Urban Transportation Planning
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Lecture. No. #13
Conceptual Aspects

This is lecture 13 th on urban transportation planning. We will discuss on modal split analysis in this lecture, as we normally do, we will first try to recapitulate what we did in the previous lecture. Before proceeding further, you may recall that we mainly discussed about the different steps involved in the regression analysis, taking trip attraction modeling as an example. Now, we know the most important, and first step in regression analysis is the understanding of the nature of relationship between, each of the independent variable with the dependent variable. We need to know whether; the relationship is non-linear or linear. If we find that the relationship is non-linear, we need to linearise the relationship using appropriate analytical procedure, that is step one.

Step two, understanding the relationship between all the involved variables, both independent and dependent variables by formulating an inter correlation matrix. This matrix will give a clear idea about the extent of influence of each of the independent variable on the dependent variable, as well as, the possible co linearity between independent variables. So, this matrix helps us to plan better for the regression analysis and eliminate some of the independent variables if necessary. Then we do the regression analysis and get the regression statistics like, co efficient of determination, standard error of estimate for comparison with standard deviation, t statistics for each of the independent variables, and so on. And finally, decide about the goodness of the regression modal.

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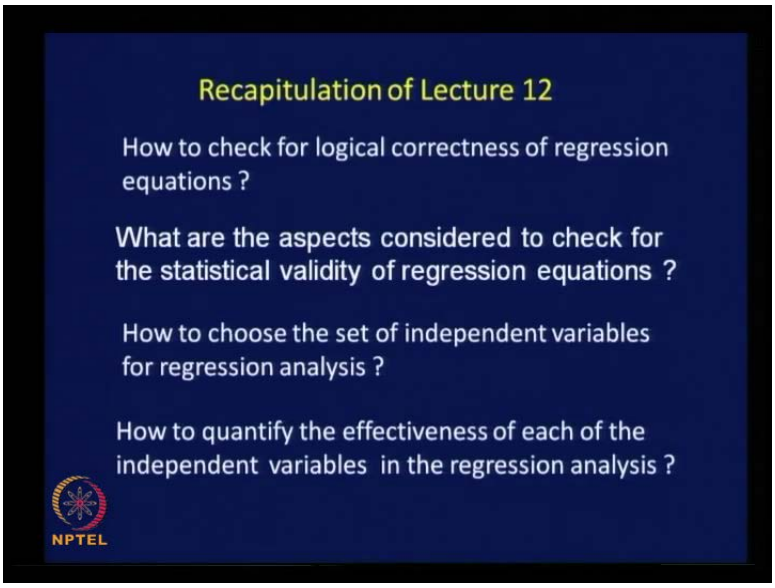

And to recapitulate some of the important aspects related to, what I said? let us pose few questions to us, as recapitulation of lecture 12. The first question is this, how to check for logical correctness of regression equations? Any answer? Checking for logical correctness of regression equation, (No audio from 02:48 to 02:55), Logical correctness here means, clear understanding of the effect of each of the independent variables on the dependent variable, whether a particular independent variable will have a decreasing effect or increasing effect. If the independent variable has an increasing effect then you will have a positive sign for the corresponding regression co-efficient.

If it is having decreasing effect then you will have negative sign, just checking the sigh for each of the partial regression, co-efficient is what we really mean by checking the logical aspects of regression equation. And also checking for the value of the intercept constant, if the intercept constant is too large that means there is a large segment of why, which is not really, explained by the set of independent variables that you are using for regression analysis. So, we must see that the intercept constant is as small as possible should have reasonable value so, this is how we need to check for the logical correctness of regression equation.

The next question is this, what are the aspects considered to check for the statistical validity of regression equations? We just estimate first the value of co efficient of determination R square. If the value is reasonable, then we say regression equation is

valid reasonable within quotes, reasonableness depends upon our requirement. We cannot fix a constant value for reasonableness of any regression equation. Then we need to check whether the total error, standard error of estimate involved in the regression process is comparable to the standard deviation.

We compare standard error of estimate with standard deviation and ensure that standard error of estimate is less than the standard deviation, or at least not more that the standard deviation value. Reflecting where the spread of the predicted value of Y or the values of Y about the regression line is not that much compared to the spread of the actual observed Y valves with respect to the mean. That is the purpose of checking for s c and s d values. Then we calculate t statistics for each of the independent variables involved, to check for the individual statistical significance of each of the variables involved in the regression analysis.

If we find that for a particular independent variable, the value of t is less than the table value that implies, that particular independent variable is not really, significant in explaining the variation of Y. There is no need to have that variable in your regression equation; these are all the three important checks we need to do with regard to statistical checking of regression equations. And one other question is this, how to choose the set of independent variables for regression analysis? You may collect data on number of independent variables number of factors. How will you choose the appropriate independent variables for regression analysis? That should be some basis, how do we do that? Can we make use of the inter correlation matrix, to get some idea about usefulness of your independent variables you can?

Because inter correlation matrix, gives you the 0 level correlation of each of the independent variables, with the dependent variable level of correlation. If the correlation is nearly 0, there is no point in choosing that independent variable for regression analysis. It is mainly based on the correlation of each of independent variables individually, considered with the dependent variable. So, that is the basis on, which we choose the set of independent variables for regression analysis is not it. And the next question is this, how to quantify, the effectiveness of each of the independent variables in the regression analysis? You may have three four independent variables.

How will you indentify the most effective independent variable in explaining the variation of Y? Any suggestion? Why do we estimate the value of t for the regression co efficient? Suppose t value is very high for one independent variable and much less for another independent variable. Then among these two, which is more significant in explaining the variation of Y the one, which is having higher value of t or lower value of t? How do you estimate the value of t? The regression co-efficient divided by the standard error of estimate of the regression co efficient, but the denominator is less, you are going to get a larger value of t.

That is what you want? Or larger the value of t more significant is your particular independent variable in explaining the variation of Y. So, t values will be able to help you to answer this particular question, how to quantify the effectiveness of each of the independent variables in the regression analysis? This is the way you can quantify. Now, with this understanding let us look back and see the example that you have seen in the previous class in, which we developed a set of regression equations and finally, decided to choose a particular equation based on logic and statistics.

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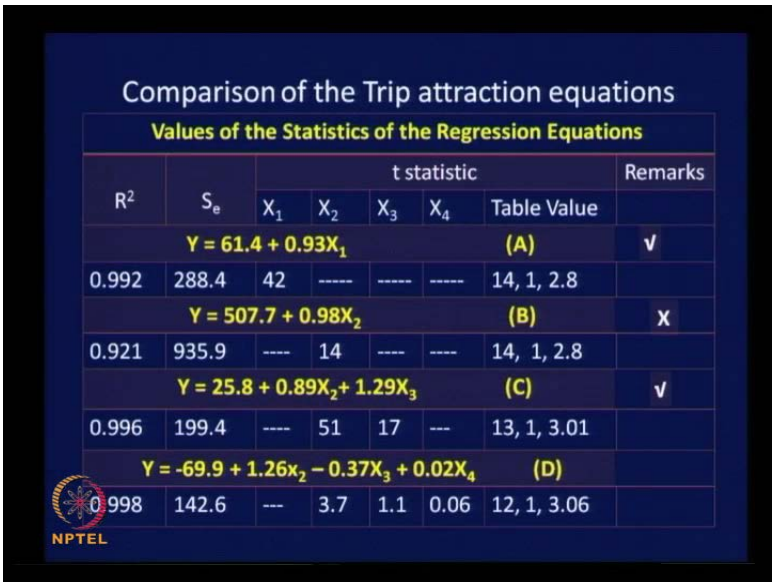

And, you may remember the regression involved a dependent variable, which is nothing but a peak hour total trip attraction. And, the independent variables where X 1 total employment opportunities in a zone and then X 2 employment in manufacturing, X 3 employment in retail and service sector and X 4 other categories of employment. So, we

had four independent variables to be related to a dependent variable namely peak hour trip attraction. Let us try to list those four equations again and try to understand the procedure of identifying, the right type of regression equation.

The first equation that we developed is this; we just used only X 1 with the dependent variable because it had a very high correlation with the dependent variable and developed this equation. And, the regression statistics for these equations are this R square was 0.992, Standard error of estimate was 288.4 and t statistic for X 1 was 42. And, table value of t for 14 degrees of freedom, in this particular case 14 degrees of freedom at 1 percent level of significance last 2.8. You can see that the table value of t is much less compared to the actual calculated value of t of that particular independent variable, on other words. The independent variable has got a much higher calculated value compared to table value.

So, shall we say that this equation satisfies all the requirement of your regression equation? How is it with regard to logic? Is it logically correct? Because X 1 should have a positive value increasing effect on Y, obviously the positive sign is right and the constant term also appears to be reasonable. Off course, reasonableness of constant term you will be able to understand and appreciate with experience only, you will not be able to appreciate the magnitude with regard to it is size with 1 or 2 examples. You must have sufficient experience to really comment on the magnitude of intercept constant. So, we can say that this modal is acceptable both on logical and statistical grounds.

The second modal that we developed is this, Y is equal to 507.7 plus 0.98 X 2 and the relevant statistics are this R square value was 0.921 and standard error of estimate 935.9 and t value for X 2, 14 for 14 degrees of freedom. At 1 percent level of significance it is 2.8, because it is only one independent variable, should be same. How do you compare these two regression equations? Which is better? If you compare the R squared value, the modal A is better than modal B. And, if you compare standard error of estimate S e value again, standard error is less in the case of modal A compared to modal B. Based on S e value also, modal A is much better than modal B.

Off course, modal B is logically fine, but if you look at intercept constant, unexplained part of the regression equation it is relatively high, large in the case of modal B compared to modal A. So, on most of the aspects we find modal A is better that modal B.

So, right away we can discard this modal, there is no need to go further so, we will say that this is not considered. Then we consider one more modal, Y to be equal to 25.8 plus 0.89 X 2 plus 1.29 X 3. The statistics for this modal are this R square 0.996 standard error of estimate is just 199.4, t values are 51 and 17 for 13 degrees of freedom at 1 percent level of significance the table value is just 3.01.

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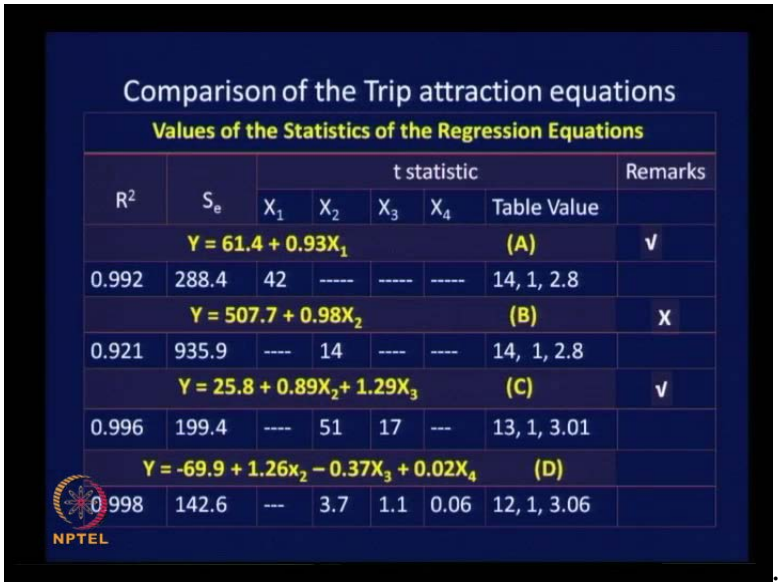

We find that R squared value of this modal is slightly, more than the R squared value of modal A, standard error of estimate is less than modal A so on, these two counts this appears to be superior to modal A. And, how about intercept constant? That is also small relatively small compared to modal A. And, logically all the variable seems to be fitting better increasing effect on Y, X 2 as well as X 3 have positive sign. So, this modal is satisfactory both on statistical and logical grounds and is superior to modal A. So, let us initially accept this modal and let us not come to a final conclusion because we have one more modal to discuss and then take a final decision. And, the forth modal that we considered was this, Y is equal to minus 69.9 plus 1.2 6 X 2 minus 0.3 7 X 3 plus 0.0 2 X 4.

The statistics for this modal are here, R squared is 0.998 the maximum of all the other cases, is not it the maximum? Standard error of estimate 142.6 reasonably, lesser value and t values are 3.7, 1.1, 0.06 at 12 degrees of freedom 1 percent level of significance, the table value is 3.06. What is the inference? Do you accept all the variables as a

significant variable in this modal based on t value? We find that X 3 and X 4 are not significant, the t values are less than the table value. They are not significant in explaining the variation of Y, only X 2 is found to be significant slightly higher t value compared to the table value of 3.06.

Also, we find that X 3 has a negative sign for it is co efficient, X 3 is what employment in retail and service. Normally, employment in retail and service should have a positive effect increasing effect on total trip production. Where as it is showing the opposite effect here, is not it? So, it is logical correctness is questionable, it is not logically correct. So, on logical grounds as well as statistical grounds, we can say that this modal is not valid is not it. We cannot accept this regression modal even though initially, we found that X 1, X 2, X 3 and X 4 had a positive correlation based on inter correlation matrix, when we put all this independent variables, together and do regression analysis one of the variables gives a decreasing effect, the opposite effect.

This is the complexity of regression analysis. When we put too many variables, some of the variables may have an opposite effect because of the interaction between the different variable. That you put in the regression analysis so, that is how we need to understand the result of this particular regression equation. So, we will say that, it is not acceptable so, discarded two equations and accepted two other equations. Equation A and C are found to be acceptable, as a transportation planner, which equation to be chosen. Which is to be chosen? Equation C.

You are just blindly looking at, the point of view of statistics of the modal, but as an experience planner, I would look at other aspects related to collection of data, of the involved independent variables. Data related to X 2 and X 3 In the case of modal C and only X 1 in the case of modal A, not only that the accuracy with, which we will be able to predict these variables, values of these independent variables for the Horizon year condition. We are calibrating the modal based on base year data, but finally, when you use your modal to forecast the trip production for the Horizon year you must have the Horizon year values for X 1 and X 2 as well as X 3.

So, look at the possibility of getting accurate prediction of these values for the Horizon year condition and also, look at the advantage relative advantage of different alternatives you have. If you look at these two models, you have a slight advantage in respect of

modal C compared to modal A. R squared values are 0.992 and 0.996, you have a difference of 0.004 in R square. Otherwise on all counts, the modal is reasonably fine and your data collection effort will be much less in the case of modal A compared to modal C. And prediction may be possible, because there will be a record of always total employment opportunities in different departments.

If, you stratify the employment then the accuracy of data may or may not be assured, since under such condition, it may not be incorrect to choose modal A itself for your trip attraction analysis instead of modal C. So, my vote is for modal A. And if you strongly feel that you can collect data of independent variables for modal C will be able to accurately predict for the Horizon condition you can go in for modal C, otherwise modal a is also acceptable. So, this is how you need to take a overview of the whole situation and take the final decision.

You can note one interesting aspect in the development of these four equations, the first two models are very clear. In the first modal we have used only X 1, second modal we have used only X 2, the third modal we have used X 2 and X 3. Why not X 1 and X 3? The X 1 and X 3 could have given a better result, is not it? Why we have not tried X 1 and X 3 directly gone in for X 2 and X 3. Similarly, modal D instead of X 2 you could have tried X 1, X 1 X 3 X 4 is not it. Why was it not done? (( )) How do you say? (( )) correlation table is there inter correlation matrix has to be used for this analysis, but to understand the correlation in different manner.

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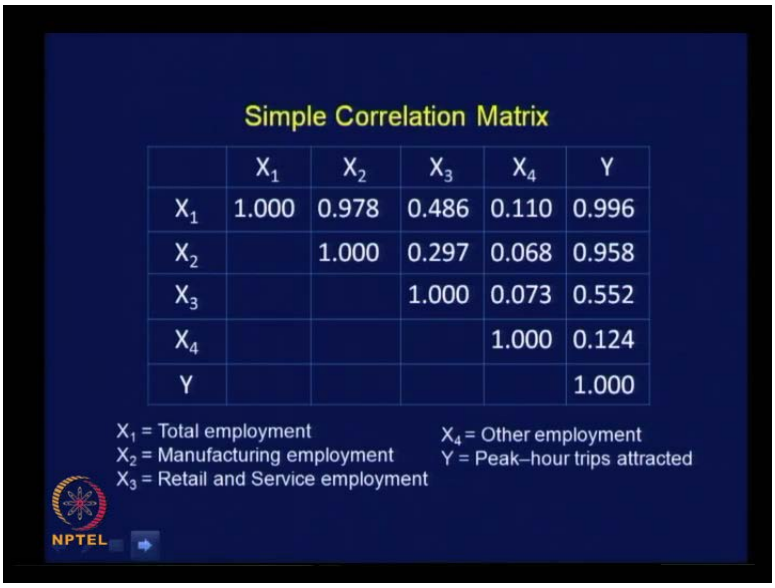

	X_1	X_2	X_3	X_4	Y
X_1	1.000	0.978	0.486	0.110	0.996
X_2		1.000	0.297	0.068	0.958
X_3			1.000	0.073	0.552
X_4				1.000	0.124
Y					1.000

I will show you, the correlation matrix, can you now explain, why we have chosen X 2 to develop equation involving in more independent variables than X 1? Let us look at the correlation of X 1 with other independent variables. X 1 and X 2 highly correlated that is why we did not put them together, X 1 and X 3 0.483, X 1 and X 4 0.110 look at the correlation of X 2 with the other independent variables, X 2 and X 3 0.297, which is less than 0.486 of X 1. Then with X 4 it is 0.068 compared to 0.110 with X 1, we find X 2 is relatively less correlated with X 3 and X 4 compared to X 1.

So, desirably we want to have less correlated independent variables in the regression equation, not highly correlated independent variables. That is, how X 2 has been chosen to develop equations, involving more independent variables compared to X 1? Probably to check this aspect you can develop the equation on your own involving X 1, X 3 and X 4. Try to substitute X 1 instead of X 2 and see what happens so, that is the homework given to, you can check for yourself. Now, with this we are concluding our discussion on trip attraction modal or in general trip generation analysis.

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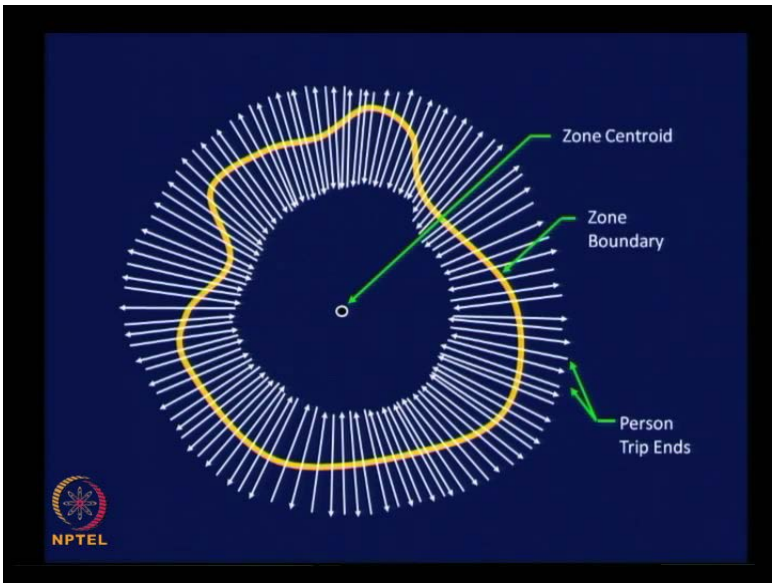

So, at the end of trip generation analysis, what is it available to us? We have traffic zones, number of traffic zones with Centroid (( )) and zone boundaries also will be known. And we would have just estimated what on completion of trip generation analysis? This is what we would have estimated, person trip ends associated with each of the traffic zones, trip ends may be deist into the zone Centroid or eliminating away from the zone Centroid. So, all these trip ends will be designated as trip production or trip n production.

If the zone is the pure residential zone, all these trip ends will be designated as trip end attractions, if the zone is a non residential zone. So, we would have estimated, the total number of trip ends either production or attraction or mix of both, for each of the traffic zones on completion of trip generation analysis is not it. So, this has to be remembered carefully all the trips are person trips not vehicular trips. Person trips are estimated, trip production as well as attraction in the form of person trips.

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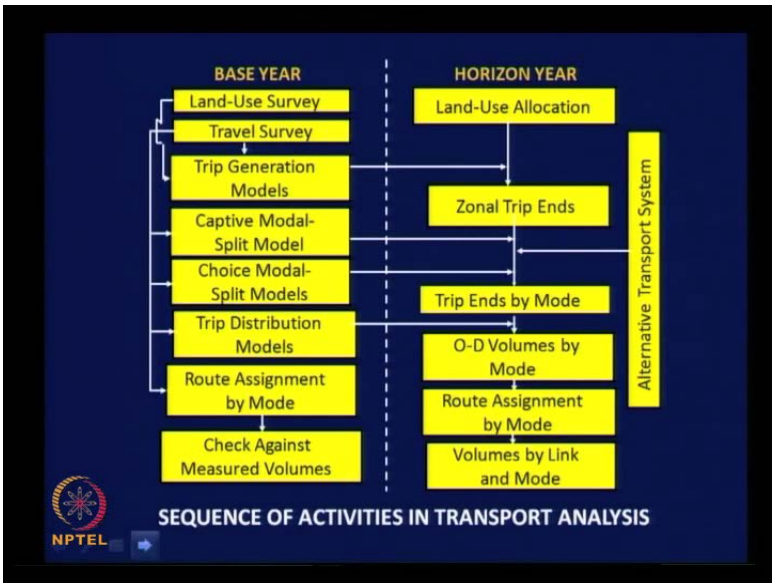

So, with this understanding let us proceed, further to discuss about modal split analysis, this flow chart is familiar to you. And we have completed one box related to trip generation models in this flow chart, next is captive model, split modal and then choice modal, split models. I have briefly told you earlier about captive modal split modeling exercise it is nothing, but segregating captive travelers from choice travelers from the pool of data that you collect with regard to mode choice. Why segregating captive travelers? Because they have captive to a particular mode they have no choice.

So, in mode choice analysis there is no point in including the data pertaining to those who do not have any choice. So, we need to segregate captive riders from choice riders that is simple analytical exercise of segregating captive riders from choice riders is what is indicated here as captive modal split modal. Then we will just discuss in detail, only about mode choice modeling or mode split modal concerned with choice riders those who really have choice of modes.

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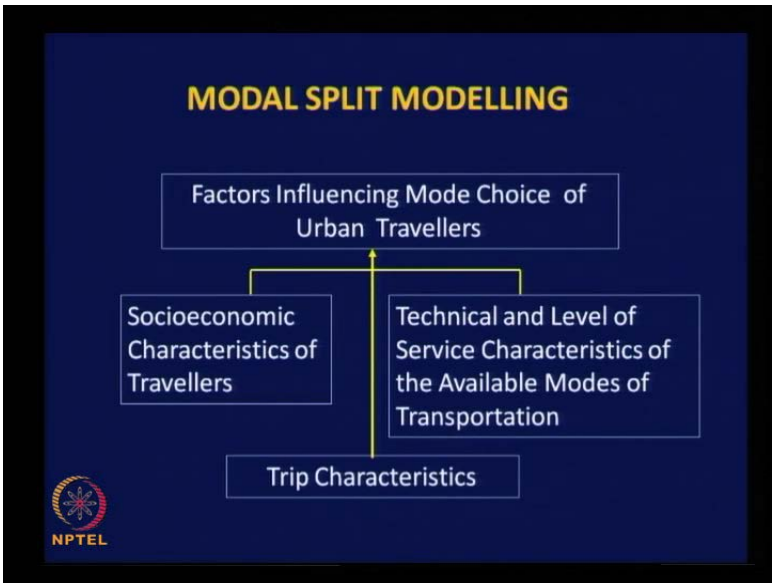

And in modal split modeling, we need to first understand the factors that influence mode choice of urban travelers. What are the factors that influence mode choice of any person? Obviously, the economic status of an individual is a significant factor in influencing the mode choice is not it. Richer a person may be car might be the choice; middle class may be motorized two-wheeler, lower middle class may be public transit bicycle and so on. So, first we can in general say socio economic a characteristic of traveler is influent choice of mode to a very significant extent any other factor that might influence mode choice. (No audio from 31:00 to 31:05)

The characteristics of the available alternative modes is not it, if a particular mode is not suitable for a particular person obviously he or she may not choose that mode. So, the modal characteristics or transport system characteristics influence mode choice at a very significant extent. To be more precise we can say that the technical and level of service of transport system is a major factor influencing mode choice. Technical and level of service characteristics of the available modes of transportation any other factor that might influence mode choice.

How about the characteristics of trips themselves? We make trips for work social recreational. You take the trip made from a household for work and social and recreational purpose, do you think that the mode chosen will be same for both the purposes, slightly to be different trips made for shopping and education modes are likely

to be different. Also, trip length might influence mode choice to a significant extent, let us say the length of travel is 25 kilometers in one case and 5 kilometers in another case and just half a kilometer in third case. The mode choice is going to be highly influenced by the length of the trip two.

So, we can say that apart from these two major factors, trip characteristics also will influence mode choice. So, this is how we need to understand the factors influencing mode choice we have basically, three baskets where from we have to pick variables for mode choice modeling. One related to socio economic characteristics, other related to technical and level of service related characteristics of the available alternative modes and third trip characteristics. First understand the trip characteristics then look at the other major factors related to socio economic characteristics and level of service and technical aspects of the available alternative modes.

Let us see, how mode choice modeling was done to start with earlier mode choice Models? Even though it is history this gives us a very good understanding of the methodology of approach for mode choice modeling. And there are two types of models that were considered at the beginning, the first one is named as trip end type modal split modal, trip end type modal split modal as the name implies, this modal considers zone related characteristics for mode choice modeling. That is why it is named as trip end type mode choice modal.

The socio-economic characteristics of trip makers were defined on zonal basis in this case, in terms of the average number of cars per household in a zone. This was the only factor representing the socio economic characteristics of the travelers, represented as a zonal average only one factor as a representative of the whole of the zone. And then the characteristics of the transport system, related to a given zone, again zone based related to a given zone, were defined by an accessibility index calculated from the following equation. A calculation was done to assess the ease of accessibility of a particular zone taking into account all the available modes for travel.

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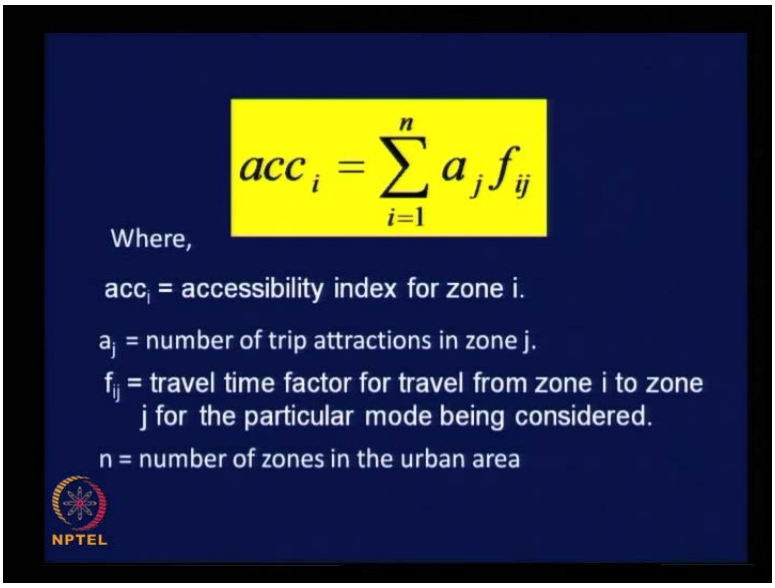

So, this accessibility index was calculated using this equation, acc i accessibility index is sigma, i is equal to 1 to n, a j, f i j were acc i is equal to accessibility index for zone i. For, which we are interested to calculate the index, a j number of trip attractions in zone j, f i j travel time factor for travel from zone i to zone j for the particular mode being considered. This is mode specific factor, we need to calculate f i j for a mode under consideration. N is a number of zones in the urban area. This implies that this accessibility index is calculated for a given zone, considering the trip attraction values of all the other zones in the whole of the urban area.

That means, this index is going to give you some idea about the level of attractiveness or gives with, which you are able to access this zone from all the other zones in the urban area. That is how you need to understand acc i value and this is more specific, you must choose a mode and then calculate acc i to understand this little better. Let us take a simple example, as shown here, let us say the problem is to calculate accessibility index for zone 1. This is an example involved in 6 traffic zones, we are interested to calculate acc 1 accessibility index for zone 1.

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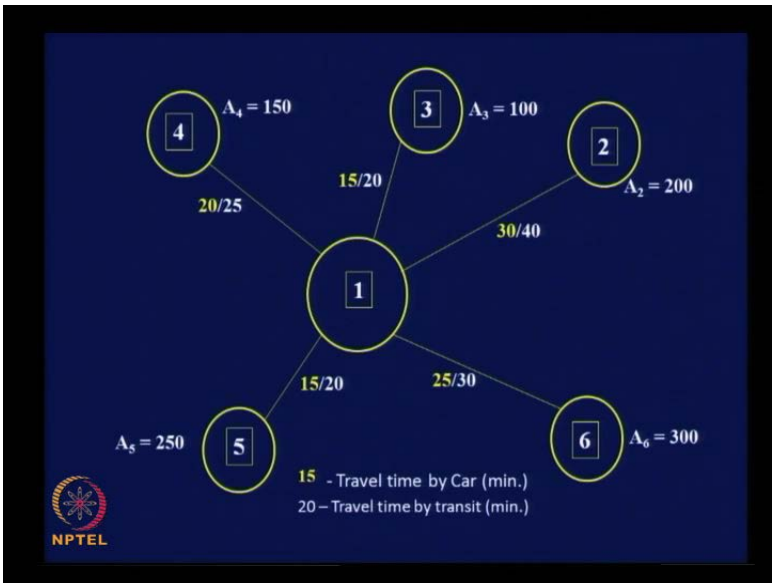

Let us say there are two alternative modes available for travel, car and public transit a broad classification, just for understanding purpose and the trip attraction values for all the 5 zones are given here. I have not given the value for zone1, because any way travel f i j value is going to be 0, because it is intra zonal. So, it is enough if you know the attraction values for the other zones, starting from A 2 200, A 3 100, A 4 150, A 5 250 and A 6 300. So, many trips are attracted by these zones, not only from this zones, it is a total trip attraction, total of the trips attracted by these zones from all the other zones. Even though, I have just given connection to 1 and all the other zones.

It does not mean that, these numbers indicate trips attracted from this zone. These are total trip attractions pertaining to each of the traffic zones. And I have given some numbers along the lines connecting zone one and the other zones in yellow and white color. These are travel times in minute, between zone centroids and yellow colored once or travel time by car in minutes, and white colored numbers indicate travel time by transit in minutes.

Let us see, how to calculate accessibility index for car travel as well as for travel by public transit for this particular case?

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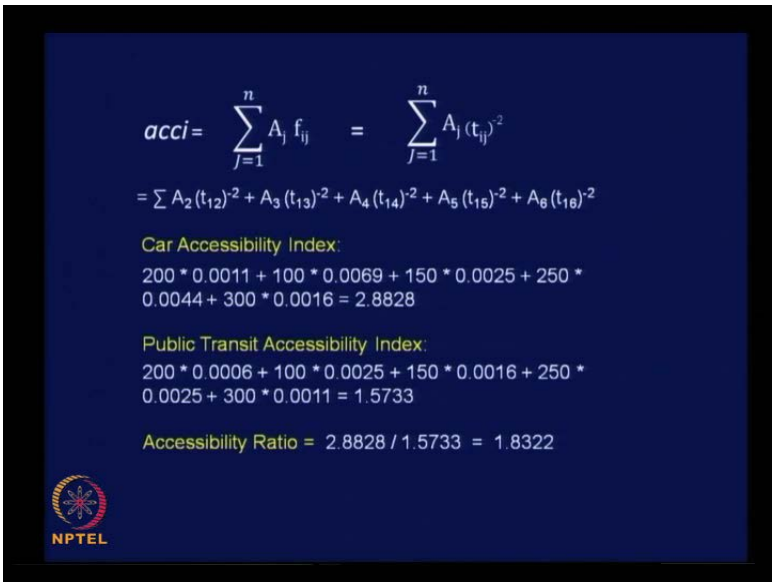

And you know this equation accessibility index is given by sigma, j is equal to 1 to n A j F i j. F i j stands for friction factor, some indicator of travel resistance. It can not be taken as a travel time itself it is normally, a function of travel time. F i j indicates the ease with, which you will be able to reach out to one point to another point, level of friction involved is indicated by F i j. So, you can just write the same equation like this you can write the same equation as sigma A j, t i j raised to power minus 2. That is how F i j is changed into a function of t i j, travel time is known to us that is the information that we normally, collect in the field and express f i j as a function of t i j, the exponent need not necessarily be minus 2, it can be anything depending upon the field condition and using this formulation.

Let us calculate a c c i for car travel and travel by public transit accessibility index, in general can be calculated for this case like this, what we will do is? We will simply add A 2 into t 1 2 raise to power minus 2 plus, A 3 into t 1 3 raise to power minus 2 plus, A 4 into t 1 4 raise to power minus 2 plus, A 5 into t 1 5 raise to power minus 2 plus, A 6 into t 1 6 raise to power minus 2. And if you substitute the values for car accessibility index, you will get a number of 2.8828, that is the value of a c c i for car. I have used t 1 2 1 3 1

4 1 5 1 6 values corresponding to car, the numbers given in yellow color are taken and this inwards of the square value is given directly here.

The result is given, inwards of the square of the travel times are given here, the trip attractions are directly given. So, we get number as 2.8828 and similarly, public transit accessibility index, numbers given in white color in the drawing are considered here and you get a value of 1.5733. (No audio from 43:10 to 43:15) So, this is how we calculate accessibility index for the available modes. This is going to be the basis for choice of mode by travelers; this reflects the ease with, which we will be able to axis different other places in urban area using a particular mode.

That is the idea, and once you get this value you can get an accessibility ratio as car accessibility index or private taxi accessibility index divided by public transit accessibility index, which is equal to 1.8322. This kind of index was calculated, are you clear about this calculation? Just simply, calculating some indicator of accessibility of the different zones from, the particular zone using a particular mode. The transport service provided to a particular zone by private and public transport modes was characterized by the following accessibility ratio, the calculation of, which we have already seen the same formula, I am repenting here.

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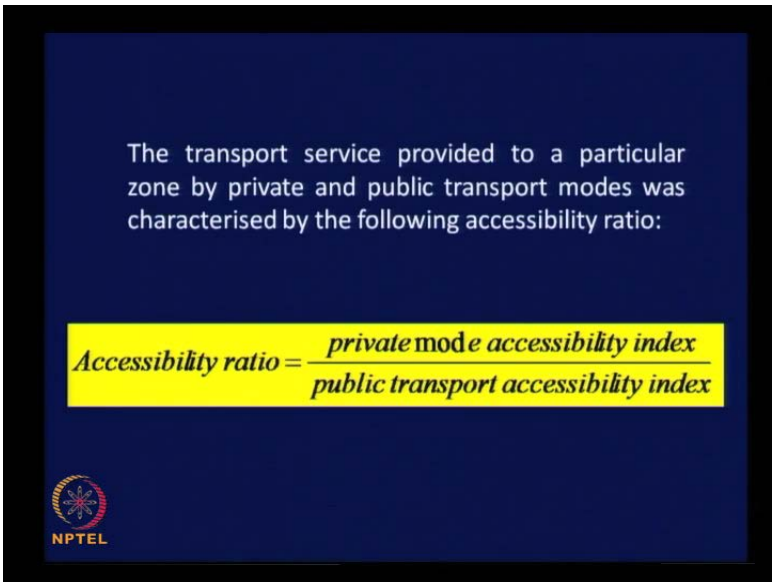

Accessibility ratio is calculated as pervade mode accessibility index in this case, we have taken the private mode of car divided by public transport accessibility index.

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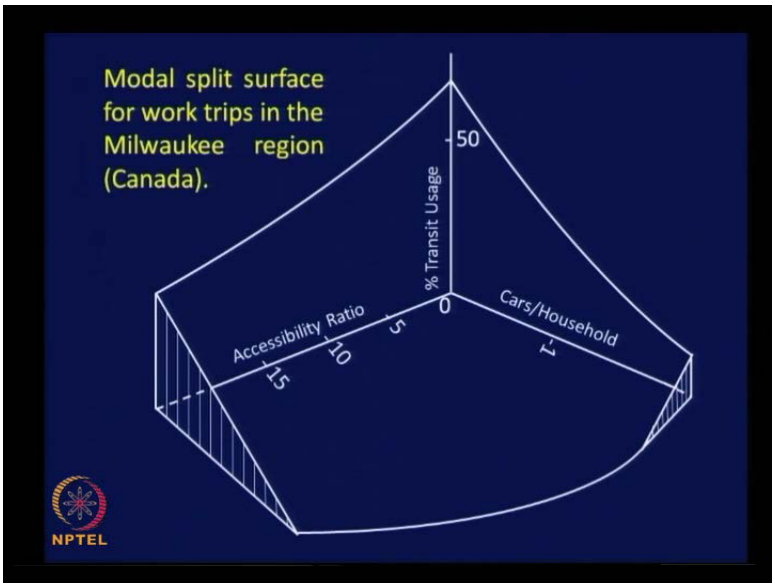

And then a graphical modal was developed, relating the technical level of service of the available alternative modes, that we have put together as accessibility index, is not it? And then accessibility ratio relating both the modes so, we have got one value relating to alternative modes, the factor that reflect socio economic characteristics here, is car ownership, household ownership pertaining to any zone these are zonal values. As I showed you the end of a sketch, we calculate accessibility ratio for a particular zone. Zone one same calculation should be done for all the other zones each zone should have this value accessibility ratio and car ownership, household car ownership.

So, we have taken two variables from the major factors, that influence mode choice namely socio economic characteristics of travelers. And then technical and level of service characteristics of transportation system, considered as simply, accessibility ratio and car ownership. And off course the trip characteristics were not considered at this stage, here it was not considered and one other factor related here is percentage transit usage, percentage of trips that are likely to be made by public transit is related. So, it is a three dimensional plot three access are involved and the plot was made to get the value of transit usage for any combination of socio economic characteristics.

And transport system characteristics, to understand this plot you need to imagine the kind of surface, curved surface connected by these lines this is the edge of the surface this line. Then this line and then this sloping straight line and the whole of the curve here

and then the sloping straight line, imagine this as the edge of a three dimensional surface. Imagine a surface connecting these lines as treating them as edge of the surface; you will have a kind of complex curved surface. Let us say, you are interested or in a particular zone you calculate the accessibility ratio, it works out to be 5.

And the average car ownership is 1 in that zone. And we need to know what percentage of travelers will be using transit, we have two alternative modes we would like to know what percentage you will use transit and what percentage you will use car in this particular case. What you should do is? You just project these two known values for that particular zone 5 projected draw a perpendicular to this axis from 5 and then make a perpendicular from the value of car ownership from this axis and the both the perpendicular lines will meet on the horizontal plane at a particular point on the horizontal plane, X and Y axis on the horizontal plane.

So, from the point of intersection of these two perpendiculars, it just goes up words to touch the imaginary curved surface. It will be touching somewhere, in the space and then from that point of touching you just drop a perpendicular to the vertical axis and if you drop a perpendicular. You may cut the vertical axis somewhere here; this implies the transit usage for this condition may be around 20 percent, clear so, that is how we need to understand and what is the condition at, which transit usage will be nil 0. A very high value of accessibility ratio let us say somewhere here, more than 15 and very high car ownership.

If we draw perpendiculars we will find that, it is meeting somewhere here right and the height of your surface is almost 0. It is touching the horizontal plane and if you drop your perpendicular to your vertical axis, you are going to touch the origin here. There is no transit usage everybody will be using only car is not it. So, that is how you need to appreciate the usefulness of the graphical mode even though this graph, it was very useful at that point of time. This was a modal split surface for work trips in the Milwaukee region Canada and they developed it and used it very effectively similarly, if you look at the very low value of accessibility ratio close to 0.

And very less car ownership, then you may get point of intersect somewhere here. And if, we go up you will be going up and up to touch the inclined curved surface and the corresponding transit usage percentage will be very high. This is how at the early stages

the mode choice process was analyzed and to summarize what we discussed in this class. First we recapitulated important aspect of the previous lecture with reference to a regression modeling exercise involving four different models. Now, we are very clear as to how to choose an appropriate regression equation, for trip generation analysis whether it is trip production or trip attraction based on logical as well as statistical aspects.

Then we discussed about mode choice analysis we know now, there are three baskets available to us, to pick appropriate factors that will influence mode choice of any traveler. One basket related to socio economic characteristics of the travelers, other basket related to the technical and level of service characteristics of the available alternative modes. Third one related to trip characteristics, then we discussed about the earlier attempts made for mode choice analysis. And we have seen that one graphical modal developed for millwork region in Canada, using three or basically, two factors involving accessibility ratio and car ownership also provides reasonably good information about mode choice process. With this we will complete our discussion for today, we will continue our discussion in the next class.