Geographic Information Systems
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Lecture - 27
GIS Analysis - 07

Hello everyone! and welcome to new discussion which is Part 7 of GIS analysis. And we will continue as mentioned earlier in the previous lecture about related with this network analysis with few different examples, more realistic examples as well. As you can see that in normal cities or that kind of setup, we are having different kind of networks.

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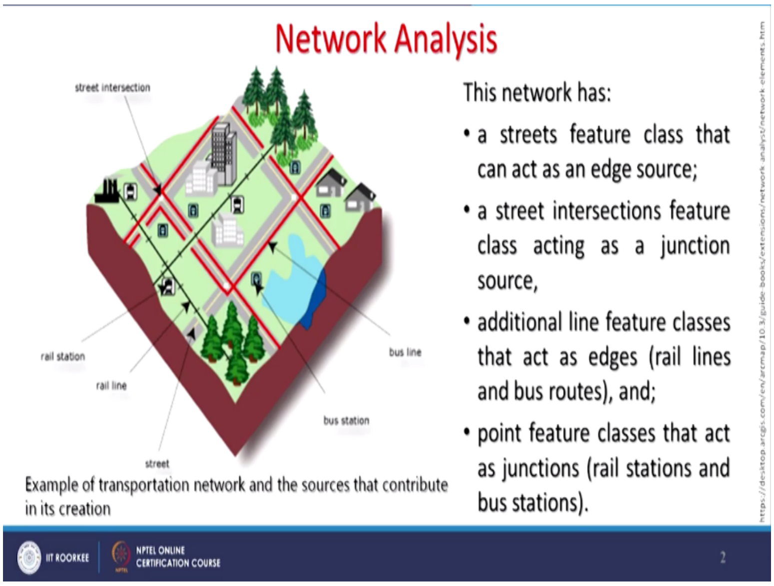

There maybe you know network like this streets network. There might be rail station. There might be metro station and several such networks maybe there along with your power network and other things. Like if I take the example of a street, that feature class that can act as an edge source. So, that is one of the sources or one of the elements of network. Then street intersection features class acting as a junction source; the second element of network.

And then third; the additional line feature class as an act as edges in rail. And also, the point feature classes that act as junction that is rail station or bus station. So, if every information is residing on your GIS database, then lot of analysis related with optimization of routes or you know, monitoring of traffic and other things can be done very easily. Not only that but also for planning.

That means say if it has to be done for planning, a prediction has to be done. And the prediction can also be done implying GIS. Now, in network analysis as you know that resources or sources are there.

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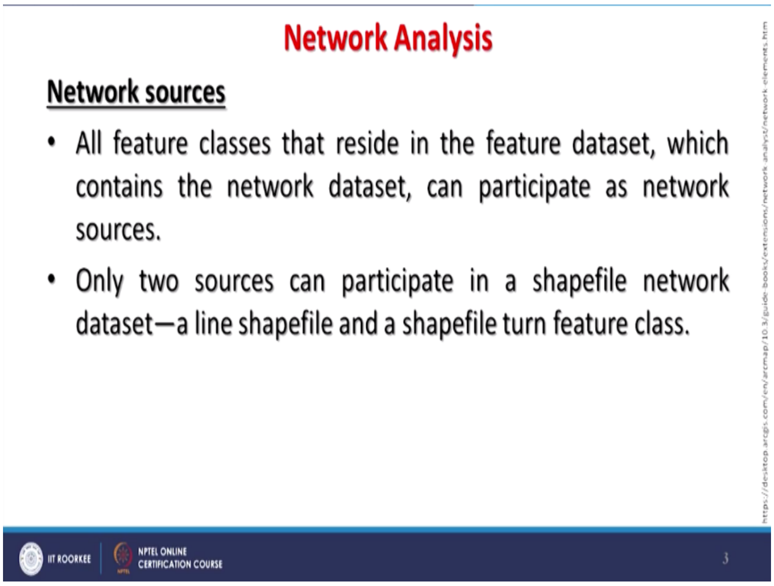

All feature class that we have discussed so far, they reside in the future database. That is our GIS database especially the vector one and attributes also and which contains the network dataset and can participate as network resources. Now, because there are also nowadays a custom designed GIS software’s or solutions are there. For example, this Ola, Uber apps; these are custom designed GIS solutions.

Similarly, you are having Google Map; that is also a custom designed GIS solution. So, because there are different types of datasets or type of databases which are suitable for certain kind of analysis. So, when we will discuss the different types of databases, at that time, it will come along with relational database model which is the most popular one. We also require hierarchical model sometimes for certain kind of analysis.

And we also require a network database. So, in network database, the organization of the data or storing of the data so that these can be retrieved efficiently is different. And all these feature classes like junction and edges; these have to be also stored very distinctly within the database so that a better route optimization can be performed. And only 2 sources can participate in a shapefile network or vector network dataset.

That is a line and a feature class or turn class, that might be you know a point in that sense also.

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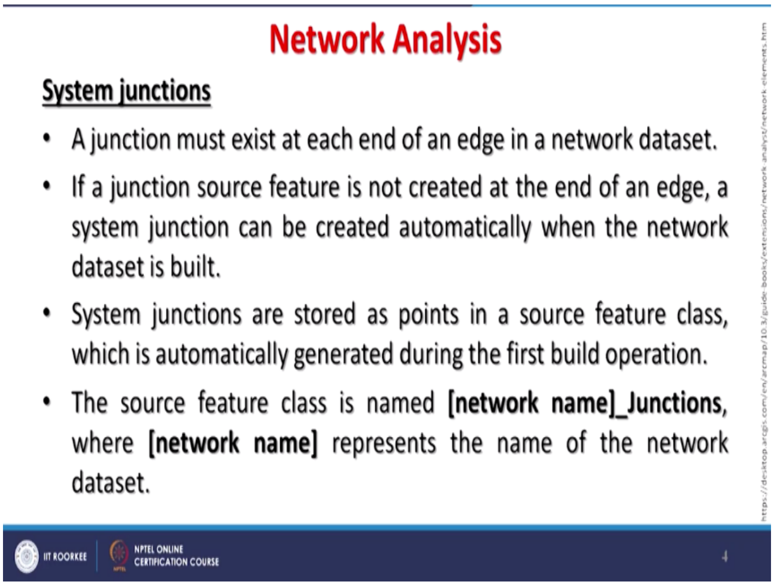

Now in network analysis, there are system junctions are there and which exists at each end of an edge in a network dataset. So, wherever these things are there then there will be a junction or a terminus also, you can say. And then if a junction source feature is not created at the end of an edge that means a polyline feature, a system junction can be created automatically when the network dataset is built.

So, once your polyline data is ready of a network then network has to be built. And while building the network then these things will also be created. Sometimes automatically if it is a very simple network then we can do it automatically through software's or with human interventions also. We have to guide the system that this is my junction; you have to define all those.

But in natural drainage system, it can be done automatically which will be demonstrated in the software as well. So, system junctions are stored as point in a source feature class which is automatically generated during the first build operation. And this source feature class because every time you do not have to do it. Once a network is ready, only then optimization or modeling will be done.

So, the source feature class is named as network name and then you are having junction where network name represents the name of the network dataset. So likewise, everything is organized in our network database. And when network dataset is created then the user will make choices that determine the edges and junction elements are created from source features.

It will depend what kind of resources are going to move or are moving through that network. So based on that, then edges and junctions will be defined. If it is a rail network, a different kind of definitions would be required. If it is a road network, again it is different.

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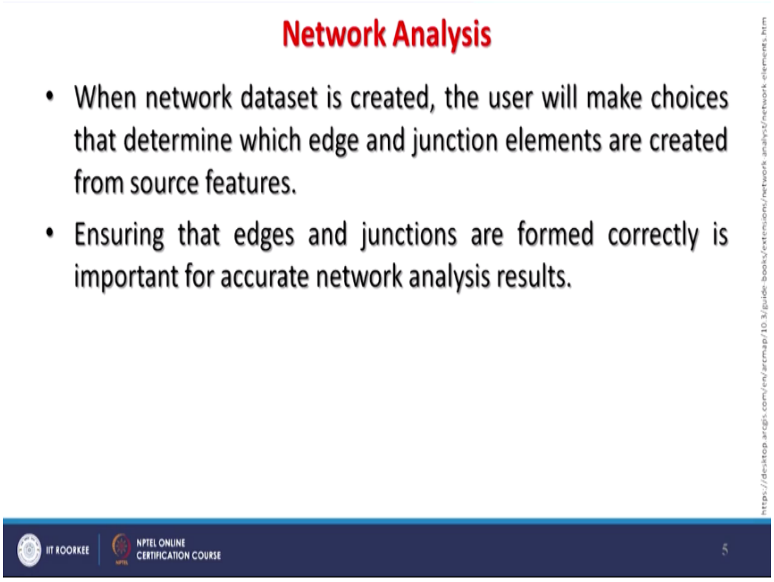

If it is a power supply network, again it is going to be different for edges and junction elements. And we have to ensure that edges and junctions are created or formed correctly because when we run for optimization or resource movement then it should work properly. So, accuracy part is also very-2 important for network analysis and reliable results. Because if we imply any system like GIS; any technology like GIS to get solutions, say about this resource movement then it has to be accurate.

If it is not accurate and if you say to your higher ups maybe, could be, something like that, then there is no use of developing such system. So basically, whatever we develop on GIS platform for any kind of analysis, it has to be highly reliable and accurate. So, this accuracy part must be always kept in mind and that is why since beginning, I have been telling that one of the rules of GIS is that after each and every operation, check for errors.

That means if we find the errors, we have to correct there itself. And if we follow this rule from the beginning of developing GIS database and analysis then we can achieve high accuracy. So, accuracy is also a key in GIS apart from precision. Precision is a different thing. When discussion will come, we will have a lengthy discussion on these 2 terms but for time being, what I am talking about the accuracy.

Because if results are not accurate; whatever the analysis you have done through GIS, if they are not reliable, nobody can use it. I heard some time back a statement by an expert who was working on landslide hazard zonation mapping. And when he was asked that how accurate your map is then he said 50%. See 50% probability means basically no prediction. I can predict anything that it may occur; may not occur.

For example, I can say in next hour, rainfall can occur; may not occur. So, no use of employing such systems then. Anybody can predict. So, accuracy has to be as far as possible to the highest level. And then only people will develop confidence in your system. Otherwise, people will discard immediately. They say it is useless. And that can be maintained from the beginning, once we start doing anything on GIS.

Now in network; another important thing is the connectivity. Connectivity between different polyline features or different edges if we talk in terms of network elements and which are based on the geometric coincidence of endpoints, line vertices and points and applying connectivity rules that set as properties of the network. Connectivity rules can be 1-way traffic, 2-way traffic.

The flow conditions, the depth, the width; all these can come as attributes. And they also may become part of our connectivity rules. Let me take some examples here.

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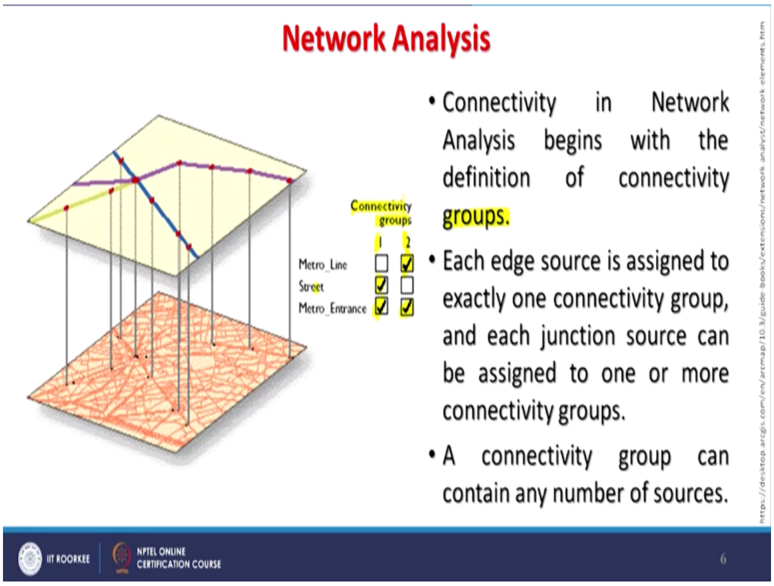

This is a connectivity network analysis begins with the definition of connectivity groups. And what are these groups are? As you can see here the connectivity groups are that I am having a metro line and then a street. And then another group number 2 is having metro line and metro entrance. Because they are part of that group of metro line whereas the other; the street and metro entrance is again because metro entrance should be connected with the street.

So, they are in the group. So, in connectivity analysis which begins with the definition of connectivity groups. And as I am just telling you that in this left diagram also, as you can see that these things are connected. So, detailed information is required before we really get the accurate results. So, this has to be created; this has to be defined to the database that which network features belongs to which group.

And there may be the same feature like road or this metro entrance is common for metro line as well as for street. And similarly, metro line is common for metro of course and the metro entrance. So, each edge source is assigned to exactly one connectivity group. And each junction source can be assigned to one or more connectivity groups as you hav e seen here also. So, these are the connectivity groups.

Now the connectivity groups can contain any number of sources. So here, we can have as many in this connectivity group, the number of sources.

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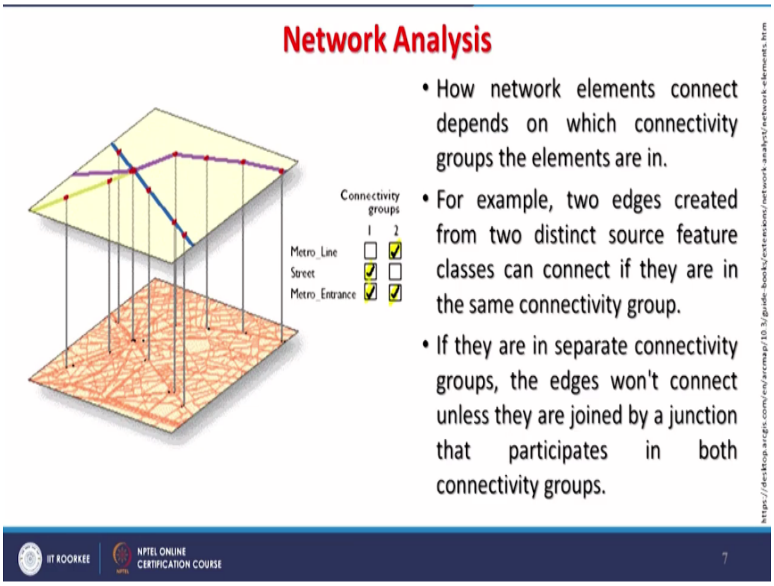

Now, how many network elements connect will depend on which connectivity groups, the elements are in? For example, 2 edges created with the 2 distinct source feature classes can connect if they are in the same connectivity group. As you have seen that like metro line and metro entrance are belongs to the same connectivity group. Similarly, street and metro entrance belong to the same connectivity group.

And if they are in separate connectivity groups; these one which I have just mentioned then the edges would not connect. And if that has not been established then you know this network analysis will not work because as unless they joined by a junction then participate in both connectivity groups. That means there has to be a junction between metro entrance and metro line. Similarly, there has to be a junction between street and metro entrance.

Then only, you can have a proper network analysis. And connectivity groups are used to model.

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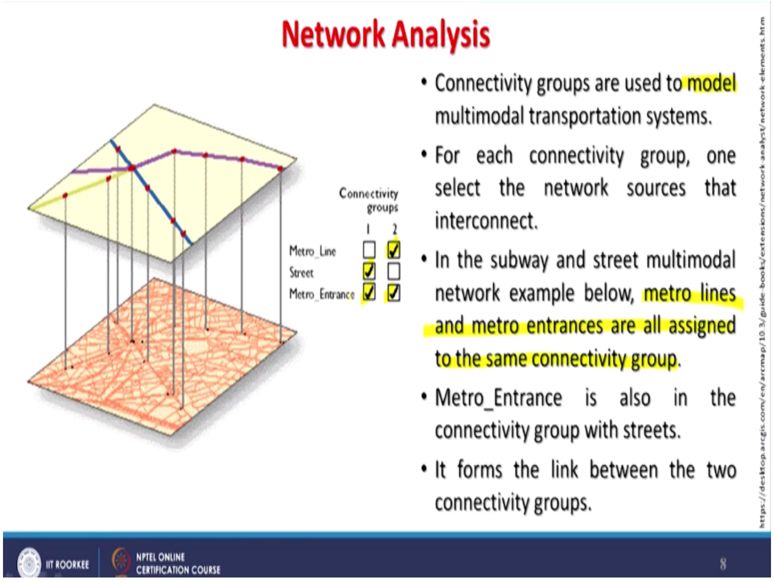

Basically, what we are using GIS ultimately, many times for predicting something. Predicting in this case; resource is moving through a network. So, model multimodal transportation systems. Here multimodal in this particular example, one is the road transport; another one is the transport which is metro. And as you know that for each connectivity group like here, one selects the network sources that interconnect.

So, if somebody is analyzing the road or metro accordingly then analysis will be done. And in case of the subway and street multimodal network examples below, here the metro lines and metro entrance are all assigned the same connectivity group. This part we have already discussed that metro line and metro entrance are assigned to the same group whereas street and metro entrance are also assigned to another group.

So that is, metro entrance is also in the connective group. So that means that one single feature class can belong to the 2 group also. This is the main point here of discussion. And once that is there then it will form the link between 2 connectivity group. So here, these 2 features like street and metro line which is here and your metro entrance. So, these will link to each other and then one can properly analyze the network.

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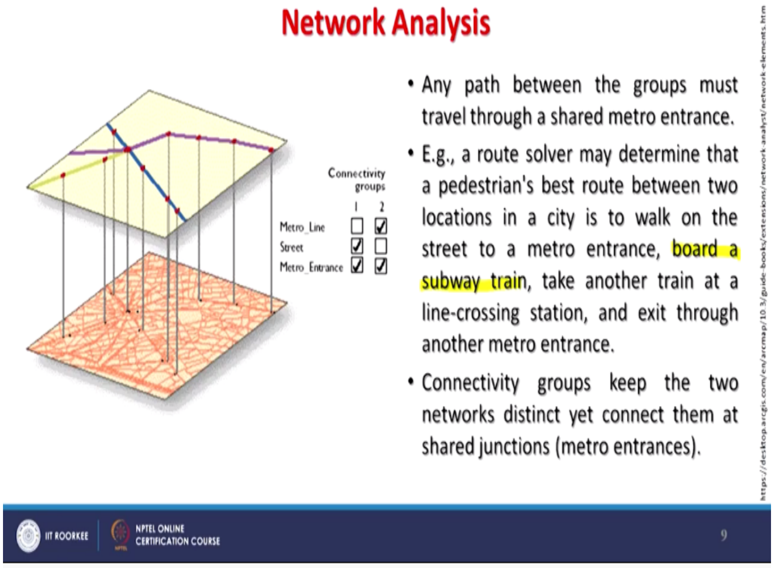

Now, any path between the groups must travel through a shared metro entrance. That means if there is another group then again, it has to be connected then only it will work. So, for example, a route solver may determine that a pedestrian's best route between 2 locations in a city is to walk on the street in a metro entrance. And you know there will be a broad subway train, take another train at line crossing stations and exits through another metro entrance.

What it means that if in many cities, you know big metros where they are having multiple lines like orange line, blue line, green line; if we are talking only about the metro and there may be a different level underground. Now, one can travel in one particular colored line. Colored are used just to make it convenient for people to remember. So, from one line, we can travel to another line.

So, we may not be coming out of metro entrance but we will be moving within that one. So, if a network analysis has to be done for or that database has to be developed for such kind of resource movement, mobilization in a metro system which is a little complex in our example then that much of details are also required that from which network or metro network; which line, a person can come and to which line, it can go.

And I have seen that at some places, there are having 4 color lines on a metro station. So, it is a really very complex kind of network. And it has to be you know properly managed and that can only be done if the network database and then connectivity groups have been created properly. So, that connectivity groups basically will keep the 2 networks distinct.

These yellow line, green line something like that. And though they are connected through the shared junction or metro entrance; this is the point which is very important. So, in many other resources also or many other types of networks, similar kind of issues will come. And if we want a very efficient network system then all that information has to be organized in a GIS database especially for the network analysis. Now, we take these connecting edges within a connectivity group.

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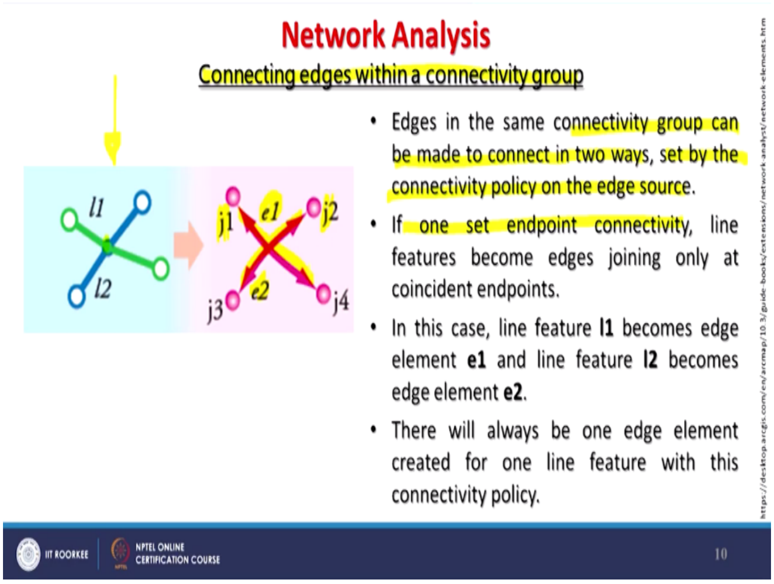

How they are connected? So here, edges in the same connectivity group can be made to connect to in 2 ways. The first one by set of connectivity policy on the edge source. If one set endpoints connectivity, the line feature becomes edge joining only the coincident endpoint. Like here which you are seeing 1 junction; 2 lines are there. Several times in a metro maps of different cities, you may find that 2 lines are crossing but there is no junction.

Junction means here that you cannot disembark one metro line and go to the another. Though on the map, these are being shown. So, if that thing is not there, that information will not be restored. But in this example, that is there that a junction is there of 2 different lines and it is kept there. In this example, though there 2 lines are crossing each other but there may not be any junction. So, that kind of details are very much required.

So, like in this case; the line features, this l1. It should have been j1. So, the line feature j1 becomes edge element of e1 as you can see. And the same l2 or j2 becomes the edge feature of e2. So, this is also e2. So one is this line, another one is this line. And there will always be

1 edge element created for 1 line feature with this connectivity policy. So, it depending on the conditions then only things will be organized.

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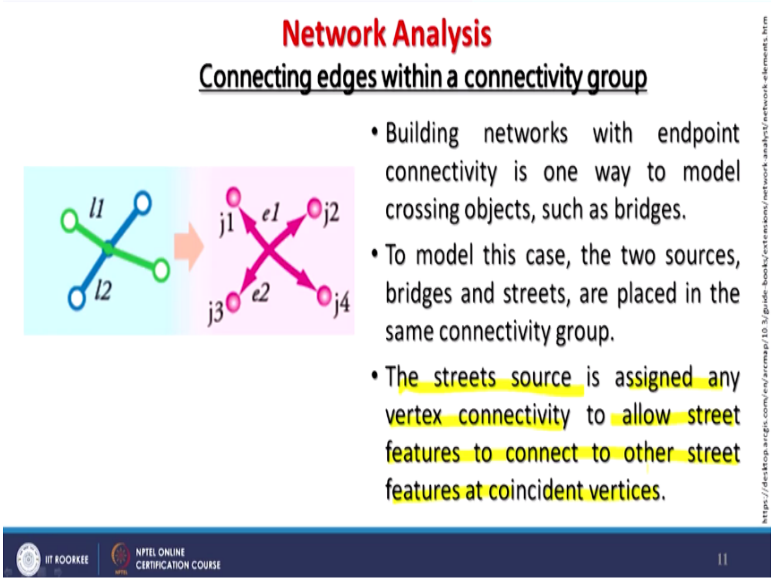

Now, we continue on this that connecting edges with the connectivity group. So, building networks with endpoints connectivity is one way to model crossing objects such as bridges. Now, you know over bridges or underpass are there. And if we want to keep that kind of information, if that is required then that information has to be also built in our network analysis or network database.

And we have to model that means to predict and organize the 2 sources; bridges and streets are placed in same connectivity group. Then only these things can be used in GIS. So, if any information has to be utilized, it has to be residing in our network database. Otherwise, it cannot be utilized. So, it's a very simple in that sense that if we want to have the information about bridges, underpass, overpasses, flyovers in case of road network, that information has to be there.

Now, in case of street source is assigned to any vertex connectivity which will allow street feature to connect to other street features at coincident vertices. Coincident vertices basically are the junctions. Coincident vertices will make the junction in case of road, it is little simpler in that sense because in case of metro, sometimes metros are running at different depth in underground conditions.

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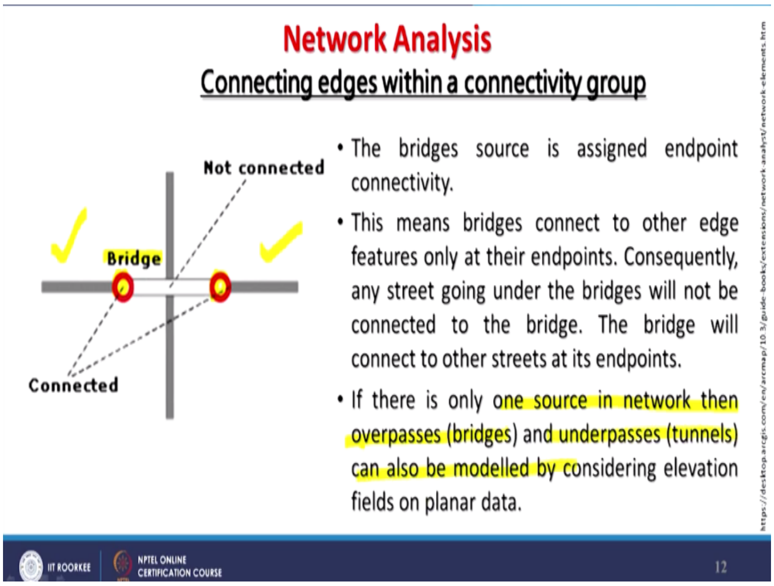

Now, if we see that like example is given here about the bridge. There is another bridge here. The bridge is there. But between these 2 bridges, there is no connection. So, then there will be a problem. So, the bridges source is assigned endpoint connectivity. And these are creating an endpoint here. And this means that bridges connect to other edge features. So, there is one edge feature like here, another edge feature like here and that other edge features.

And, what will happen? Consequently, any street going under the bridge will not be connected to the bridge. And the bridge will connect to other streets at its endpoint. Then in complete network; if that kind of error is there, obviously any kind of modeling or any kind of management will not be possible. So, development of accurate network database is of prime importance in case of network analysis.

If there is only one source in network then overpasses like bridge, underpasses (tunnels) can also be modeled by considering elevation fields on planar data. That means if there is a change in elevation because in underpasses and overpasses, one line is going over some line then the depth information has to be also stored like in case of metros in case of overpasses, tunnels and everything.

That much information will be required to be stored. Now, further in this that if user said any vertex connectivity like here the vertex connectivity.

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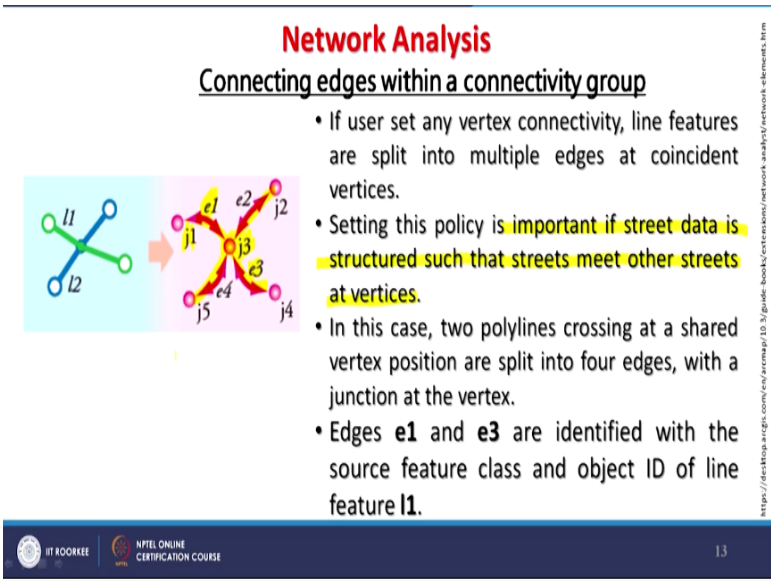

In previous example, we have not seen the junction 3. Now, when it is connectivity and split into multiple edges at coincident vertices. So, once a junction has been created, now these are splitted. Earlier there were only one like and like this. Now, we are having 4. So, there are 4 edges because a new junction has been created. Now if this junction is at the same level, then there will be different issues in case of you know road transport or other thing.

But if they are on different levels then you know the sideways or other things have to be provided and from traffic management point of view. So, that information will also be required to be stored in our database. So, setting this policy about creating junctions is important if street data is structured in a manner that streets meet other streets at the vertices.

But if you know a junction like this but as I have said if junction is having 2 different levels, then there will be a different scenario. So, in this case, 2 polylines crossing at a shared vertex position are split into 4 edges with a junction at the vertex. This is what you are seeing, the j3. So, junction at the vertex is j3 in this example. So, edges e1 and edges e3 with source feature class and object ID is feature; that is j1. So, that is the j1. Similarly for other edges also, it can be defined.

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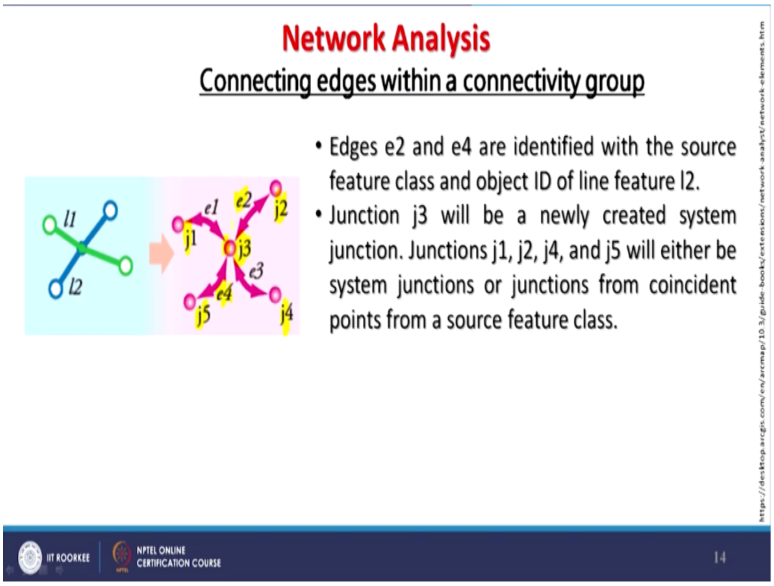

Now, edge e2 and e4 are identified with the source feature class and object ID, that is the j2 which is this one. And the junction j3 which we have been discussing will be newly created system junction. So, this system may create this one depending on our information. And then we will have the junction j1, j2, j3, j4 and j5. So, 4 are the end vertices. And one j3 is the cross vertices and that is truly a junction. Otherwise, these are the terminals.

But any will in network analysis point of view, these are also called junction because they may have connectivity with another network. So, that is why they are called junction or this is the junction from coincident point from a source feature class.

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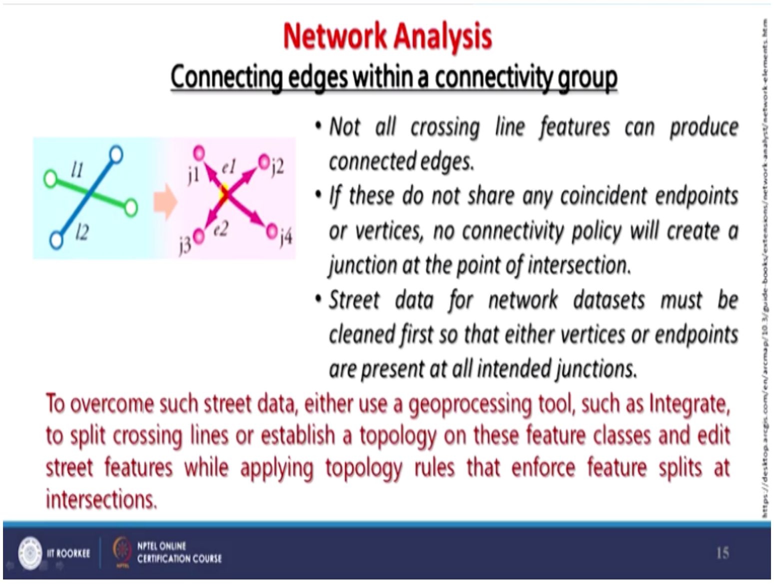

As we know that not all crossing line features are produced connected edges. That means there may not be junction in all the cases. And if they do not share any coincident endpoints or vertices, no connectivity policy will create a junction at that point. So, it depends on how your network is there. If there is a junction which is required which can be created, if not that also can be avoided.

So, street data with that much attributes have to be required for network datasets and which must be cleaned first so that it can be retrieved efficiently. And clean here means accurate and having good quality of the data, cleaned here. So, if it is not then it has to be organized first. Then only any kind of modeling or operations can start. And to overcome such street data; either a geoprocessing tool in like in GIS which are available like in ArcGIS which can integrate to split the crossing lines or establish a topology on these feature classes

And edit street features while applying topology rules that enforce feature split at junctions. Now, automatically these things cannot be done for say road network or you know power network or rail network. So, that means human interventions would be required to declare that which is the intersection, which is the junction, which is the edge and so on so forth.

And therefore, among other GIS databases; the network database when we will discuss in detail what is exactly network databases or advantages with that or what disadvantages. This is the most complex database generation. But once accurate network database has been generated then one can really exploit extensively and can have lot of applications on it.

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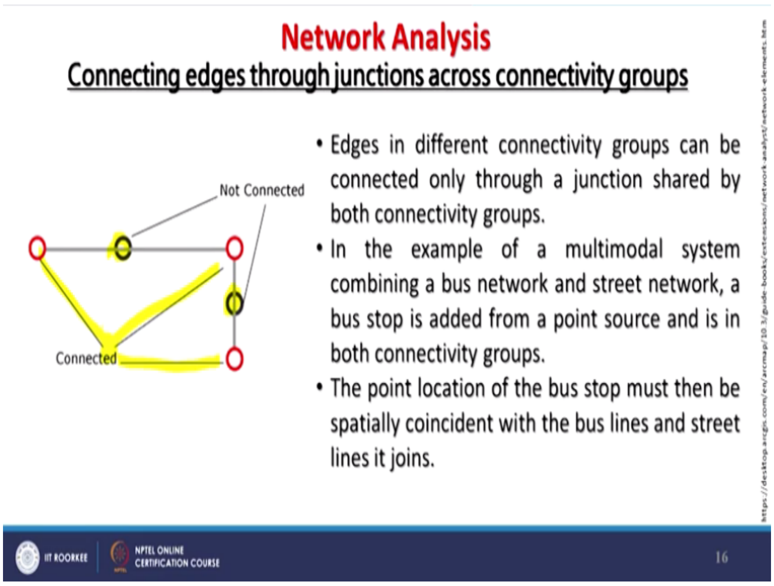

Further on the same discussion that edges in different connectivity groups can be connected only through a junction shared by both connectivity groups. So, like here, this is not connected by any other group. And this also; the black circle that is maybe a junction but not shared by any other group. Only one which is connected is this one with this thick gray line and another one is like this one; this is relatively thin line.

So, 2 networks are there and likewise. So, in this example, a multimodal system combining a bus network, a street network, a bus stop is added from a point source and in both connectivity groups. So, by creating a junction, you can connect 2 different multimodal systems. And point location for bus stop then we especially coincident with the bus lines and straight lines also. Bus stop cannot be created away from a road network.

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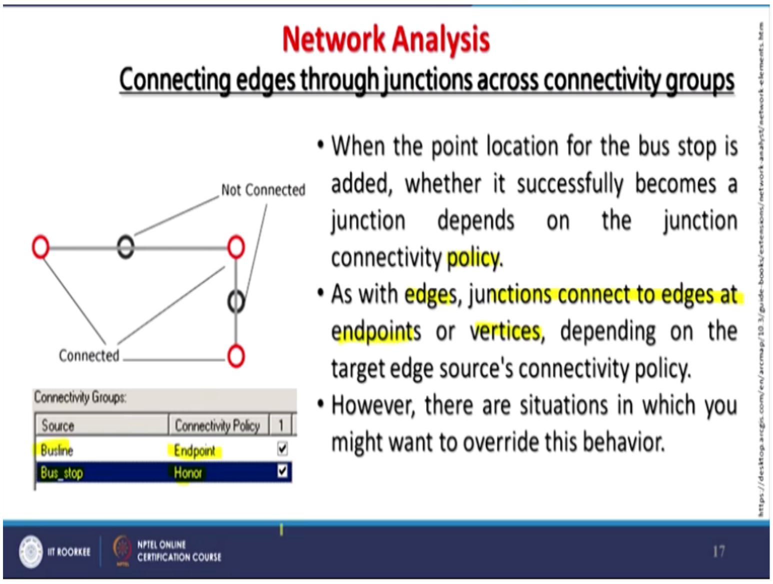

How in database it will be reflected? Here as you can see that bus stop is marked here. And then you can have a policy that it has to be honored. That means it is very much required. And whereas a bus line, it is the end point within our database. So, against basically each polyline feature, this detailed information is required in our network database. And when the point location like end point for the bus stop is added, whether it successfully becomes a junction depends on the junction connectivity policy.

And these policies which I am talking is not policy made by some administrations. These are the policies within your network GIS database. So, we have to define policies that how these junctions or other multimodal systems will work. And at as be the edges, junctions connected to edges at endpoints or vertices and this will depend on the target edge source connectivity policy.

So, lot of declaration to the system has to be done that this is what I want, this is what I do not want and that becomes basically our policy. So, there may be a situation in which you might want to override this behavior or this policy and that can be also changed. Because everything is in a digital form so it can be changed.

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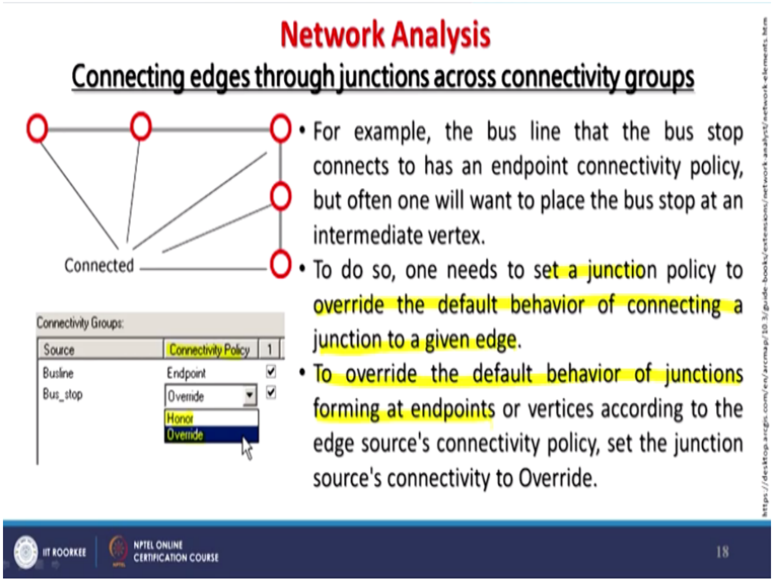

Now when you go for creating this thing, there will be you know options available in a good software like here it is saying honor or override. So, if you want to honor that policy, that what is that policy is the connectivity policy, you can choose accordingly. For example, the bus line that bus stops connect to has an endpoint connectivity policy but often, one will want to place the bus stop at an intermediate vertex.

So, you can also if it is in planning stage, that can be done that you do not want bus stop at the end. You want bus stop before that also. And in order to achieve that one, one has to set a junction. So, a junction policy has to be required which will override the default behavior of connectivity junction to a given edge and then it can be done. So, override default behavior of junctions forming an endpoint or vertices according to the edge sources connectivity policy set the junction source policy to override. And this is what it is being done here depending on our requirements,

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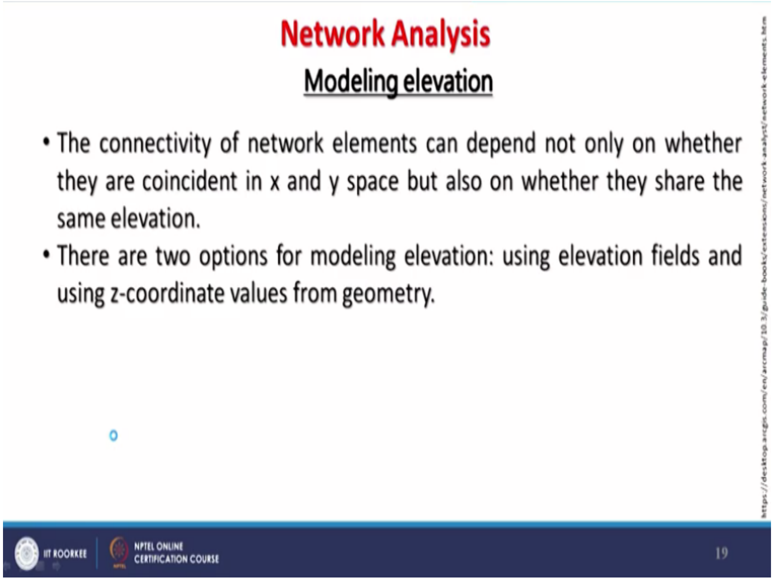

Now, when we bring the elevation part means that there are different levels then things become more complex. So very briefly, we will also discuss this part that the connectivity of network elements can depend not only on whether they are coincident in x and y space; that is in horizontal space but also, whether they share the same elevation or not.

I gave the example of different metro lines at different levels at least at the junction. Away from junction, they may not be at different levels. But at the junctions, they are maintained at different levels and 3-4 lines can be at a one junction. And therefore, people can use different levels, elevators to treat those levels to get different colored lines. So, there are 2 options for modeling elevation or different levels using elevation fields; that is the z value from our geometry.

And that is very much required if such scenarios had to be developed or such modeling is required. If there are different levels, the elevation z value is very much required.

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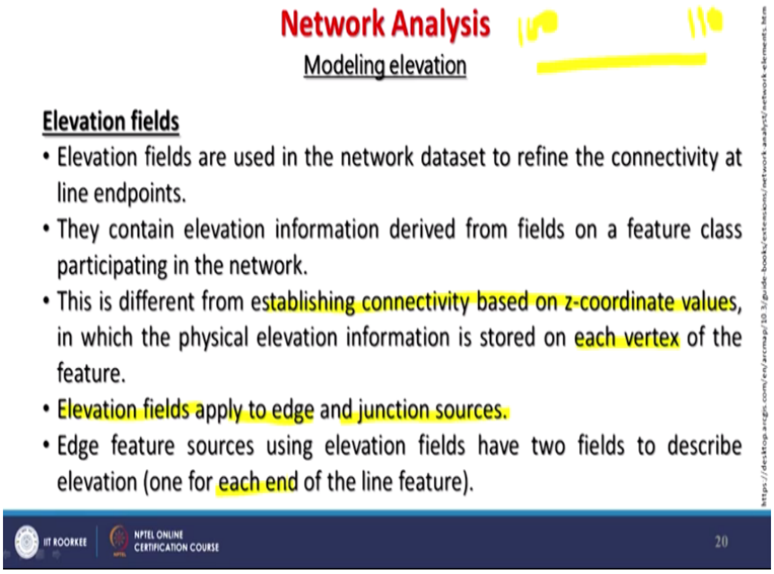

So, elevation fields which can be created in a database are used in network dataset to redefine this connectivity as line endpoints. And they contain elevation information which is derived from the field on a feature class participating in the network. So, the height above mean sea level or depth; whatever information has to be collected and then it has to be stored in our attribute table as a feature class participating that in network.

And this is basically different from establishing connectivity basically which is based on z coordinate values. Because so far, what we have been discussing when we did not involve elevation was only in the xy plane means everything was considered as a planner or in horizontal. But when there are up-down or different levels then different policy or connectivity has to be established which will incorporate the z values.

And basically, these are the physical elevation information which is stored for each vertex. Like in a GIS, earlier we were told that a point is just having x, y and it is a point. But now in literature or in some software, they say 3D point. Now by definition, vector element; this point is a zero-dimensional entity so how it can be 3D? So, basically what we are adding, the z value.

Now, that z value can come automatically in our GIS database for any given point either from a digital elevation surface like DEM or some other field data based on GNSS data collection or some other topographic survey. So that point, though it is called 3D but it is not exactly 3D. Only it is having location x,y and also z value. So, when we are doing this modeling or incorporating elevation for a network then for each vertex, that information about elevation will be very much required.

Though our network database may become little complicated but it will be more realistic. Then only people will adopt it or use it or appreciate it. Otherwise, you say no! You have to assume everything and as a planner only in x, y then no use of such solutions through GIS. And therefore, elevation fields apply to edge and junction's sources as well. For each vertex, once you have stored then vertices are part of edges and junctions also.

An edge features sources using elevation fields have 2 fields to describe elevation. One for each end of line features because a polyline may have different elevations. So, suppose it is having 100 meter above mean sea level; it is having 110. And therefore, for each vertex, elevation information has to be stored and here for each end member, line feature information has to be stored.

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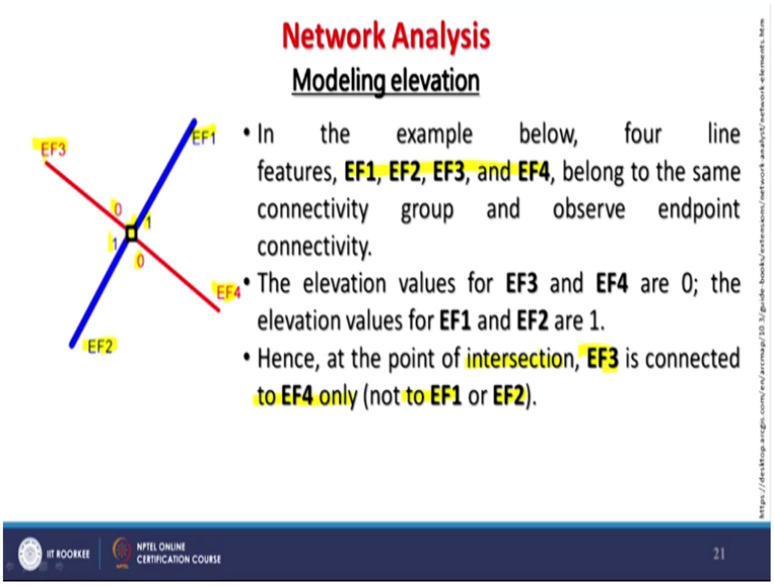

Then you can get even the slope information as well. So, like here in this example; very schematic and simple example that 4-line features are there. This EF1, EF2 and EF3, and EF4 element features. And you are having these 4-line features belonging to the same connectivity group. So, there is a basically junction defined. So, coding has been done for this is 0, 0 connectivity group. And this blue is the one connectivity group.

And which observe endpoint connectivity is also shown here with a junction. Now elevation values at like for example EF3 and EF4 maybe 0 and whereas elevation values EF1 and EF2 are 1. For simplicity, these things have been capitalized. Now if it is junction, it is at 2 different levels in terms of elevation. And then the point of intersection of EF3 is connected only to EF4 and not to EF1 and EF2.

If it is you know metro line and those 2 lines, I mentioned earlier also may cross each other but on a plan or on a 2D map. But if they are at different levels then they may not be connecting; there may not be intersection or there may not be any junction. Now if junction has to be established say in sub-ways or in case of underground metros then within these underground conditions, that junctions have to be created. So, therefore people from level 0 can reach to level 1.

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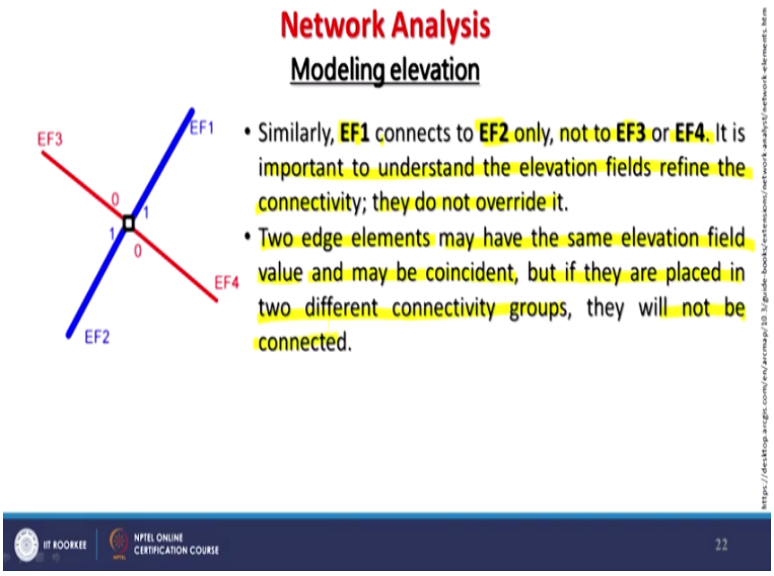

Now further that same with the EF1 connects to EF2 only and not to EF3 and EF4. So, it is true for both type of you know network here. And it is important to understand that elevation fields defined connectivity, they do not override it. Because in your policy, you cannot instruct the system to forget about elevation, no . When you are dealing with a system which is also having elevation information then that cannot be overridden.

And 2 edges elements may have the same elevation field values means on the edges, they may have same and this I have also mentioned that different networks except for a junction if they are connected, they have different elevations. But away from junctions, they may not have different element elevation. They may have the same one. Because in metro systems, this is how it is developed.

So, 2 edges elements; here we are having like these red and blue lines may have the same elevation field and may be coincident. But if they are placed in 2 different connectivity groups, they will not be connected also. So, even if they are on the same elevation then they maybe not connected so simple.

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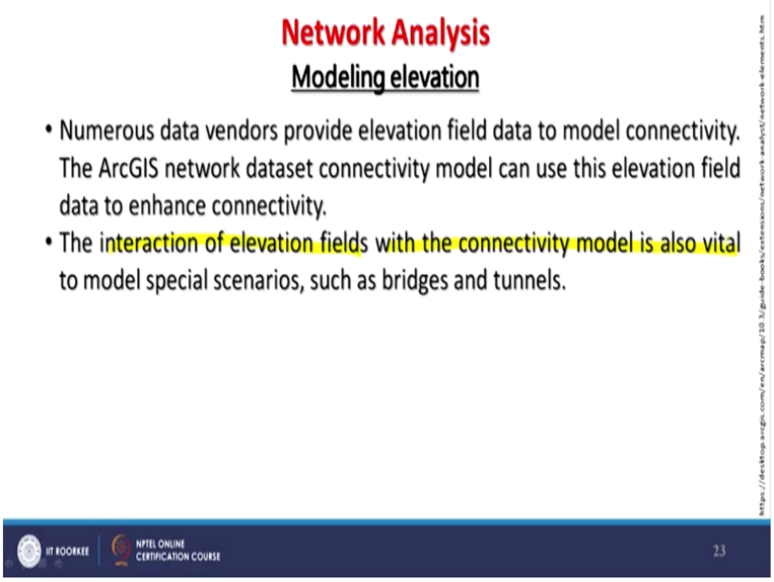

So, numerous data you know vendors are provide elevation field data to model connectivity. In case of ArcGIS network dataset connectivity model, one can use this elevation field data to enhance connectivity or basically to make more realistic network analysis by involving elevation field if it is required and if that information is available. If that elevation information is not available then of course, a real scenario cannot be prepared.

So, the interaction of elevation fields with the connectivity model is vital to model special scenarios such as bridges or tunnels.

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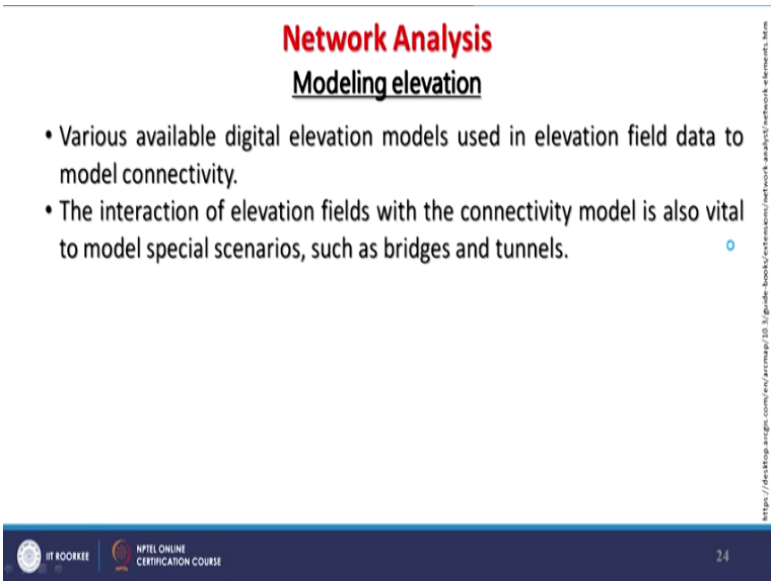

Further various available digital elevation models can be used in elevation field data to model connectivity but only in case, if things are moving on surface. But if you are having subsurface conditions like underground metros then digital elevation models cannot be employed. Then that elevation information has to come from other sources. So, interaction of elevation fields in our network database with connectivity model is vital to model these bridges and other features.

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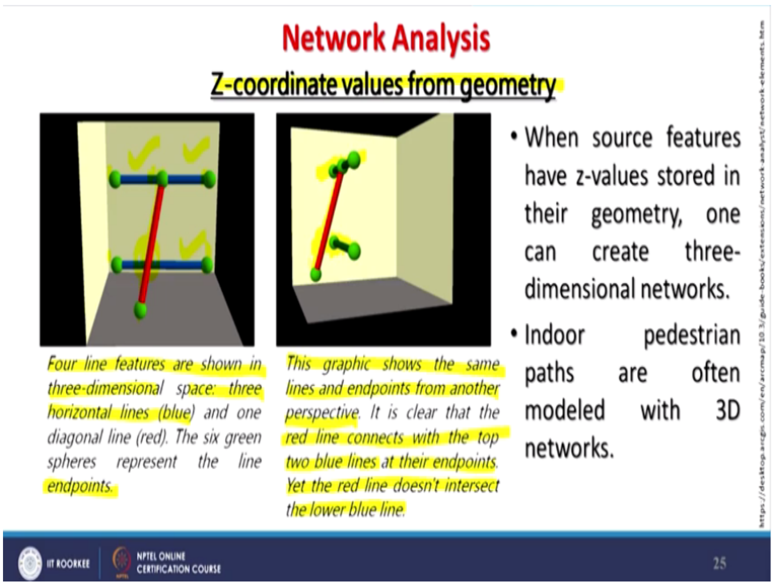

Now, how these things are organized which we can understand through this 3D perspective view that we are having Z coordinates value from a geometry. So, this 4-line feature are shown in 3-dimensional space and 3 horizontal lines are there. Though it is looking inclined one only through this but you can see that this is also horizontal and the other one and this one.

So, the 3 horizontal lines; the blue line, this line and this blue line and 1 diagonal line which is the red line in this model. And 6 green spheres which you can count here, they are there which are representing the end points of each line. Now, we can rotate this graphics once it is in computer that this graphics shows the same lines and endpoints from another perspective.

And it is very clear that there is a no connectivity of this blue line with the red line. So, it is clear that red line connects with these top 2 blue lines and their endpoints. Yet the red line does not interconnect with the lower line. So, depending when we are working in a 3D or for subsurface transport system then in one perspective view, we may feel that there is a junction like here.

But when we change the viewing angle then we see that there is no connectivity at all. So, depending on our requirements basically, these things have to be organized. If junction has to be created then in subsurface condition, excavation has to be done. And then a junction will be created here and then connectivity. So, when source features have Z values stored in their geometry, one can create 3-dimensional networks like example here given.

And indoor pedestrian means in subsurface conditions or in underground conditions, path are often modeled with 3D.

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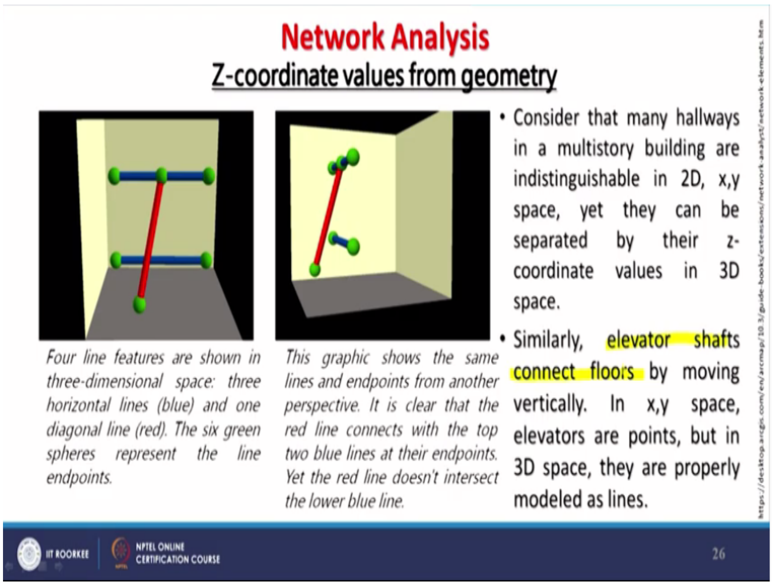

And consider that many hallways in a multistory building like nowadays lot of huge malls are also coming. There also, connectivity has to be established with escalators, with lift and pathways. So there also, it will be very much required to bring this like elevator, shaft, connect floors. Everything has to be stored in a system; all detailed information.

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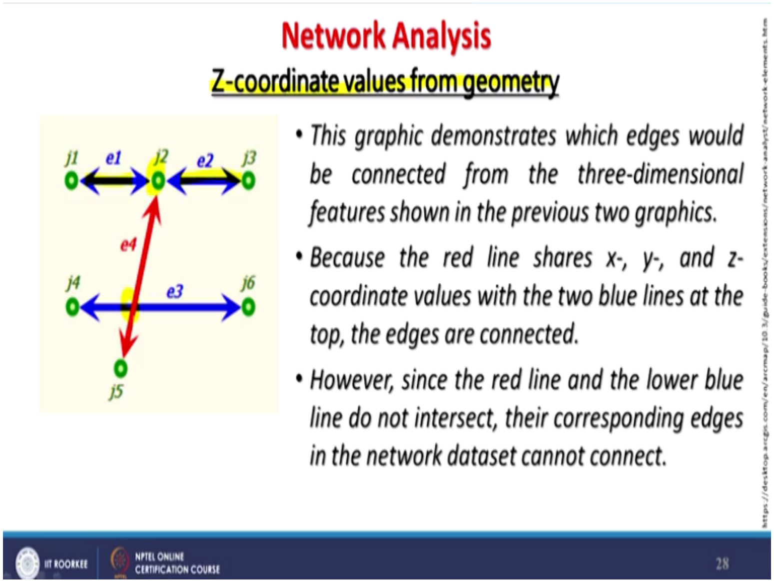

And if that is done then we can have this you know the z coordinate values in our geometry. If that is available then only, a nice network can be established. Like here, we are seeing that there is no connectivity between blue line; this e3 and e4. Though, this red line is meeting with junction 2 of e1 and e2. Now, that means they are at different levels, the red and this blue; the e3 and e4 are at different levels.

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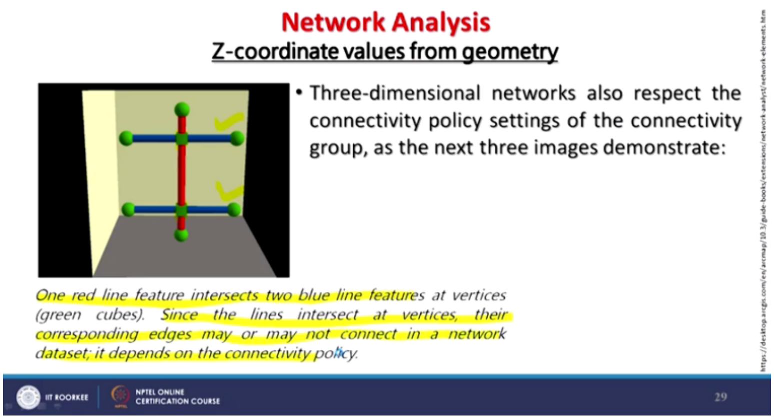

But if we see in a different perspective, they may look. So, if we want the connectivity then junctions are required like here 1 red line feature intersect with the 2 blue line features; the top one and the bottom one. And since the lines connected at vertices, their corresponding edges may or may not connect a network dataset depends on the connectivity policy.

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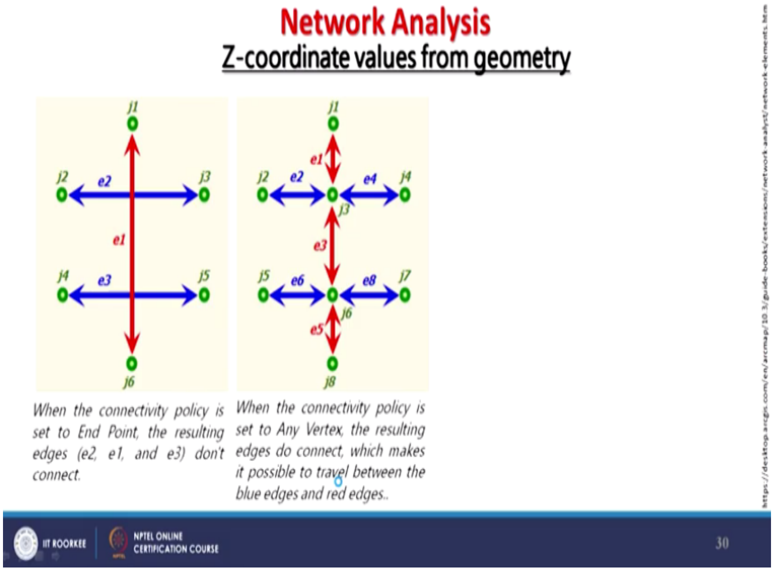

So, that much information is required when we are dealing with the z coordinate. So, things become really complicated. But if everything is organized, elevation informations are kept in our database then 3D analysis can be performed very easily using network. It will take lot of time to develop a network database in a GIS platform. But once an accurate network database has been developed then we can really model or monitor or manage our movement of resources or mobility. So, with this, I end this discussion. Thank you very much.