Urban Transportation Planning
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Lecture No. #28
Route Assignment Contd.

This is lecture 28 on urban transportation planning. We will continue our discussion on route assignment in this lecture. You may recall that we discussed about three important aspects related to route assignment in the previous lecture. The first important point was with regard to conversion of person trips into vehicular trips. The key to that is the information about the average vehicle ownership of different categories of vehicles that we come across in an urban area; that information is used to convert person trips into equivalent vehicular trips of different categories. Second important aspect is about, why did not you use microphone, please?

Temporal variations of vehicles during the day.

Temporal variations of demand for travel in general. So for, or in the first three steps, we were dealing with full day travel demand; twenty four hours traffic; whereas in real life situation, the demand where is over a period of time. So, we need to account for temporal variation of the demand for transportation. In that context, we discussed about assigning trips separately for morning peak, evening peak and during non peak hours. And finally, the third important point that we discussed about was with regard to direction of movement of traffic. That is very important, because ultimately we need to predict the actual traffic flow in the whole of the network after doing completing the assignment. So, that is how the direction of movement is also an important factor.

After discussion of the three important aspects, we try to understand representation of the road network in the form of nodes and links. And now we know, we can represent the road network using just a set of numbers; numbers will directly indicate the nodes; and the two numbers related to two nodes at the end of about its road stretch can be used to designate a link. Is it not? That is how we have understood representing road network using nodes and links.

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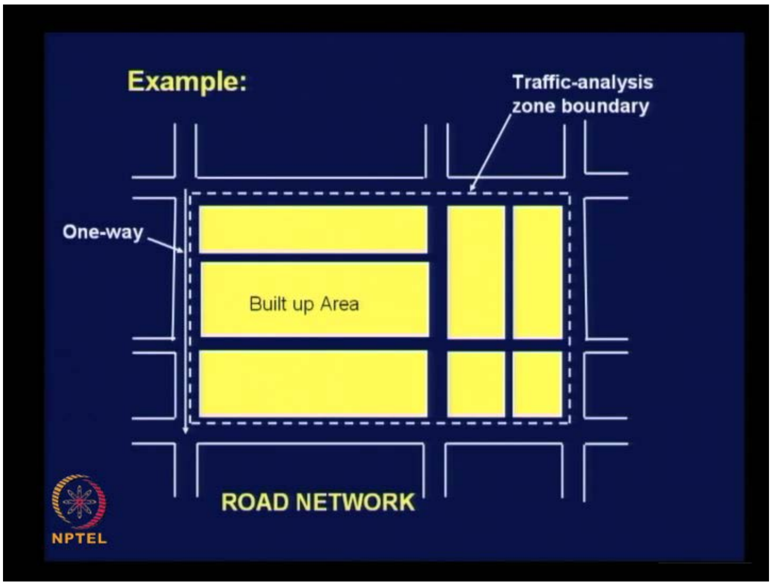

And this is the traffic zone that we consider as an example in the previous class. And the zone boundary was given like this. And the coded road network for this case, as you may recall is this.

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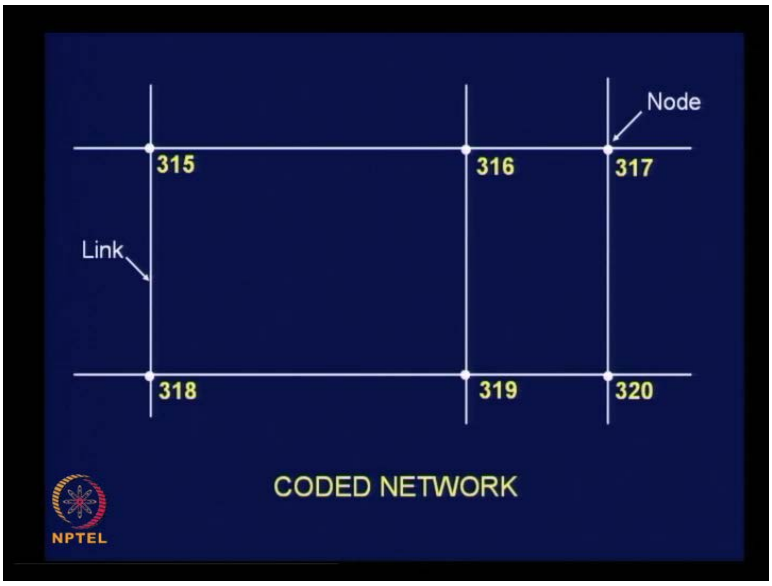

We have ignored some of the minor roads; only major roads have been considered; and all the points of intersection of the roads are given numbers, which all node numbers. And now, we can represent any intersection using this numbers, and any structure road can be representative using a set of numbers; for example, 315, 316, refers to the structure of road connecting the nodes 315 and 316. Clear? So, let see advantage of giving node number, and then expressing nodes and links using these numbers.

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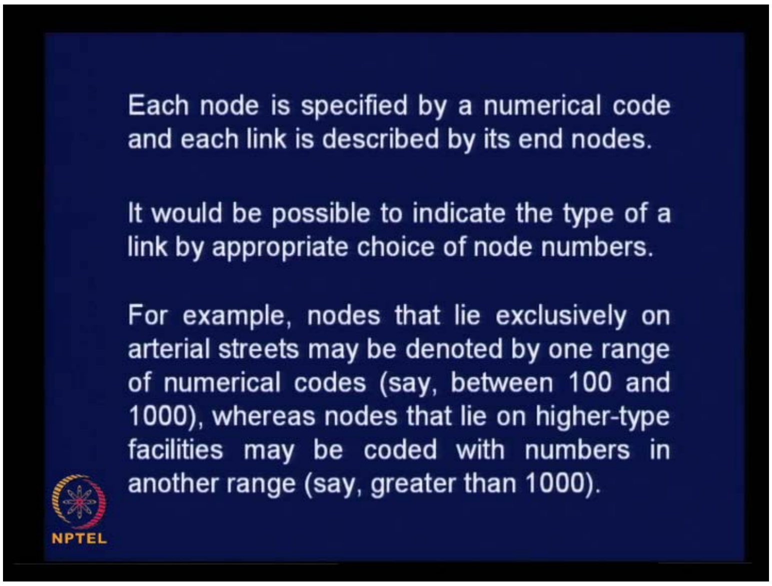

And each node, as we know is specified by a numerical code as we have seen, and each link is described by its end nodes; 315, 316, as I told you. And it will be possible to indicate the type of a link by appropriate choice of node numbers. What you understand by type of link? We may have different categories of roads in major urban areas, arterials, sub-arterials; in certain cases, even express ways as in the case of developed countries. It is possible by appropriate numbering of these nodes to given indication of the type of link or you will be able to know whether the link pertains to an arterial or sub-arterial or in express way that is also possible. So, that will give a better perception of things, when you look at the link and node numbers right. How we do that?

For example, nodes that lie exclusively on arterials streets may be denoted by one range of numerical codes; say between 100 and 1000. So, whenever we come across node numbers in this range, we will realize that these nodes pertain to arterial right. You fix a range; we know the total number of nodes in urban area; knowing the total number, you can always fix a range right; whereas nodes that lie on higher type of facility say express way; may be coded with numbers in another range say greater than 1000. So, whenever your node number is more than 1000, you can have a feel of that node, and you can understand that this node pertains to express way not an arterial. Clear?

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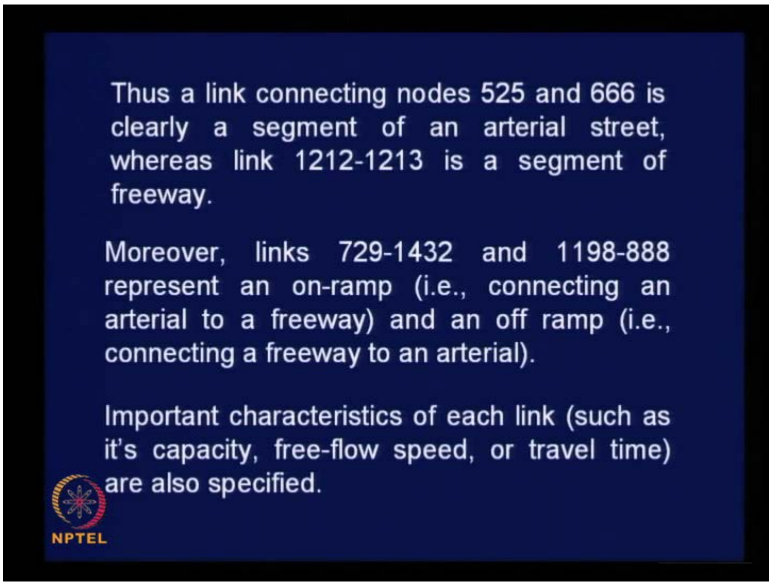

Thus a link connecting nodes 525 and 666 is clearly a segment of an arterial street, is it not? It is lie in the range of to 1000; whereas a link with nodes numbers 1212 and 1213 is a segment of freeway, because the value is more than 1000. Is it not? We are not looking at the network map; we are looking at the numbers, still we are able to perceive the type of link, because of this methodology of giving numbers for the nodes right. Another interesting aspect is this. Links 729-1432 and 1198-888 represent an on-ramp; on ramps or the ramps, which take the traffic from the ground level to a higher level in the case of great separated intersections.

Please remember the express ways will have all its intersections great separated; otherwise it cannot be called as an express way. There will not be any interruption of cross traffic as far as an express way is concerned. When you great separated all the intersections, the flow will be free right. So, when you try to connect an arterial to an express way, there need to be a ramp connection from ground level to the higher level. Clear? So, that is how we must understand the numbers given here; 729-1432 means from arterial to express way. This refers to an on-ramp going on to the express way; from arterial to express way.

And an off ramp is having the number 1198, and triple 8 - 888; from the express way to arterial right. So, we are not referring to your intersection layout; we just look at the numbers still we are able to perceive whether it is an on ramp or off-ramp and so on. So, that is advantage of planning your numbering process, and then giving appropriate numbers for the nodes, the network. Clear? Important characteristics of each link; what are the characteristics of links? Such as its capacity, link capacity is a very important factor; is it not? What is a capacity? What is the maximum traffic volume a link can carry is very important information.

Free flow speed; what you understand by free flow speed? As a term implies, when the traffic is flowing freely without any hindrance by the presence of other vehicles, what is the speed that can be maintained by vehicles on particular stress, is what is indicated here as free flow speed right or travel time along each link by a particular mode; it is also another important characteristics of a link right; capacity, free flow speed, travel time, these are all link characteristics, which are very relevant for planning purpose right. And these information can also be given in addition to the node numbers indicate nodes and links. So, each link must have information with regard these characteristics also.

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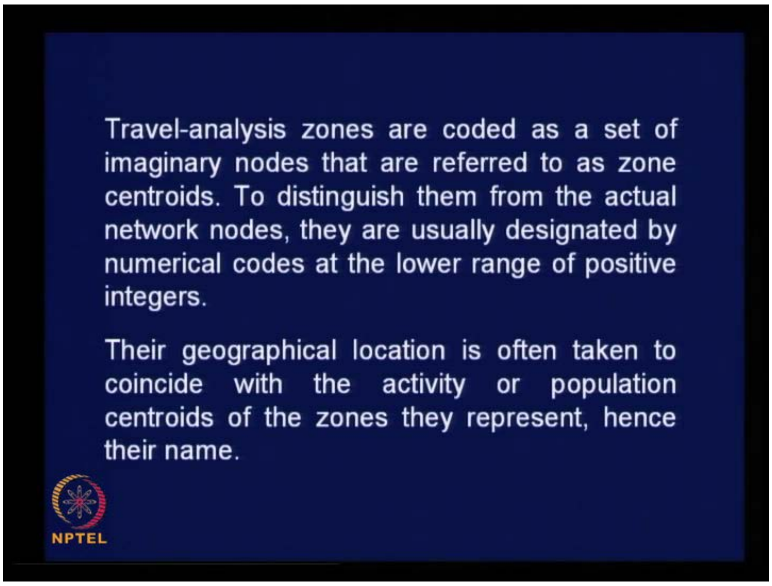

And then travel-analysis zones are coded as a set of imaginary nodes, as I pointed out in the previous class; the zone centroid are also given are considered as nodes and given node numbers right; that are refer to as zone centroid. To distinguish them from the actual networks or network nodes, they are usually designated by numerical codes at the lower range of positive integers; or in other words, you choose a range of numbers at a lower level to give numbers for zone centroids. There are also nodes, so that by looking at the number, you can understand that this node is not a road intersection, it is a zone centroid. So, fix the ranges for different categories right.

Their geometrical location is often taken to coincide with the activity or population centroid of the zones they represent, hence their name. When we say zone centroid, when we say zone centroid, it is not the geometric center of traffic zones; it is this center of activity, if it is a non residential zone or the center of the spread of population, if it is a residential zone right. And your activities may be spread unevenly in a particular zone, concentrated only on one half; the other half may be relatively less concentrated. Then your zone centroid will be shifted towards the more intense part of your zone right; it will be eccentric; physically that will be representative of the centroid of the activities. And similarly if the population concentration is more over one part of the traffic zone, then your centroid will shift towards that part. Clear? So that when you assume that all the trips are emanating from point, it should be more or less realistic; that is the idea.

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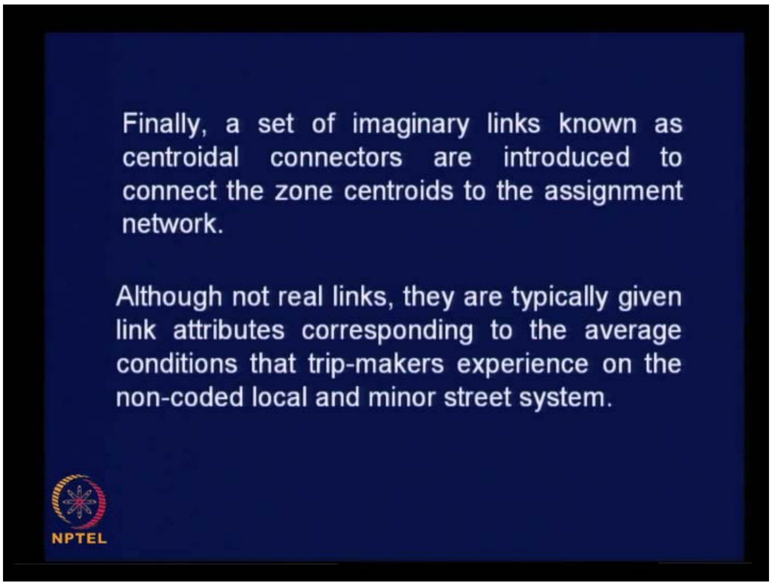

And finally, a set of imaginary links known as centroidal connectors are introduced to connect the zone centroids to the assignment network; that is important, when we give or when we consider zone centroid as nodes, then these nodes are to be connected to the main network; otherwise you will not be able to analysis the traffic flow and assign traffic right. So, we need to introduce imaginary links known as centroidal connectors to connect the zone centroids to be assignment network. Why imaginary links? Why not realistic links? Any responds? Anyway after few seconds, I will show you a picture, which will depict the imaginary link, then we will able to understand much better.

Although not real links, they are typically given link attributes corresponding to the average conditions that trip-makers experience on the non-coded local and minor street system. There are several local minor streets, which free traffic on to the main roads. These imaginary links represent the traffic flow and all the minor roads within a traffic zone right. You considered the same traffic zone here.

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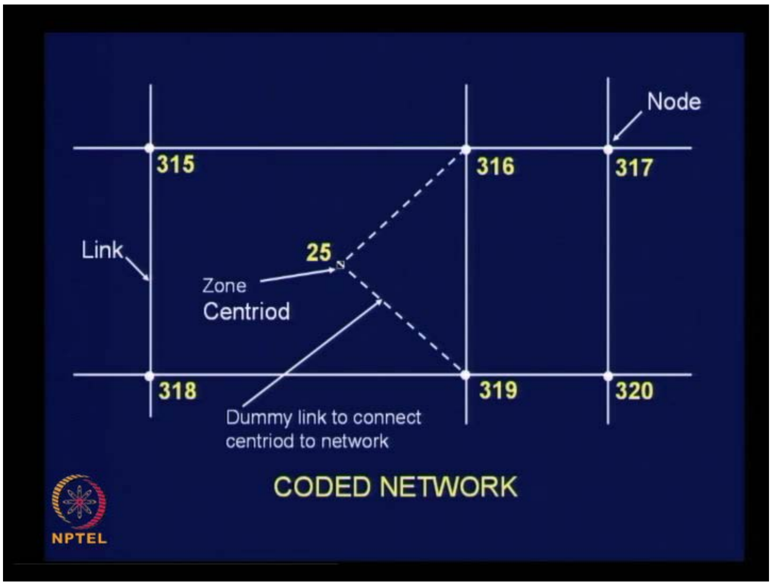

And let us say for zone centroid is fixed in this area, and given number 25 at the lower range less than 100 right. And these two dotted lines connecting the adjoining road intersection, which are also nodal points at the zone centroid are called dummy link to connect centroid to the main network right. And this implies that we need to consider these dotted lines as real links with all link attributes for the purpose of route assignment, because we are going to assume that all the trips of this zone are emanating from that point from 25. They have to move to the dotted lines, and get connected to the main network. The reverse direction, they have to come from the main network through dotted line into the traffic zone.

And actually these trips may emanate from any point of the zone, let it be a set of trips from here, from here and so on. Please note, they assume that all the trips together are emanating from only one point right, and then we are just providing two links for connection to the main network. This implies that the travel time along this dummy links, is a representative travel time experienced by uses of all the minor roads winning the zone. Somebody living here may take about two minutes to reach this node; somebody living in this area may take about four minutes to reach out this nodal point; somebody here may take just one minute to reach out this place right.

So, the attitude or link travel time pertaining to this dummy links is the weighted average of the travel times related to all these movements right; so that is how we need to understand the attributes of the dummy links. Clear? And you may wonder, why having two dummy links? Why not only one? For why not more than two? Any response? Why not have less or more number of dummy links? Why only two? It depends on the actual traffic flow that we experience in the field. If the people living in this area or getting connected to all this intersections, all the four intersection evenly, then our links must represents the realistic flow condition. And we have to have more dummy links, and we must have connection from 25 to 315 as well as 318 right.

And in this particular case, you can assume that entry into this network is not possible for this people. And they have to get connected the main network only through this two intersection; under such condition, we are just introducing only two dummy links. It represents the actual traffic flow in the field. And if connection to this node is prohibited, then we will have only one dummy link, and everybody will be assumed to make use of only one path. Clear?

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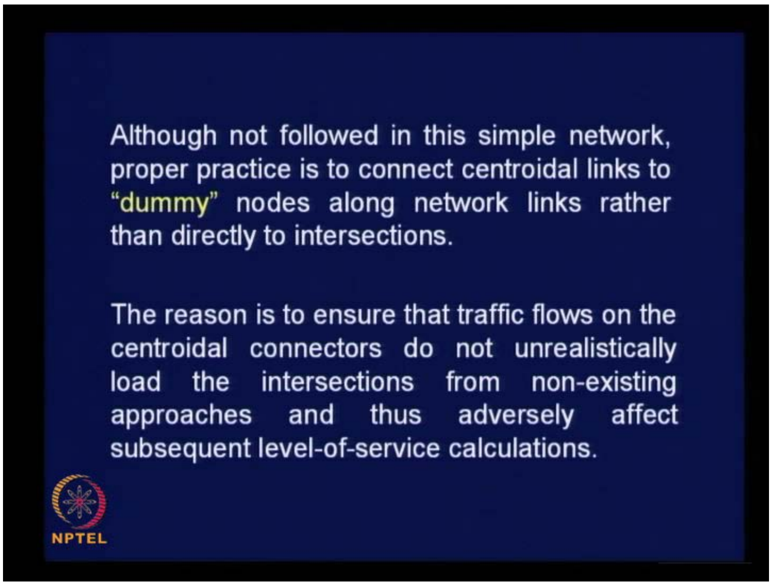

There is one more aspect regarding the dummy link. Although not followed in this particular example that we saw, proper practice is to connect centroidal links on the dotted lines to dummy nodes; dummy nodes along network links rather than directly to intersection. What is implied here is, we should not connect the dummy link directly to the adjoined intersection, and we must connected to the link, adjoining link, and then indirectly connected to the intersection; that is the point made here. And we should know why we should do so? What is the problem? Any responds? Why should we not connect zone centroid directly to the adjoining intersection? Think of the analysis of traffic flow at the intersection area.

Let say that particular intersection has got two intersecting roads; that means, there will be four legs for the intersection or four approaches; and your connecting one more dummy link to that intersection, that implies, that we are introducing fifth approach with intersection; is it not? Because you are connecting directly a zone centroid to the intersection; the physical meaning is you are adding one more approach to the intersection, which is non-existing; intersection has got only four approaches, because of manipulation, it gives a impressions as far as analysis is concerned that intersection is going to be treated as a five legs intersection; even though it is only the four leg intersection, which will give you a erroneous results, when you assign traffic. Is it not?

You treat intersection totally differently compared to the existing geometry of intersection.

How we get over this problem? The solution is as indicated here to just shift the dummy link to the intersection approach area, get it connected to the link, not directly do a node, and then the link will fit the traffic to the intersection. Clear? Then it will be more realistic. The reason as I said is to ensure that traffic flows on the centroidal connectors do not unrealistically load the intersections. The loading of the intersection will be unrealistic, from non-existing approaches right, and thus adversely affect subsequent level of service calculations. You are going to calculate delay at each of the intersection and so on; all these things are linked to the number of intersection approaches, the traffic on each of the approaches right. So, that is the reason, why we should not connect the dummy links directly to the intersection.

So, this is way, we should shift the dummy link, and connect them to the adjoining links not directly to the nodes, and create dummy nodes again on the link, because any connecting points should have node number. Since it is going to be practically connected to 316, have the same number, and add one more alphabet, so that it gives a clear idea of why you are doing so; and to which node is really connected to. Clear? Similarly, here instead of 313 will be name it as 319 D; D stands for dummy. So, this is how we need to give node numbers for network, particularly when you connect zone centroid. Clear?

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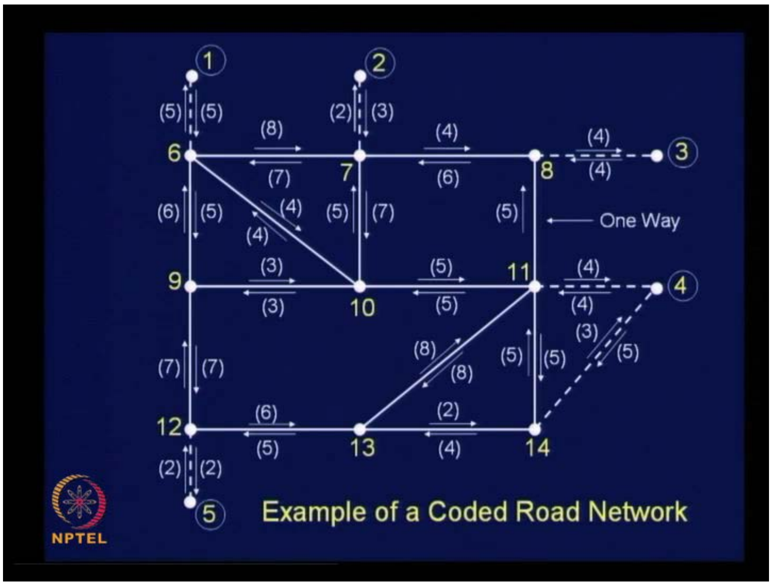

This is an example of a coded network; just give you an idea of a fully coded network in the form of a picture right. You have all the nodes numbered and link destination you can get from the node numbers and the numbers in the parenthesis or the travel times in minutes along each of this links. How many zones centroids are involved in this example? There are five zone centroids right. And how many centroidal connectors are involved? Yes, only one zone has got two centroidal connecters; zone four has got two connectors right. And how many nodal points are involved in the main highway network? You can count and check; and you can also count the number of links involved right.

Now, you can see the numbers in parenthesis indicated travel time on each of these links; direction wise information is given. It is necessary to give travel time information direction wise, when we say Sardhar Patel road? Can we nodes give only one travel time why is, why giving travel time information direction wise? Could it changed based on the direction of movement? It can change, because of what are the, a possible reasons for a different travel times based on direction of movement. Let say one direction of flow has got relatively higher travel time. What could be the possibility or possible reason for increasing travel time compare to the other direction of movement? Unless we are able to understand and appreciate the reason, you would not be that comfortable with the different numbers for different directions. Will it happen? It seems it is happening, and what are the possible reasons? Any responds?

When the (( )) are going to one direction is likely to be more congested and travel time will likely be increased.

Yes, but normally for route assignment analysis, we consider free flow travel time. So, the effective traffic volume is not there right. It is almost free flow travel time. And still there is difference in travel time based on the direction of movement. Any suggestion? Let say, there is a divided road, four link divided road way right. And there could be cross roads connected to the main road that you considered or cross road connected to your link under consideration right. On one side you may have five cross roads getting connected, joining your link. On the other side there may not be any connection at all; it may be totally free. Then in that case, the side which has got no connection will have least travel time, because there is no interfere from cross traffic; whereas from this side, always there will be vehicles entering the main stream; and the main stream traffic has to slow down adjust to the interfere crossed by the cross traffic right.

This is one possible reason. You can (( )) different types of examples; in another case for example, one side of your road may have some institutional land use with very limited access; one or two entry points. The other side may have dense residential land use right with lot of entry points; as well as there is need to restrict the speed, because it is a residential land use right; what is the normal way of restrings speed? They may introduced speed breakers, add frequent intervals or speed itself may be limited by installing speed limit sign boards; that case are one side, you can move fast; and the other side, the speed is going to be much less. So, practically these things can happen.

So, that is how we have to accept different numbers given for different directions of movement; for example, if you take link 7 8, 8 7 travel time is 6 minutes, whereas 7 8 travel time is only 4 minutes; there is difference, significant difference 6 minutes and 4 minutes. There are few links, which have same travel time implication on the both direction; it is possible; and the conditions are similar right. So, let us try to summarize what we have discussed.

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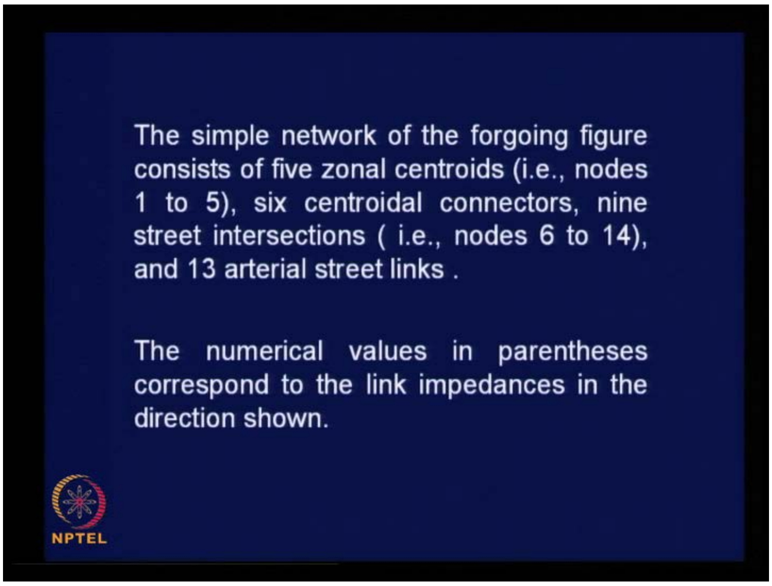

So, this simple network of the forgoing figure consists of five zonal centroids right that is nodes 1 to 5, six centroidal connectors, because one zone centroid has got two connectors; nine street intersections right that is nodes 6 to 14 and 13 arterial street links, 13 links are involved in that example. Please remember these values, because we will be discussing about this network, frequent link to understand few other aspects related to assignment. The numerical values in parentheses correspond to the link impedances in the direction shown. We generally term it as link impedance, but in practice, we take it as travel time. Link impedance means different aspect, it is not simple travel time.

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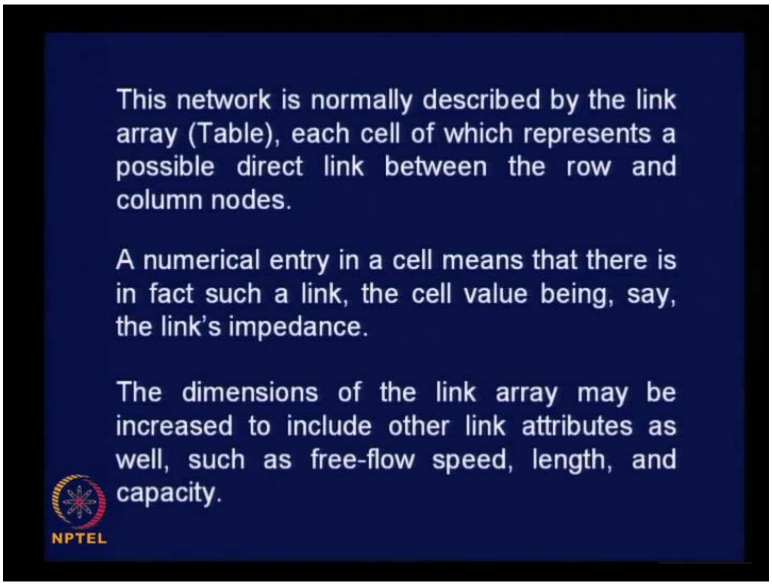

This network is normally described by the link array table. As I told you in the previous class, we are not going to give this picture as input to the computer program for analysis; we have to deal with numbers only. So, this same picture can be represented by a link array table; each cell of which represents a possible direct link between the row and the column nodes. A numerical entry in a cell means that there is in fact, such a link first, then the cell value being, say, the link's impedance; possibly travel time. The dimensions of the link array may be increased to include other link attributes as well, such as free flow speed, length of the link itself and capacity of the link and so on.

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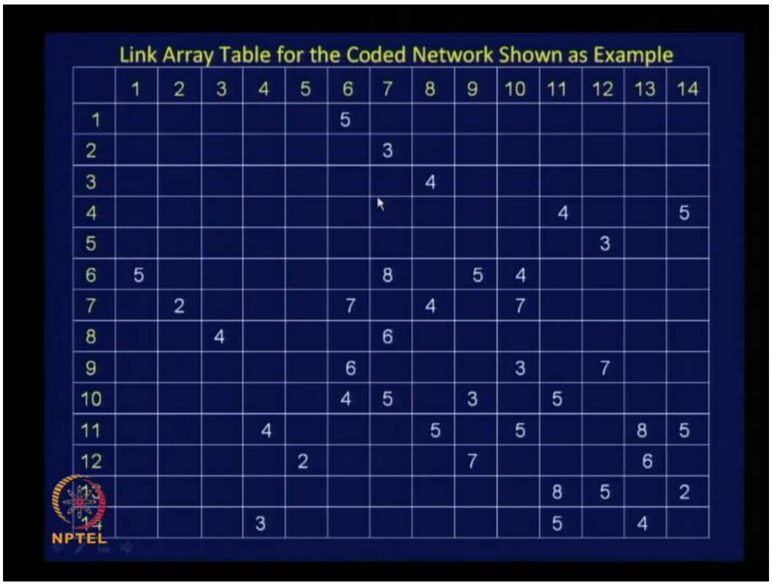

Link Array Table for the Coded Network Shown as Example

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1						5								
2							3							
3								4						
4											4			5
5												3		
6	5						8		5	4				
7		2				7		4		7				
8			4				6							
9						6				3		7		
10						4	5		3		5			
11				4				5		5			8	5
12					2				7				6	
13											8	5		2
14				3							5		4	

This is the link array table. It is not difficult to understand make yourself comfortable right. And I have just given numbers 1 to 14 along the row, and 1 to 14 along the column; these are nothing but node numbers right or you may recall numbers 1 to 5 refer to the zone centroid numbers, and rest are referring to the road intersections right. Now, we find number 5 in this cell of the matrix. What is the destination of the cell? This cell is 1 6.

So, when you have the number, the first inference in that there is a connection between the nodes 1 and 6. There is a link named 1 6 or 6 1; there is a link connecting 1 and 6; that is a first inference. Second inference is this number actual means, a link travel impedance; to be more specific, this is a travel impedance for movement from 1 to 6, not from 6 to 1. This is the travel time or travel impedance from 1 to 6, 1 6; clear? Of course, in this particular case, 6 1 travel time also happens to be… The 6 1 is here, that also happens to be 5 that need not be the same in all the cases. Now we have number 3 here. This implies what? What is the first inference? There is a link connecting node 2 and node 7 right; and the travel time for movement from 2 to 7 is 3 minutes; in the other direction from 7 to 2 is only 2 minutes right.

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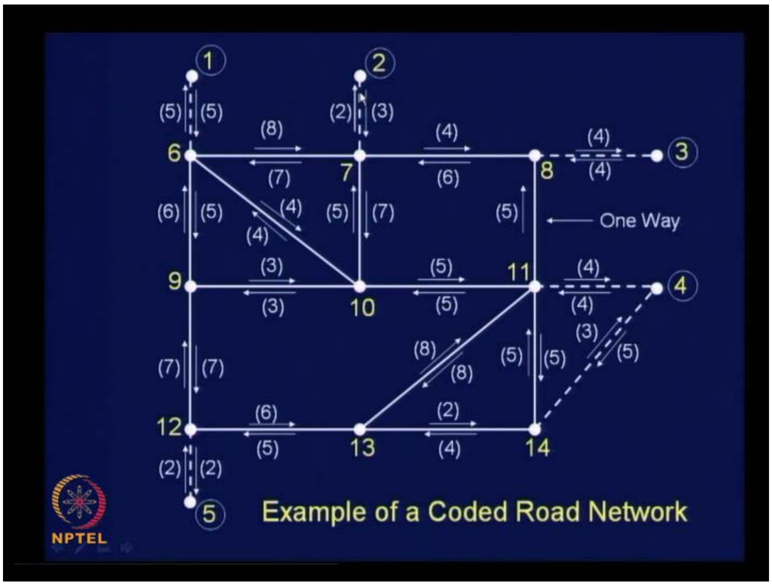

See, if you want, you can just look at the picture again, and try to understand; 2 7 and 7 2, 2 7 7 2, there is a connection. In one direction, we have 2 minutes; and 2 7 - 3 minutes, 7 2 - 2 minutes. Now, you can look at the cell values, and try to understand the representation of the network, links and nodes in the form of link array table. Are you convinced now that is possible to represent a road network in the form of simple link array table? It gives all the information that you get from a picture that we have seen earlier.

Suppose you want to in cooperate other attribute of the link, length of the link, capacity of the link, all this things can be included; for for example here, 1 6 if you want to include capacity, you can say 5 comma the capacity value right; and put one more comma and give the value for length; it is a notational giving. And your analytical program will understand, what you really mean by this numbers? This sequence is fixed right; you can fix the sequence, and give whatever link attributes, you want to give for a link right.

So, this is what we have discussed; the same picture is represented the form of link array table. And so far, we have understood how to represent road network in the form of links and nodes, and then how to represent the whole thing in the form of a link array table. Now we are ready to go further to actually assign traffic. Your traffic assignment should reflect the way people choose their route for travel from one zone to another zone. Is it not? Your assignment process must replicate the choice process of route by the travelers. So, it is better or it is important to understand, how people are choosing route for movement from one traffic zone to another traffic zone right.

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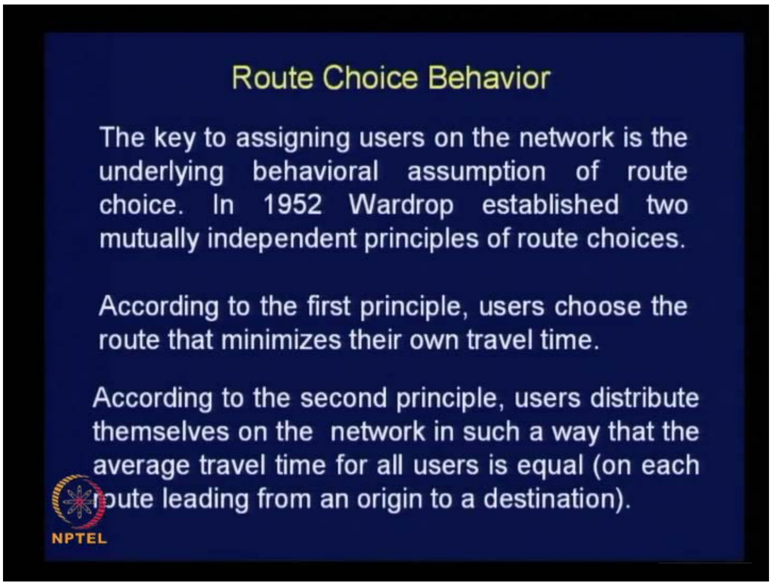

The behavioral aspects with regard to route choice; route choice behavior: The key to assigning users on the network is the underlying behavioral assumption of route choice; of course in 1952, Wardrop established two mutually independent principals of route choices; two important principals. According to the first principle, users choose the route that minimizes their own travel time. If there are two three alternatives, they look at the travel time implication of each alternative, and choose the one which has got least travel time right.

According to the second principal, users distribute themselves on the network in such way that the average travel time for all users is equal on each route leading from an origin to a destination. How it is possible let say there are three alternative routes available for travel from zone one to zone two; as per this statement, the users distribute themselves in such way that the travel time almost balances, is almost same on all the routes.

Let say that free flow travel time along route 1 is 2 minutes, along route 2 - 2 and half minutes, along route 3 let say 3 minutes. So, three alternative links may have three different travel times, but users distribute themselves in such way that the travel time equalizes. Is it possible? In practice if more people are making use of the route, which has got least travel time the congestion will link increase; resulting in increased travel time. Once it is congested, they get shifted to part of them will get shifted to the next shorter route. Then in the process that also route that route also will get congested, then there will be shifted to other route. So, in the process, there will be a kind of balance, so that the travel time implication on all the three alternative routes, become almost same right.

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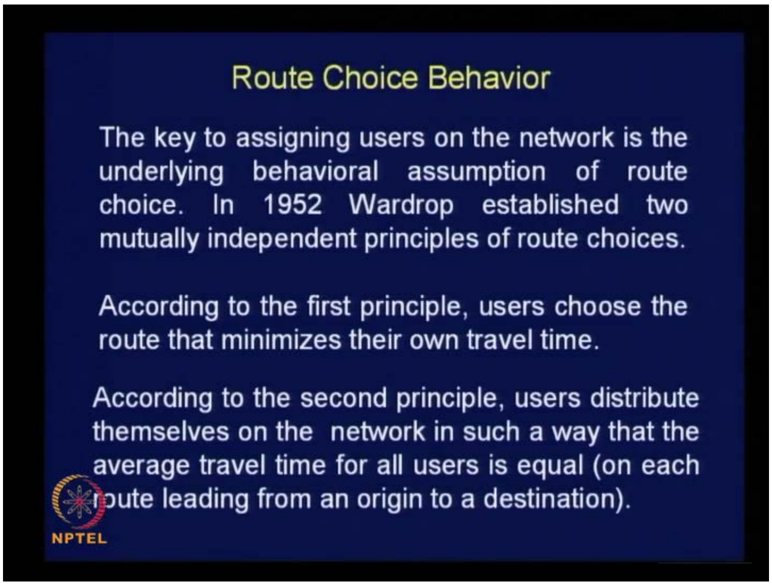

So, these are the two philosophies or concepts purposed by Balram. The first role defines the user equilibrium; whereupon each user goes on the shortest path. So, the nomenclature given for this particular concept is called user equilibrium approach. Clear? The second role defines the system equilibrium, whereupon the total cost of the using the system is minimized, total cost or travel time whatever is minimized. The terms a shortest and cost typically refer to travel time in general that elaborate equilibrium formulations account for generalized costs, which include not only travel time also fuel consumption or simply cost of travel, fare price in the case of public transit and so forth; so forth includes comfort, convenience safety and so on.

If all these things are brought into route choice process, then you will be dealing with generalized cost of transportation, but it is very rare may be for research purpose, people do with generalized cost of transport. In practice travel time is taken as a basis for route assignment, because after said that the time implication for urban travel is not large, it ranges between few minutes to about 60, 70 minutes in most cases right. So, there is no need to bring in all other related aspects like cost of travel, comfort, convenience and so on.

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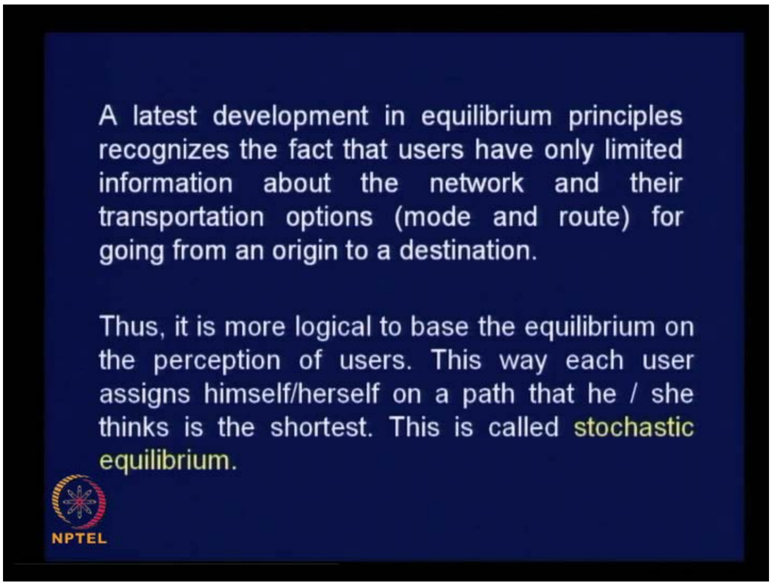

A latest development in equilibrium principles recognizes the fact that users are only limited information about the network and there transportation options either mode or route for going from an origin to destination, is based on the information they have. So, when we talk about shortest route or minimum travel time, it is based on the assumption that every traveler is clear about the travel time implication along a particular path; in practice, it may not be true. I may assume that taking Anna Salai to go to central station may take about 30 minutes, and she may assume that it will take only 25 minutes. So, there are all perceptions.

And thus it is more logical to base the equilibrium on the perception of users. This way each user assign himself or herself on a path that he or she thinks is the shortest. This is called stochastic equilibrium right; it is stochastic process; quite random; a based on the perception of individuals with regard to travel time.

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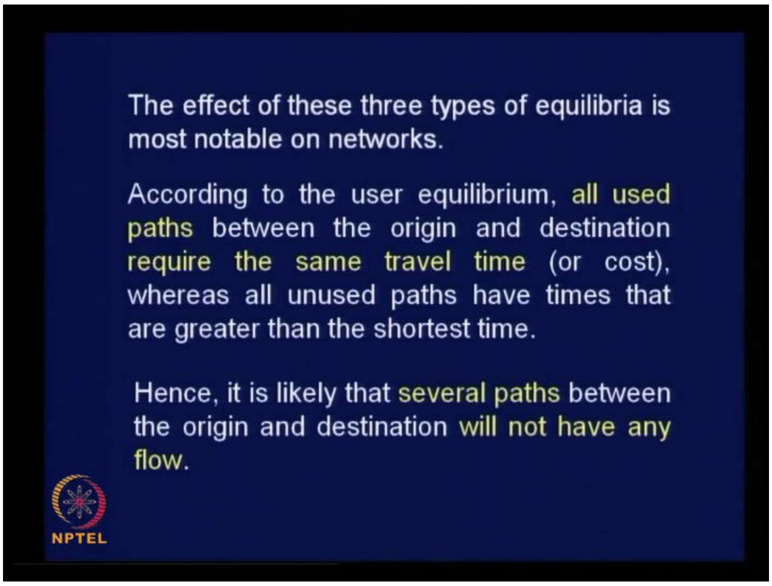

The effect of these three types of equilibria is most notable on networks. According to the user equilibrium, when we have different alternative routes, according to user equilibrium, all used paths between the origin and destination require the same travel time or cost; whereas all unused paths or times that are greater than the shortest time. User equilibrium implies that every user is going to take the shortest path. If there are two shortest paths with same travel time, then both the paths will be made use of by the users; if there is only one path, then that is the soul route that will be used by all the users. That will be effect in the field. When we have three alternative routes, you will find that only one route, which is the shortest used by everybody.

Hence it is likely that several alternative paths between the origin and destination will not have any flow at all, if you assign traffic based on this equilibrium, you will not be assigning any traffic for other alternative routes, you will assign the whole of the traffic only to the shortest route.

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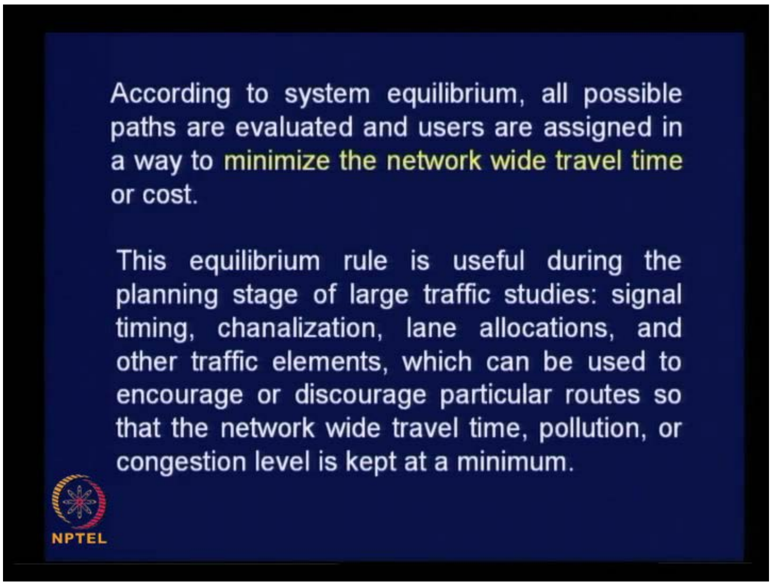

According to system equilibrium, all possible parts are evaluated and users are assigned in a way to minimize a network wide travel time or cost. There is a balance developed for the whole of the network. This equilibrium rule is useful during planning stage of large traffic studies; mostly not for transportation system planning, only for traffic studies involving signal timing, channelization exercises, lane allocations and other traffic elements, which can be used to encourage or discourage particular routes, so that the network wide travel time, and the resulting pollution or congestion level is kept at minimum. This assignment is mainly used for traffic management purpose, to balance a traffic flow in the network by some management measure right.

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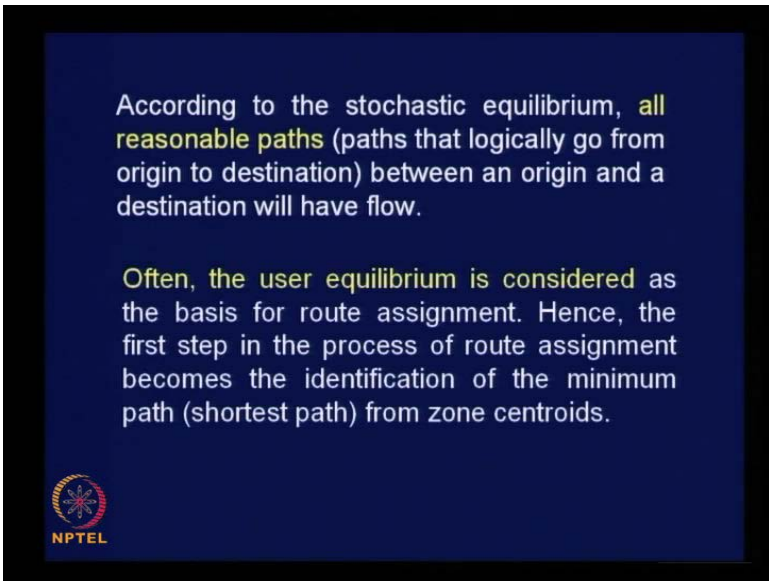

According to the stochastic equilibrium, all reasonable paths; what do you understand the reasonable paths in perception of the users? Whatever they feel reasonable, between an origin and destination will have traffic flow. Often, the user equilibrium is considered as a basis for route assignment, user equilibrium is a soul basis considered for route assignment. Hence the first step in the process of route assignment becomes the identification of the minimum path or shortest path from zone centroids. Why? Because as per this equilibrium, we assume that all the users will use the shortest path. So, it is important for us to know the shortest path from a zone centroid to all the points of interest, points of interest are the centroids of other zones. So, that is the first step as per user equilibrium principal.

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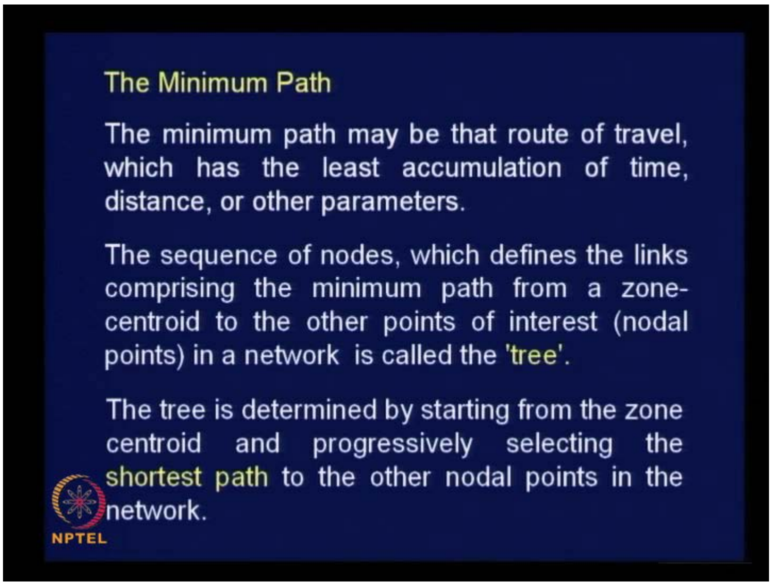

Now, how to find out the minimum path from a zone centroid? The minimum path may be that route of travel, which has a least accumulation of time, distance or other parameters, more commonly time. The sequence of nodes, which defines a links, comprising the minimum path from a zone centroid to the other points of interest, nodal points in a network is called tree. We just trace of the minimum path, and it will go through a number of nodal points. So, this complete set involving a set of links and nodes is called a tree. The tree is determined by starting from the zone centroid and progressively selecting the shortest path to the other nodal points in the network. Obviously, it starts from the centroid and progressively add the accumulative time to get the shortest path information.

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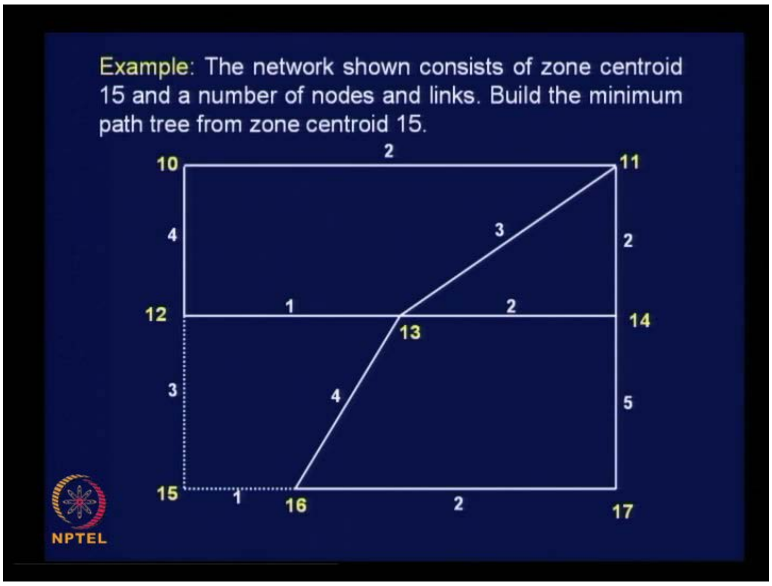

Let us consider this simple example; the network shown consists of a zone centroid 15, because you can see the dotted line connected to number 15 right. And a number of nodes and links, the question is or the problem is to build the minimum path tree from zone centroid 15. There are no other zone centroid shown here right; we are just taking a small segment of the network connected to one zone centroid here right; and trying to understand the principal of minimum path tree to reach out to all the other nodes right. And will see how to go about doing this exercise in the next class. To summarize what we have seen now in this class, we started our discussion with regard to representing road network using nodes and links; and we understood clearly, how to represent zone centroid with node numbers.

And how to connect zones centroid with dummy links, and in this regard, we need to remember that zone centroid should not be connected directly to the adjoining nodes by dummy links. They should be connected to only the adjoining links, and in turn connected to the intersection nodes to avoid the problem of unrealistic analysis of intersection traffic flow. Then we discussed about representing the network in the form of a link array table right. And now, we are clear where it is possible to represent the whole of the road network, along with the attributes of the link right in the form of a link array table.

Then, we discussed about the principal followed in route assignment; in that context, we discussed about user equilibrium, system equilibrium and stochastic equilibrium. And finally, we understood that user equilibrium is a principal normally adopted for route assignment. This implies that there is a need to identify the shortest path from zone centroid to all other nodal points, if we are going to use user equilibrium for route assignment purpose; and we will proceed with this process in the next class.