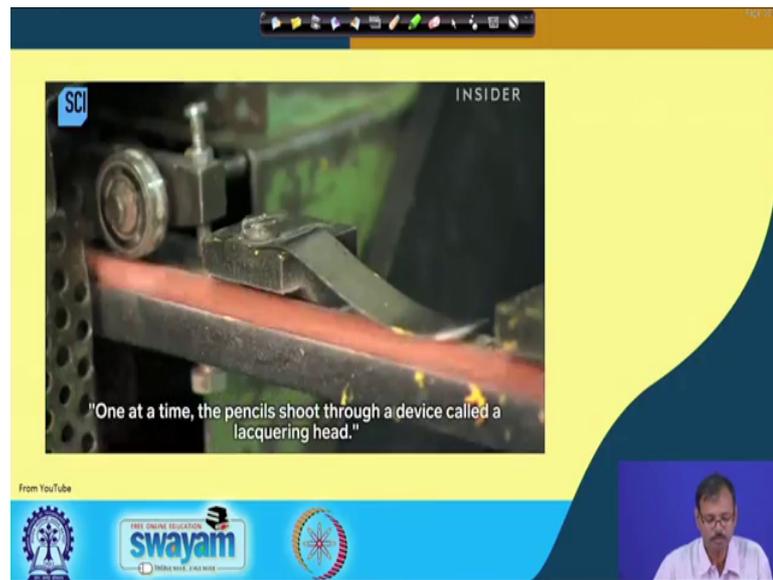
And then sharp it from the different sized sides.

(Refer Slide Time: 04:12)

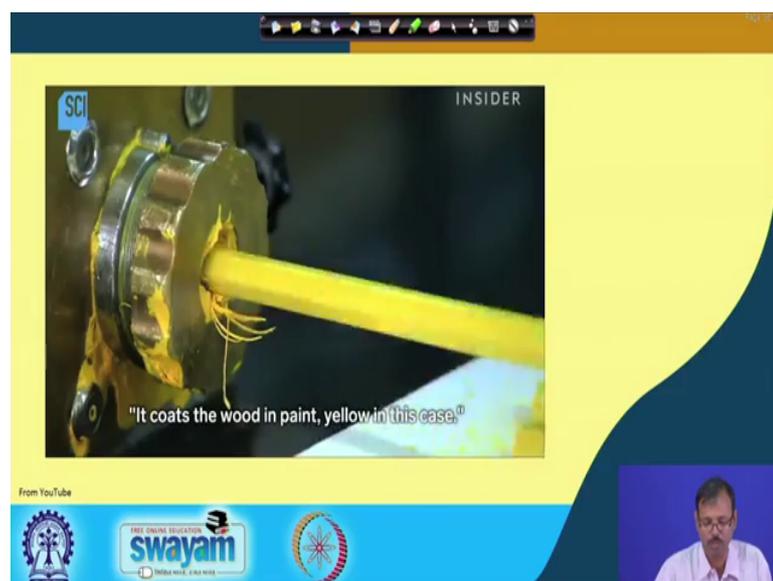


Then the decorations are made on the pencils.

(Refer Slide Time: 04:15)

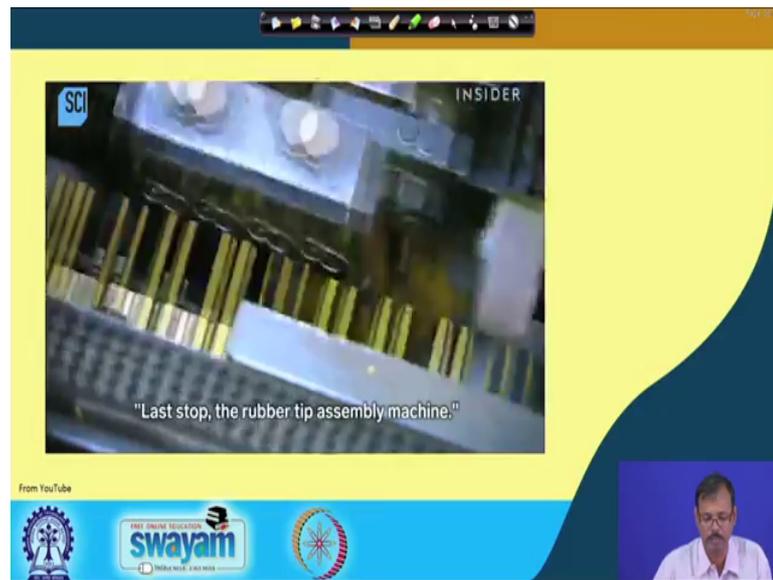


(Refer Slide Time: 04:19)



Colouring also made so fine, this is the final finishing colors etcetera are being provided.

(Refer Slide Time: 04:23)



(Refer Slide Time: 04:27)



Then if it is required the eraser will be placed in the back side of the pencil, one side of the pencil.

(Refer Slide Time: 04:43)

CONCEPTS COVERED

Concepts Covered:

- Terminologies related to the construction of network.

The slide features a dark blue background on the left with the text 'CONCEPTS COVERED' in yellow. The right side is yellow with the text 'Concepts Covered:' and a red-bordered box containing the text 'Terminologies related to the construction of network.' The bottom of the slide includes the Swayam logo and a small video inset of a man speaking.

So, in this lecture we will learn the different terminologies used in the network analysis. So, how this term, terms are little bit different.

(Refer Slide Time: 05:02)

Activity or Job

- Activity or job is a part of total work to be done.
- Any activity requires some resources and time for the accomplishment.
- It can be represented by an arrow having a definite start and end point.

Where, A is an activity that can be completed in time t hours,

node 1 is the starting point and
node 2 is the ending point of activity A

1 → A (t' hours) → 2
Starting point End point

The slide has a yellow background with a dark blue curved border on the right. It contains a list of three bullet points defining 'Activity or Job'. Below the text is a diagram showing an arrow from node 1 to node 2, labeled 'A (t' hours)'. Node 1 is labeled 'Starting point' and node 2 is labeled 'End point'. To the right of the diagram is a handwritten orange sketch of a drilling operation with the word 'Drilling' written next to it. The bottom of the slide features the Swayam logo and a small video inset of a man speaking.

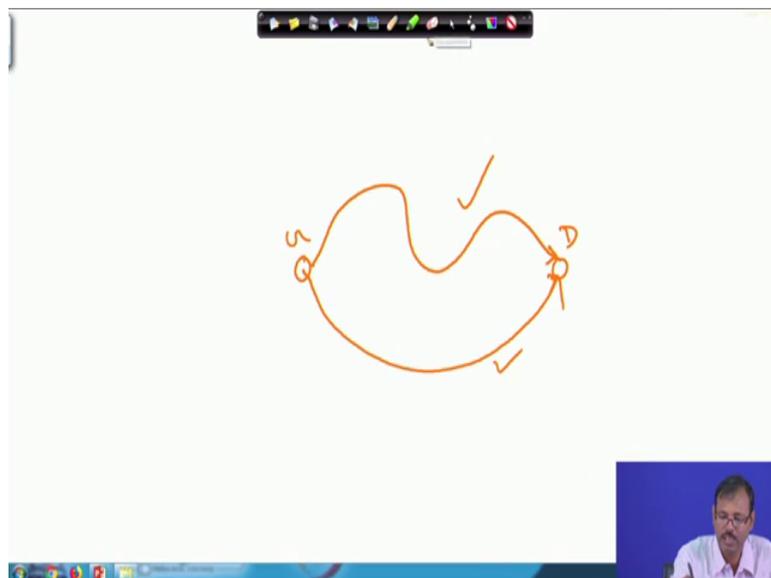
So, that is why we use different terminology. So, basically you know network is nothing, but the comprising n number of activities. So, any unit operation is basically called activity or job. So, say as you are mining people if you are considering that drilling is basically one activity, blasting is another activity. So, the excavation of material from the mine required drilling, blasting, (Refer Time: 05:37) marking, transportation etcetera. So,

all these are unit operations and this each unit operation operations are called activity or jobs. So, basically activity is nothing, but a job or nothing, but an unit operations, a unit operation.

And that operation is expressed with a arrow ok, but there must be some starting point of the arrow and some endpoint of the arrow. So, this starting point of the arrow and endpoint of the arrow if you consider the drilling; that means, the starting point of the arrow is the bench top, and end point of the arrow is the bottom of the hole. So, that is the drilling requirement. So, that is why this is arrow must there must be a starting point and that is must be a ending point.

So, these activities are expressed in those terms that this will be the drilling work carried out here and this is expressing as the drilling which is being started at this point to this point, but not physically this points. You can consider this may be starting time x , this maybe starting time x plus t ok. Suppose if you are considering a person as we have given the example in the last class, a person is moving from Ghaziabad to Delhi.

(Refer Slide Time: 07:38)



So, this consider this is Ghaziabad, this is Delhi the person has taken a car route and moving Ghaziabad to Delhi like this, the person has taken a rail route and moving from Ghaziabad to Delhi like this.

So, that means, the job is basically from going to Ghaziabad activity is from going to Ghaziabad to Delhi, but paths are different. So, this is one path this is another path and this paths, this activities are also paths which are shown in the arrow.

(Refer Slide Time: 08:37)

Activity or Job

- Activity or job is a part of total work to be done.
- Any activity requires some resources and time for the accomplishment.
- It can be represented by an arrow having a definite start and end point.

Where, A is an activity that can be completed in time t hours,

node 1 is the starting point and
node 2 is the ending point of activity A

Handwritten annotations on the slide include: '1 to 2', 'A(t)', 'A(t₁)', 'A(t₂)', 'B', and 'a'.

So, basically arrow is nothing but an activity; arrow is nothing, but an activity named or job named as A in the bracket the duration of the activities is expressed in the network. The activity has a starting point, activity has an ending point.

That means the Ghaziabad to Delhi journey activity has the starting point at Ghaziabad is 0 starting point at the Delhi is x. So, this Ghaziabad to x this journey is carried out is the journey activity A is carried out in a time T if it is through car. The same activity may be carried out in some different, using some different machineries that is also A activity, but the duration is T 1. So, that means, the activity or job or unit operations are expressed in terms of an arrow which must have a starting point and must have a an ending point and the arrow is showing the activity.

That means activity is represented by an arrow and the name of the activity is placed, whichever it is the symbol you are using and in the bracket you mentioned, in the bracket you mention the important thing which you wish to analysis that is the in this case it is time. If you would like to analyze, analysis it based on the money you may keep the money at this point because that is the variable which you would like to analyze. So, the variable is expressed under the bracket when you are expressing an activity, this starting

point and ending point of the activities must be fixed otherwise open ended activities cannot be there.

So; that means, you cannot start from Ghaziabad and you do not know you have to you may arrive at Delhi you may arrive at Calcutta, you may arrive at Chennai that is not a possible process and that is not allowed in network analysis. That means, activity must have a starting and ending process and that is essential requirement, open activities are not allowed. It may be finished activities; that means, if you see the pencil manufacturing in the previous one the last activity where the pencils are placed in the box which are being sent to the market.

So, that is the last process placing the pencils on the box and that ends in the finish place. So, that is why there may be starting point, there may be ending point, but those are fixed for the individual jobs, this points are also called node. These points are also called node in the network analysis. So, that must be remember that the point starting point ending points are also called node, starting node ending node ok. So, here nodes are given as the number one is the starting node and two is the ending node.

(Refer Slide Time: 12:26)

Activity or Job (cont.)

Predecessor activity
In a schedule, a predecessor activity logically comes immediately before another activity, which is dependent on the predecessor.

Successor activity
In a schedule, a successor activity logically comes after and depends on an activity immediately preceding it.

The slide features a hand-drawn network diagram with nodes and arrows. One node is labeled 'a(k)' and another is labeled 'a(k)'. There are also nodes labeled 'w' and 'v'. The diagram shows a flow from 'w' to 'v' and from 'v' to 'a(k)'. There are also arrows pointing to 'a(k)' from other nodes. The slide is part of a presentation, as indicated by the 'swayam' logo and a small video inset of a man in the bottom right corner.

Activities may have some predecessors activities; that means, this predecessor activities are essentially required for carrying out this activities, say in our last video what you have seen that pencil manufacturing, say for placing the lead inside that wooden pieces the lead manufacturing is previously required.

So; that means, lead is manufactured, lead must this is say lead manufacturing which takes t time and this is gluing lead inside the wooden piece. So, this is lead manufacturing must be complete before the placing the leads into the glue is essential requirement. So, essentially required requirement lead manufacturing must be there otherwise gluing of the same inside the wooden peace is not possible. So, that is why this activity is the essential activity required before this activity or before this unit operation.

That is why it is called predecessor activity, predecessors job. So, in a schedule a predecessor's job must be logically comes immediately before the another activity on which the activity depends. So, without this activity cannot start. So, that is why the completion of this is essentially required that is called the predecessors activity. Similarly if you are considering this is this is the success of activity of this activity because only after the completion of the lead the next activity which will be started. So, this lead will basically go into that unit operation to start that operation so this is the successor activity, it may be possible there are more than one predecessors activity if you are considering the gluing of the pencil.

If you are considering the gluing of the pencil we will find out the lead must be manufactured before hand, second one that the wood piece the glued wood piece must be placed at this position. And then only you can glue the lead into the wood piece so; that means, there may be more than one predecessors are possible, similarly there may be more than 1 successors are also possible ok. So, but the nodes are; that means, you can use this for some other thing also that is also possible. So, that is why these are essentially required there may be more than one predecessors, there may be more than one successors and finally, analyze we will understood this you will understand this much much in a better way.

So, this number of predecessors, number of successors may be more than one and that makes the more complex more the complex situation for this network analysis.

(Refer Slide Time: 16:25)

Event

- An event is a point in time, a milestone in the total work to be accomplished.
- It marks the beginning and end of an activity.
- Events do not consume resources or time.

Here, node 1 shows an event i.e. start of activity A and node 2 show the end of activity A

Starting point End point

A ('t' hours)

The slide features a yellow background with a blue header and footer. A hand-drawn diagram in orange shows a central node with three arrows pointing outwards. Below the text, a simple network diagram shows a horizontal arrow from node 1 to node 2, labeled 'A ('t' hours)'. Node 1 is labeled 'Starting point' and node 2 is labeled 'End point'. The footer contains the Swamyam logo and a small video inset of a man speaking.

So, an event is a point in time or a milestone in the total work to be accomplished and it marks the beginning and end of an activity, event do not conserve resources or type so; that means, this events basically nodes are not basically consuming anytime or material. So, the condition is not in network analysis is that the different activities are unit operations are combined with the nodes and it is assumed that the nodes are not consuming any cost, nodes are not consuming any time.

So, whatever is the time requirement those are basically the activities is laid in the activities those are the cost requirements those are also laid in the activities, there is no cost no time requirement for the nodes. So, this is the essential assumption made in the arrow diagram of the activity on the network analysis.

(Refer Slide Time: 17:46)

Network Diagram

- The graphical representation of all the project activities interrelated through precedence relationships with the help of arrow and node.
- Networks should begin with one node and end with one node joined by an arrow.
- A network diagram can be of two types:
 1. Activity on arrow (AOA) → Arrow diagram
 2. Activity on node (AON)

The slide features a yellow background with a blue header and footer. The footer includes the Swamyam logo and a small video inset of a man speaking. Handwritten orange text and arrows are present, pointing from the AOA and AON items to 'Arrow diagram' and 'AON' respectively.

So, network diagram which are made basically classified into 2 types, one is the activity on arrow are called arrow diagram or activity on node diagram or AON diagram basically the presentation is different in the arrow diagram and AON diagram. Let us look into a deeper way into this.

(Refer Slide Time: 18:19)

Network Diagram

Activity-On-Arrow (AOA)
In this network diagram, arrows represent activities and nodes represent events or milestones. AOA diagrams can only indicate finish-to-start relationships.

Activity-On-Node (AON)
In a network diagram of this nature, nodes represent activities and arrows illustrate logical relationships between activities. AON diagrams can illustrate four relationship types: start-to-start, start-to-finish, finish-to-start, and finish-to-finish.

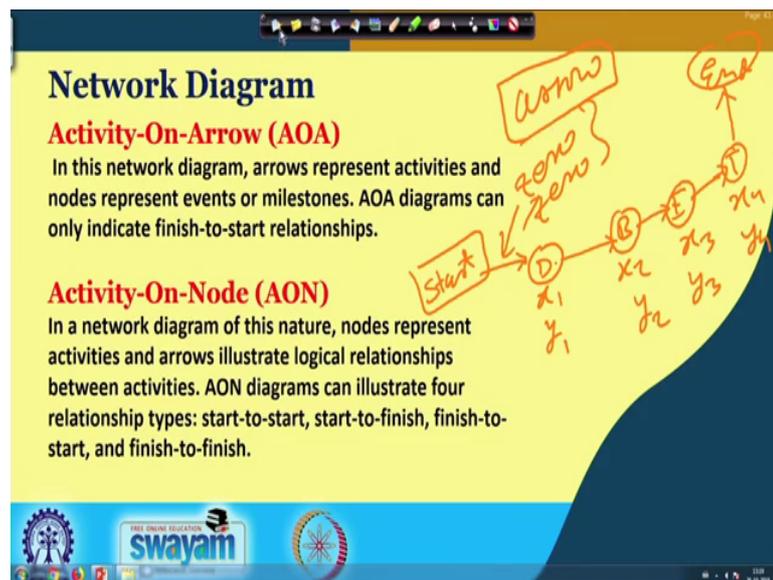
The slide features a yellow background with a blue header and footer. The footer includes the Swamyam logo and a small video inset of a man speaking. Handwritten orange text and diagrams are present. A diagram shows a sequence of nodes labeled 0, D, B, E, 3. Node 0 is the start, and node 3 is the end. Activities are represented by arrows: 0-1 (Drill), 1-2 (Blast), 2-3 (Excavation), and 3-4 (Transportation). The diagram also shows a 'BOND' label and a 'T' label. A list of activities is written below the diagram: 0-1 → Drill → $x_1 - y_1$, 1-2 → B → $x_2 - y_2$, 2-3 → E → $x_3 - y_3$, 3-4 → T → $x_4 - y_4$.

Say in activity on arrow diagram we are having activities combining together, say suppose we are having drilling then blasting then excavation then transportation ok. So, this is the starting point, this is the ending point.

And these are the nodes of 1, 2, 3. So, starting points 0 to 1 this starting point is basically describing us drilling activity and this drilling activity may have the characteristics it takes x_1 hours and it may take y_1 cost or say x_1 hour x_1 hour y_1 cost 1 to two is the blasting activity that takes x_2 and time and y_2 hour. 2 to 3 replace represents excavation activities, x_3 y_3 and 3 to 4; 4 is the end point which is basically gives us transportation of the same that takes x_4 y_4 time expect 4 time y_4 cost.

So, these are the representation of each activities on the network form so; that means, here arrow, this arrow point is basically showing the activity cost time that expenses in the node is basically 0. So, these activities are called activity on arrow or arrow diagram is the way where we are presenting this activities. Activity on node is a different types of activities where the arrows are basically connect the different activity.

(Refer Slide Time: 20:50)



Say first activity is the drilling which are expressed in on the node and before that there must be a starting point; that means, we start our analysis process. Then the first activity which is expressed in the node is drilling, next activity expressed in the node is blasting, next activity expressed in the excavation is in the node, next activity expressed in the node is transportation and finally, it ends. So, here we represent the drilling time requirement is x_1 , cost requirement is y_1 x_2 , y_3 time and cost requirement, x_3 y_3 time and cost requirement, x_4 y_4 time and cost requirement for transportation and the essential assumption is that there is 0 cost is 0 time is 0 on the arrow.

So, arrows are basically connecting the activities, but the time and cost expenses on that is 0. So, basically it is the reverse way of presenting the different unit of operations in the different type of network formalism.

(Refer Slide Time: 22:23)

Arrow

- An network diagram represents a network of any process that uses arrows to represent activities and nodes to represent events or milestones.
- An arrow represents the start and end of a job or activity where initial point shows the start and terminating end show the end of an activity.
- An arrow can represent an activity or a path to connect two activity depending if the network diagram is AOA or AON.

An arrow connecting 2 activity A and B in a AON diagram

An arrow representing activity C connected by two nodes 1 and 2 in a AOA diagram

So, let us now see the and a network diagram represents a network of any process that uses arrows to represent activities and nodes to represent the events or milestones. That means, if you are considering in this activity 2 by 2 the activity c is complete, but here that facility is not available in activity on node diagram.

An arrow represent the starts and end of a job or activity where initial point was the start and terminating point so that is the end activity that is A 1, A 1 activity and an arrow can represent an activity or a path to connect two activities depending on the network diagram is either AOA or AON types of presenting of the network. So, this is the two basic types, arrow diagram activity on node diagram are commonly used for presenting a network and their analysis are also similar type. Both are having some positive and negative features, we will discuss those things when we will discuss in detail how the networks are being analyze analyzed in the arrow diagram and activity on node diagram.

(Refer Slide Time: 24:06)

Node

- In a network diagram, a node is a point at which dependency lines meet.
- A node can be represented as an activity or it can be represented as the event
- The starting node is called initial node and the end node is called terminal node.
- An arrow connects 2 nodes to completed a path in a network.

Node representing activity A and B in a AON diagram

Nodes 1 and 2 are connected with an arrow representing activity C in a AOA diagram

swayam

So, these are the nodes, already described to you at the point where the arrows are meeting and in AON diagram the jobs are assigned on the nodes not on the arrow.

(Refer Slide Time: 24:22)

Alternate

In an activity on arrow diagram, the nodes are numbered. An activity is represented by connecting two nodes by an arrow. For example,

Alternate (1,2) represents activity A
Alternate (1,3) represents activity B
Alternate (2,4) represents activity C
Alternate (3,4) represents activity D
Alternate (4,5) represents activity E

This is an AOA diagram
Where A, B, C, D and E are activities represented on arrow and nodes are represented by 1, 2, 3, 4 and 5

Starting Node
End's Node

swayam

Alternative is basically some people they used to represent the activities in a different form, in this form say they represent activity A where first one is representing the starting node number, and second one is representing the ending node number. So, basically this gives the benefit, this gives the benefit to analyze the network in a computerized form. So, basically it is an array in the computer programming in that array it is showing the

starting node and ending node so that either graphically or in during the analysis this can be easily represented and is easily analyzed.

So, basically alternative is the type of representing different activities by giving its starting node number and ending node number under the bracket ok. So, this is another type of representation of the activities in a different form.

(Refer Slide Time: 25:52)

Precedence Relationship

- Some activities cannot begin until others have been completed.
- For example, a contractor cannot lay cement blocks until the foundation has been laid. The foundation cannot be laid until the soil has been excavated.
- Precedence relationships must be defined in order to determine the sequence of activities in the network.

Handwritten notes: W.S, Sub, Sub Base, Embankment

Diagram: A sequence of nodes A, B, C, D, E connected by arrows, indicating a precedence relationship.

So, this precedence relationship establishment, successor relationship establishment is the essential requirement of the construction of the network. So, this is very very important and the user must be very very careful about this assigning; say suppose as we are observing into the drilling, blasting, this predecessor drilling is always the predecessors of the blasting. You cannot carry out blasting without drilling and drilling is not the predecessors the successors of the blasting because we do not go for drilling after blasting. So, that is why drilling is essential predecessors of the blasting and blasting must be carried out before the excavation, these are the predecessors. So, the establishment of the relationship is very very important in these cases.

As in the first last class we have seen the example of construction of road. In the road there are layers, say first layer is the embankment second layer is the sub base, third layer is the base fourth layer is the wearing surface ok. So, the embankment which is the soil one or sub grade one has to be placed first and that must be rolled properly, then only the sub base which is basically granular sub base those aggregates must be placed on this

where it is the soil layer. So, the layering that is the precedence of the construction of the embankment is the essential for the construction of the sub base layer.

So, this precedence must be followed properly and that is why they must be identified, they must be identified. So, precedence activities are essential unless and until the completion of the precedence activity is there successors activity cannot be started. So, that is why these are the essential requirement and that must be properly followed while the network analysis is being carried out.

So, what I would like to emphasize there this terminology; this terminology you must adopt in you so that in next class onward when we will discuss and that time we will only discuss this terminology. Say we will not tell it a unit operations any more we will tell it activity or job, we will tell from node 1 to node 2 we will not tell that node is the basically connector of the arrows and that.

So, these terminologies you must in still you knew. So, that next class onwards when we will discuss about the arrow diagram we are we will discuss about the activity on node diagram that time it is easier for you to understand.

Thank you.