Urban Transportation Planning
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Lecture No. # 14
Modal Split Analysis Contd.

This is lecture 14 on urban transportation planning. We will continue with your discussion on modal split analysis in this lecture 2. Before we proceed further, let us try to recollect what we did in the previous class. You may recall, we first completed our discussion on trip generation analysis in the previous class, then on completion of discussion on both trip production as well as trip attraction analysis. We started our discussion on modal split modeling.

First, we identified the factors that might influence mode choice of travellers. Then we discussed about earlier mode choice models, starting from trip end type mode choice model, and discussed about usefulness of the graphical model that was developed taking Milwaukee region in Canada as the case for the study.

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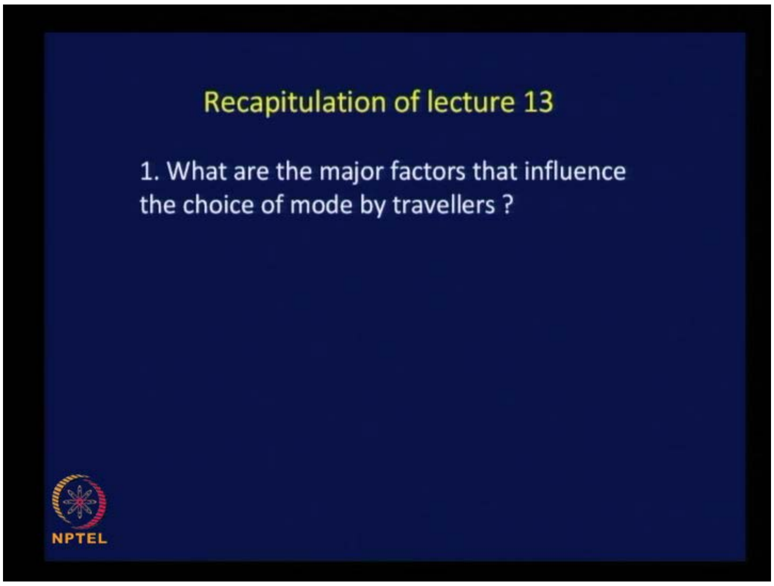

To check, whether we have really captured the important points of the previous lecture, let us try to answer the following questions. The first question is this, what are the main factors that influence the choice of mode by travellers? Anybody? Major factors that might influence mode choice of travelers, I will give a clue, we have identified three major factors, what are they?

(( ))

Yes

(( )) technical characteristics of the particular mode, and the trip characteristics etcetera.

Very good. These are the three major factors that influenced choice of mode by travellers. Social economic characteristics of the travelers, technical and level of service characteristics of the alternative modes available in the system and then the characteristics of the trip such as trip purpose, trip length and so on.

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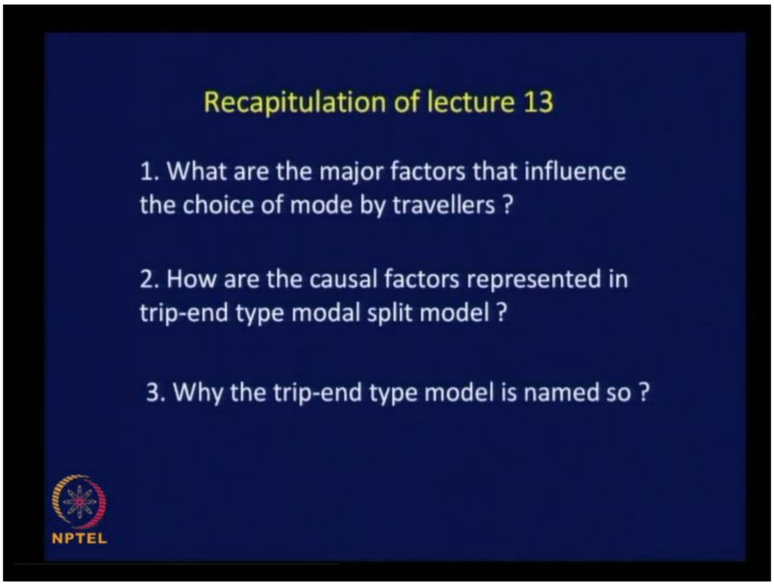

The next question is this, how are the causal factors represented in trip-end type modal split model, representation of causal factors in trip end type modal split model. As we discussed, we have to represent the socio economic characteristics and transport system characteristics in some form, how do we represent these characteristics in this particular type of model, anyone? Fine. Let me answer this question, we represent transport system characteristics in the form of accessibility ratio, we just calculate accessibility indices for public transport and private transport mode and then at the ratio represent system characteristics and social economic characteristics is represented the form of car ownership per house hold and of course, trip characteristics were not really represented in this model, is not it.

The next question is this, why the trip-end type model is named so? Why should it be named as trip-end type model? (no audio from 04:09 to 04:13) any response? Trips are ending where, ending at traffic zones, trips are starting starting at traffic zones, is not it. So, trip ends are associated with traffic zones right and we consider the characteristics related to transport system as well as social economic characteristics on zonal basis for this particular model, that is why, this model is termed as trip-end type of mode choice model.

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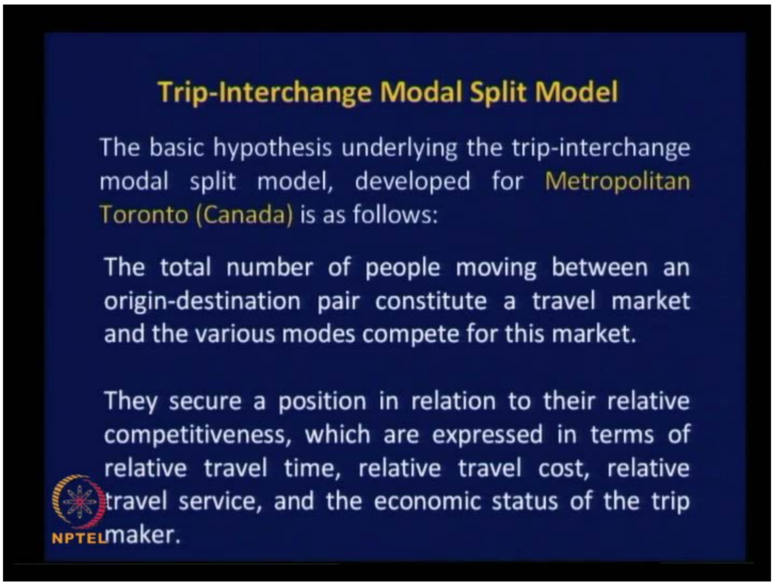

So, with this understanding, let us proceed further and see one more type of model which was initially developed named, trip- interchange modal split model. The basic hypothesis underlying the trip- interchange modal split model, developed for Toronto metropolitan area in Canada is as follows, there are certain assumptions or hypothesis based on which this trip- interchange modal split model was developed. The assumption is this, the total number of people moving between an origin- destination pair constitute a travel market and the various modes complete for this market, the this is the important hypothesis.

They consider the demand for travel between origin- destination pairs as travel market and available modes are competing for this market and reach a certain level depending upon their relative competitiveness right. And they, the modes secure a position in relation to their relative competiveness, which are expressed in terms of relative travel time, relative travel cost, relative travel service and the economic status of the trip maker. These are the factors based on which the different modes capture, a position in the travel market or the position of a particular modes depends upon these factors namely travel cost, travel time, travel service, of course, the economic status of the traveler, who considers these various alternative modes for travel, clear. And let us see, how these factors were really taken into account in the modeling process.

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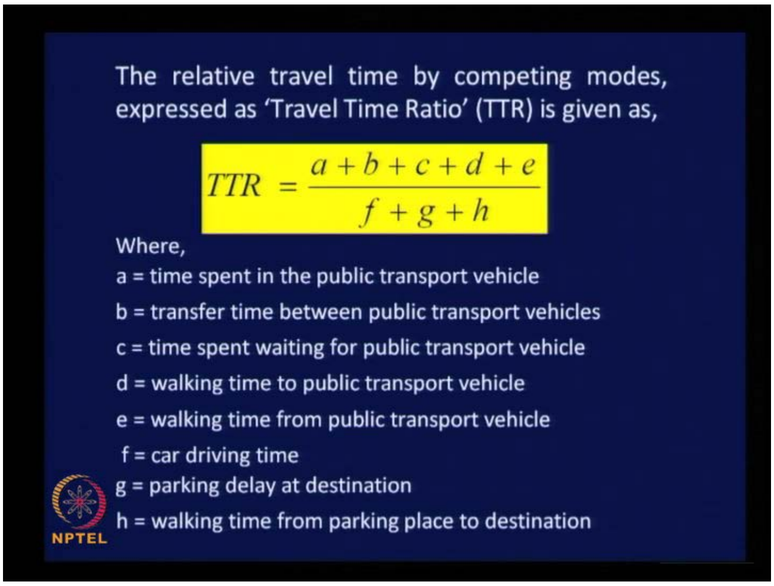

The relative travel time by competing modes, expressed as Travel Time Ratio is given by this equation. By looking at the equation, you can understand that, there are only two alternative modes being compared here. It travel time related to one mode is given the numerator and the travel time pertaining to another mode is given as the denominator for the equation. And modes considered are, as you have seen in the previous case, public transport mode and personal car.

These were the two alternatives considered in this particular study also. If you think of the travel time in case of public transport, you should think of door to door travel time, from the exact point of origin to the exact point of destination. Based on this assumption, can we split the travel time components or the total travel time into different components, how do we spend time while travelling by public transport. First, yes please

(( ))

Home to public transit station, we spend some time.

(( )) many stations not directly

Do you get a transit vehicle immediately on reaching the station, you wait for some time. So, there is another component namely, waiting time then you take transit vehicle and spend some time inside the vehicle, you can call it as, in vehicle time and then get out of the transit vehicle, if necessary, you transfer to another transit vehicle and this process may involve one more aspect of waiting time, you may have to wait for another transit vehicle. Take second transit vehicle, if required and go closer to your destination point then you walk from transit station to your exact destination point.

There are so many components in the travel time by public transport. On the same lines, if you think of travel time components, while you make use of car, you have one component only or more than one component, you think of all possible situations of course, car is available at home there is no problem. So, there is no waiting time for car or access time for car, you just get out of your main door and get into the car. There is no access time or waiting time involved in your car travel then it is only in vehicle time.

And if you are reaching your destination directly by car and touching a building in which your destination is located then there is no delay with regard to walking from parking area to a destination point. If there is a common parking lot, you take your car to that parking area, if the parking area is crowded; you wait in a queue to park your car then park your vehicle and then walk from the parking lot to your exact destination.

So, there are several time components involved in making use of the car also, that is what has been listed in this particular equation, let us see, what is indicated here with the symbols a b c d e and so on. A is the time spent in the public transport vehicle, in vehicle travel time; b, transfer time between public transport vehicles, if any; c, time spent waiting for public transport vehicle, waiting time; d, walking time to public transport vehicle; e, obviously, walking time from public transport vehicle to exact point of destination right and f, car driving time, in vehicle time for car travel; g, parking delay at destination, if any and h, walking time from parking place to the exact destination point.

So, this is how the travel time ratio was calculated, to compare the relative merits of the two alternative modes available. The essence of the whole thing is that, travellers think of door to door travel time implication, in respect of different alternative modes and that is the guiding factor to decide about the choice of the particular mode, it is not just in vehicle travel time alone; it is door to door travel time, clear. So, this is how, travel time was put into the modeling process then we had mentioned other factors like travel cost, is not it, also travel service. Travel cost was taken into account in the modeling process as follows.

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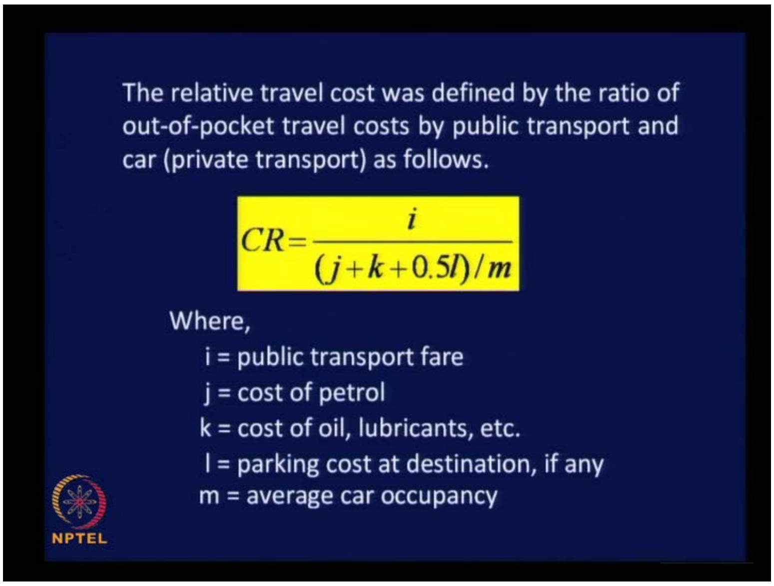

The relative travel cost was defined by the ratio of out- of- pocket travel costs by public transport and car as follows. What do you understand by out-of- pocket travel cost? You always take out money out-of-pocket and spend. Why not simply mention it as travel cost, why out-of-pocket travel cost to emphasize a point that, the travellers normally perceive the expenditure incurred during a trip, there will be consequent expenditure, related a trip, which is not normally preserved or taken into account in mode choice right.

In the case of public transport, the out-of-pocket expenditure is just the par fare you pay during your trip right, probably you may not take into account, the fact that, you are taking a cycle rickshaw to reach the bus station, if a person is an elderly person right. Normally, people think of the fare paid, instantaneously during a trip and similarly in the case of private transport vehicles, we frequently pay for fuel at fuel filling stations, while taking travel decisions that alone is in our mind, we forget that once in six months.

We spent lot of money in servicing the vehicle that is not taken into account while you compare the money involved in trip making. How many kilometers per liter I make, what is the cost of fuel per liter then what is the per kilometer cost, let me compare that with transit fare, it appears to be fine, let me use my car. So, that is the comparison people normally a make that is why here, it is very specifically indicated as out-of-pocket expenditure. So, this is the equation given to calculate cost ratio C R as i divided by (j plus k plus 0.5 l) whole divided by m and numerator correspond to public transport, it is very straight forward and simple, just the fare paid for travel.

In the denominator, we have two, three terms pertaining to car, j stands for cost of petrol or in American terms gasoline; k cost of oil, lubricants, etcetera because this is a consumable spent depending upon the number of kilometer age made by a vehicle right. So, that is how, this is also going into the calculation and and l, parking cost at destination, if any right and m average car occupancy, number of persons traveling in the car and the average. My question here is, why we take only 0.5 l, where l is the parking cost at destination, why not simply l, you pay parking cost; you can directly take parking cost.

Sir, basically we have two trips involved, one is the trip to the destination and second strip will start from the destination.

Excellent, for two trips, there is only one parking activity involved and only one cost component is there. Since our interest is to calculate the cost per trip, we divide the parking cost or we take parking cost as half of the actual expenditure per trip right and why dividing the whole thing by m because we are interested in cost implication per head per person because the fare i stands for, the fare paid by one individual then only we will be able to get the correct value of C R cost ratio, cost implication per person. This is how, C R value was calculated.

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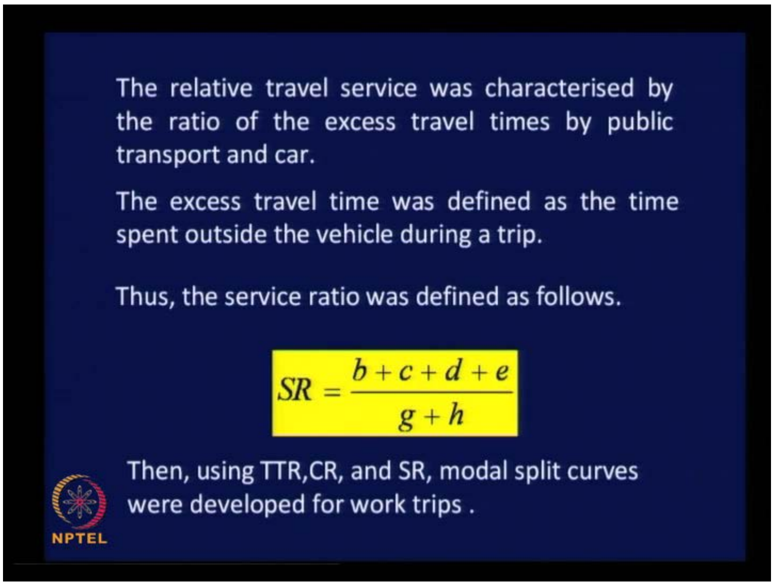

And then service ratio was calculated by considering the excess travel time implications relative to the alternative modes. What do you understand by excess travel time? We normally spend travel time required travel time. In this particular case, excess travel time was defined as all components of travel time except in vehicle travel time. The time spent in actual movement was not considered right, all other time outside the vehicle were taken into account and that ratio was taken as service ratio.

It is reasonably logical because when you think of a transit vehicle, if your waiting time is less, you will perceive that public transport services good, if your access time is less than your transit service is preserved by you to be very good, is not it. So, it is logical to consider all the time components involved, when you spend your time outside the vehicle related to the service provided by a particular mode of transport. So, that is how, the service ratio was calculated. The excess travel time was defined as the time spent outside the vehicle during a trip.

Thus, the service ratio was defined as follows, S R to be b plus c plus d plus e divided by g plus h, all these components are already defined. Then using T T R travel time ratio, C R cost ratio and S R service ratio, modal split curves were developed for work trips first because work trips constitute a major junk of the total trips made and in this example, we are going to consider only work trips, on the same lines they developed models for other trip purposes.

You may wonder, how to consider or develop mode choice curve without consideration to social economic characteristics. All these three ratios pertained to transport system characteristics, travel time ratio, travel cost ratio and service ratio. They considered the factors related to social economic characteristics by dividing a group of travellers into three basic groups, low income, middle income and high income groups and developed mode choice curves for these three groups independently.

That takes care of the social influence of social economic characters on mode choice. Once you have a data set pertaining to a particular income group then your data set is homogenous, there is no need to differentiate between individuals within a homogenous income group. Then you can consider only these characteristics pertaining to transport system as factors influencing mode choice.

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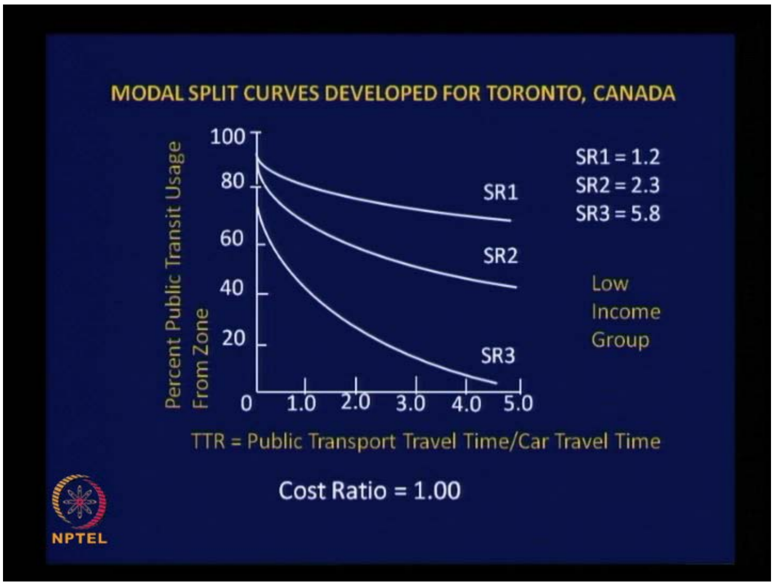

So, that is what they did and this is how the curve was developed, taking T T R along x axis and percentage transit usage along y axis of course, they considered three service ratios. Service ratio was considered as not a continuous variable, they just found that they can group S R into three categories with values 1.2, 2.3 and 5.8 based on field conditions. So, they developed three curves for each group of travelers; that means, we now consider the actual mode choice, travel time ratio and some factor representing social economic characteristics.

And they developed this curve for one particular cost ratio with value one, similar curves were developed for different cost ratios. The income group considered was low income group and this was the shape for these curves. I hope, you will be able to appreciate the shape of these curves. There are three lines pertaining to S R 1, S R 2 and S R 3, service ratio 1, service ratio 2, and service ratio 3. S R 1 curve is on top, is it logical to have the curve on top. The curve, S R 1 curve will result in the higher usage of transit service, is not it for a given value of travel time ratio.

Let us say, we are interested it to know, what will be the use time of transit by this particular low income group, when the travel time ratio is two, if it is S R 1, you can say about eight percent of the travelers will be using public transport and if it is a S R 2, it is going to be just 60 percent only will use public transit and 40 percent will make use of their own car and if it is S R 3, it is going to be thirty percent thirty percent will use public transit, rest will make use of their own car.

This is because of the influence of service ratio; please, recollect how we calculated service ratio, sum of all the time components spent outside the vehicle in the case of public transport, divided by all the time components spent outside the vehicle in case of car. So, when the ratio is very high, implies what, you spend more time outside public transport vehicle that is why, it is high In such a case, public transport may not be attractive to you and only less and less number of people will make use of public transit.

So, that is what is indicated here, clearly, S R 3 is 5.8 very high, compared to just 1.2 in the case of S R 1, time implication is almost same like car, just twenty percent more, isn’t it 1.2. So, that is how for a chosen travel time ratio, we find that quiet a significant proportion of travelers make use of transit vehicles. Even though these these are simple graphs, they are very sensitive and significant in nature, you can find out the mode choice for any complex situation because we have put in so many factors into it, travel time ratio, service ratio, cost ratio as well as something to represent, the social economic characteristics of travelers.

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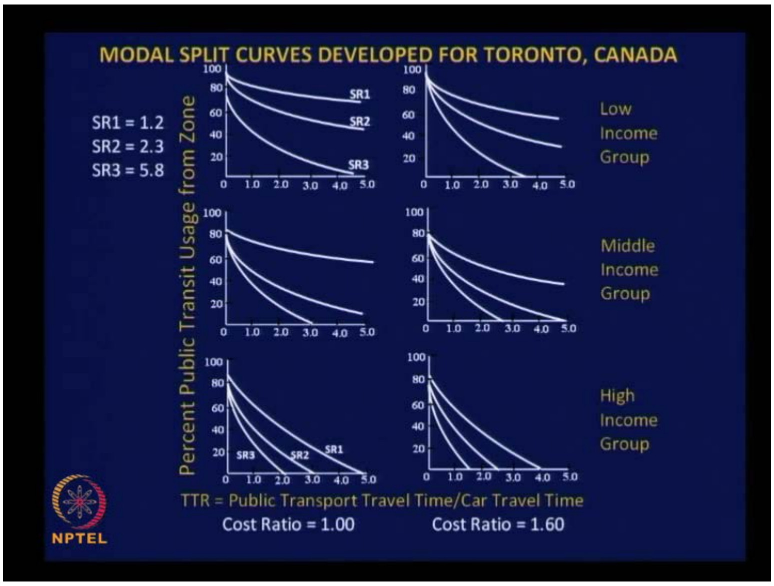

And let us see, how they did, the same exercise for other social economic group of travelers, on other words, we will take an over view of all the groups together and see how the mode choice model look like. Same variables were taken along x and y axis, travel time ratio along x axis and percentage transit usage along y axis and two cost ratios were considered, based on the actual field observed data, there were two distinct cost ratios, 1 and 1.6 had there been more, they would have considered more also, may be 2.2 or 2.7and so on.

In this particular case, it was sufficient to consider only two cost ratios and service ratio as was done earlier, three values for service ratio and three income groups, low income group, middle income group and high income group and for low income group, this is how the cost looked. Why these two curves are different or what is the factors which is differentiating these two curves, cost ratio is differentiating these two curves, how the curve, set of curves on the right hand side is different from the set of curves on the left hand side.

You can see the right side curves are little steeper in respect of their slope, compared to left hand side curves right. For example, if you take the curve corresponding to S R 3, it is tending to touch the x axis at around travel time ratio of 55.0, whereas here, the same S R 3 line is touching the x axis at around 3.5, so; obviously, this is steeper than the other set of curves right. What is the implication, what does it mean, yes please

Public transport slope is higher. So, the people who tend to use the transport (( )). So, it can drop down immediately after before it can even (( ))

That is the point that is the point. So, when the cost ratio is more, this implies that public transport fare is, how would we calculate cost ratio.

(( ))

Obviously, so, when the cost ratio is more, public transport cost is more right, so; obviously, less and less people might be using public transit. You take for example, travel time ratio of two, travel time ratio two and take the case of S R 3, when the cost ratio is one, what percentage of travellers will use public transit, 30 percent 30 percent and for the same travel time ratio, but for the cost ratio of 1.6, you can see only 20 percent will make use of transit. So, these curves represent the actual observed data.

So, you can treat these curves as a very valid and significant mode choice model, this is for low income group. And for middle income group, similar set of curves, the right side set of curves, little steeper than the left hand side set of curves as you could see, reflecting the same variation as you have seen in the case of low income group and then for high income group of travellers ,you can see a similar variation. So, we are able to compare now, the curves along the row horizontally, let us have a vertical comparison now.

You case, you take the case of cost ratio 1 and same travel time ratio of two, in the case of high income group, what percentage of travellers will use public transit, when travel time ratio is two negligible, nearly 0, whereas in the case of middle income, group of travellers, you can see about twenty percent will be making use of transit. In the case of low income as we have see nearly thirty percent will make use of transit service right.

So, when the cost ratio is same, when the travel time ratio is same for a given service ratio, when we try to hold all other given factors constant, we find that, there is a significant difference in mode choice process, which is mainly influenced by the socio economic characteristics of the travellers, that is, what we need to understand by this particular model, even though their graph, they are really very interesting and important mode choice models and when the cost ratio is 1.6 and when travel time ratio is two, in case of high income group, it is interesting to know that, no one will use public transport, if the service ratio is 5.8 S R 3 right and similarly, in the case of low income group, if the travel time ratio is 4 for a cost ratio of 1.6, what will happen. Nobody will make use of the category of vehicles with S R 3 here also, they will choose only service with S R 2 or S R 1, there are extreme cases.

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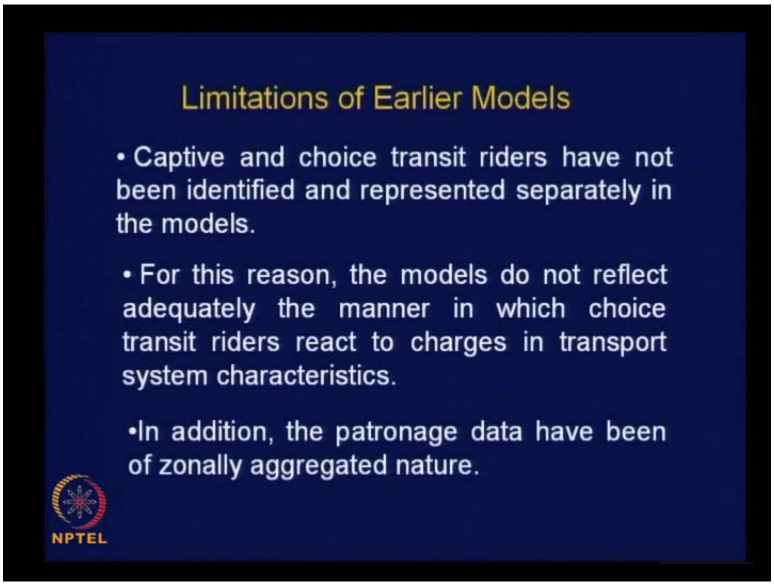

So, that is also reflecting the reality right, even though these models are good, there were some limitations of these models. One important limitation was found to be this particular aspect. Captive and choice transit riders have not been identified and represented separately in the models. It is a very important aspect unfortunately, this was not done. It may not be a major mistake in the context about which we are discussing.

We are discussing about the choice mode modeling for Toronto Milwaukee region etcetera in Canada, where the car ownership house hold car ownership is very high, meaning that most of the travelers will have a choice of either making use of car or transit. The percentage of captive riders might be very small, but still the point made here is even, if the percentage is small you have to segregate captive riders. So, that you deal with dataset pertaining to those, who have a real choice. Then your model will be hundred percent representing the choice process of those, who have a choice of modes of travel, clear.

And for this reason, the models do not reflect adequately the manner in which choice transit riders react to changes or charges in transport system characteristics, react to changes is the right terminology, changes in transport system characteristics. In addition, the patronage data have been of zonally aggregated nature. What is wrong with zonal aggregation of patronage data, patronage data is nothing, but data related to the travel time, travel cost and travel service of the available alternative modes and we are zonally aggregating this patronage data, this implies that, we assume that every individual or every household in a traffic zone will have the same preference, same choice for a given situation in a particular traffic zone.

It need not necessarily be hundred percent correct there will be variation even for a same cost ratio for example. Let us take the previous example, as I said earlier for a travel time ratio of two, cost ratio of 1.6, as per this model, nobody from high income group will choose public transit, if S R 3 is the level of service available in public transit is not it, but it need not necessarily be hundred percent correct, in practice still, there could be a handful of people in higher groups using public transit for their own reason.

Similarly, on the same lines, we found here, when the cost ratio is 1.6 for a travel time ratio of four, we consider people belonging to low income groups, they may not choose the system, if the service ratio is S R 3, but it need not be true hundred percent, there might be a small proportion of travelers belonging to this group choosing the transit, but that does not been considered here, it has been based on zonal average. This variation, if possible should be taken into account to accurately represent the reality. Later, we will see, how these variations can also be taken into account in our mode choice model.

And now, the moral of the story is that, we cannot assume every individual to be same as far as mode choice modeling is concerned. Each and every individual is different from one another; they have their own perception of things and choose the mode of travelled. So, it is not right to work on aggregate data for mode choice modeling. We must go in for disaggregate database for mode choice modeling, how to disaggregate data, what basis, if we agree that each and every individual is different from one another even within a household then we must consider every individual as independent entity, as far as mode choice analysis concerned. You treat every individual traveller as an independent entity and then take their characteristics into account in your mode choice modeling process, that is, what is implied by this particular point.

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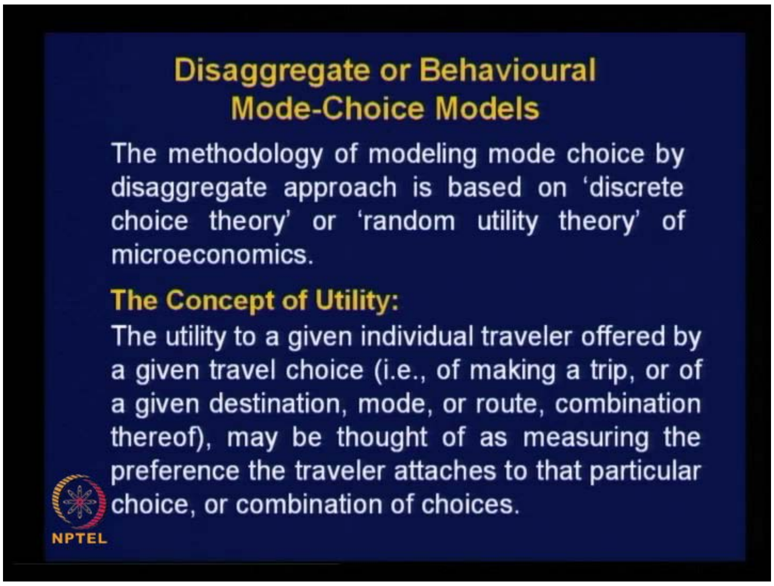

So, with this understanding, let us look into some basic aspects related to Disaggregate or Behavioral Mode-Choice Models. The methodology of modeling mode choice by disaggregate approach is based on 'discrete choice theory' or 'random utility theory' of microeconomics. This is the basis, discrete choice theory comes into the picture here because we treat each individual as discrete entity, that is how, this theory is found to be applicable for this particular context. Then the context of utility has to be understood clearly because the related information about this theory is random utility theory is the input, that will be given to this modeling process.

So, we need to understand the concept related to random utility theory. This is the concept, the utility to a given individual traveler, utility or usefulness to a given individual traveler offered by a given travel choice offered by a given travel choice choice could be with regard to decision with regard to making a trip or not or choosing a route or choosing a mode or choice a destination could be related to anything right in general, may be thought of as measuring the preference, the traveler attaches to that particular choice or combination of choices. As indicated here, one may simultaneously decide about trip making destination choice, route choice as well as mode choice right. So, combination of all together may be a factor to be considered in mode choice analysis depends upon the way you analyze the choice process.

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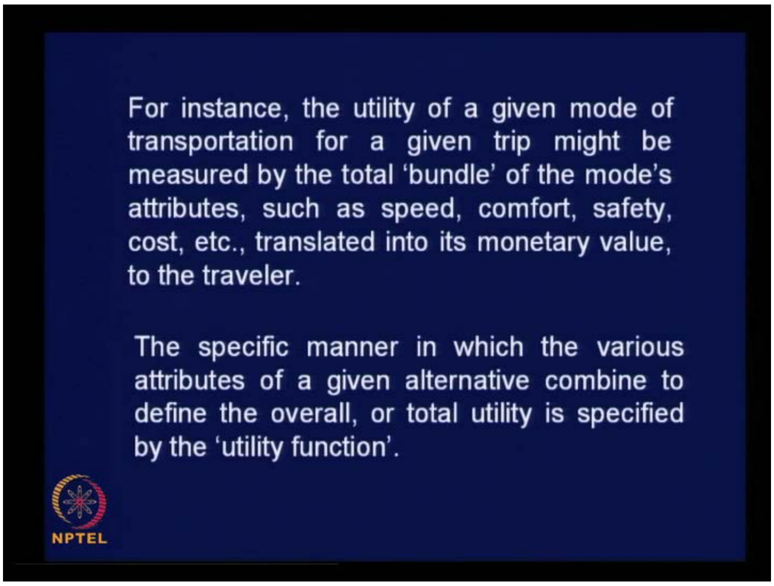

For instance, utility of a given mode of transportation for a given trip might be measured by the total bundle of the modes attributes attributes of modes, all of us are very clear, such as speed, comfort, safety, cost, etcetera translated into it is monitory value to the traveler, that is, how we understand utility, utility is sum of a set factors and you must transfer all these factors into a common measurable unit and then quantify the whole thing and do this for various alternatives and then compare or it is assumed, that is how the comparison process is done or perceived by the travelers right.

It is a total bundle of modes attributes, it depends on how you consider the modes attributes as factors influencing your trip choice or mode choice, you may consider only travel time and travel cost or sometimes only travel time and so on. The specific manner in which the various attributes of a given alternative combine to define the overall or total utilities specified by the utility function. As I said, we must combine these factors to assign some value and then add them together. So, some factors are to be assigned to each of these attributes of modes and this process is called utility function formulation, formulation of utility function. Let us take a very simple example and try to understand the concept of utility function for transportation modes.

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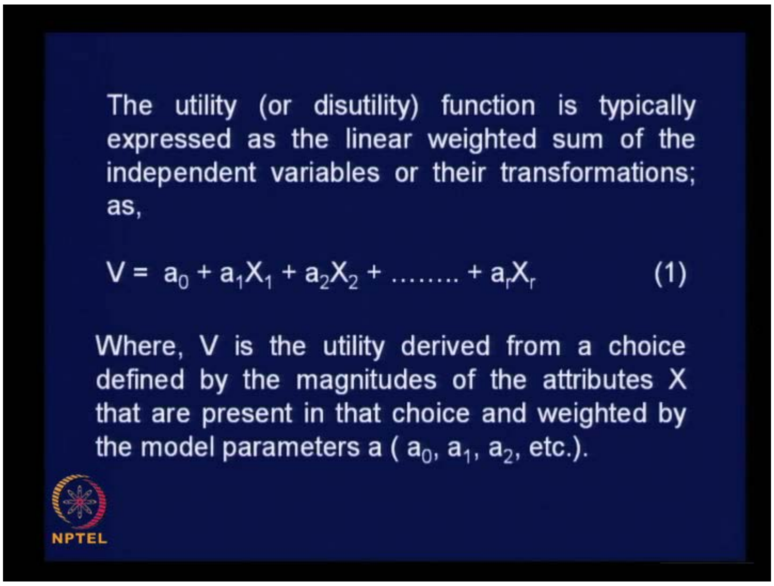

The utility or disutility, why disutility suddenly, some others instead of utility, name the same bundle as disutility, mainly because what do we do in trip making, we spend our time, we spend our money isn't it. So, it is expenditure. So, instead of utility it may be right to call it as disutility. So, both are giving the same meaning as per as this particular context is concerned. Function is typically expressed as linear weighted sum of the independent variables or their transformations or representing various modal attributes.

In general, you can write the utility function V to be equal to a 0 plus a 1 X 1 plus a 2 X 2 plus and so on a r X r, where, V is the utility derived from a choice defined by the magnitudes of the attributes X, that are present in that choice and weighted by modal parameters a, implying a 0, a 1, a 2 and so on. It is a very simple linear equation representing various modal attributes considered to calculate some utility value for a particular mode.

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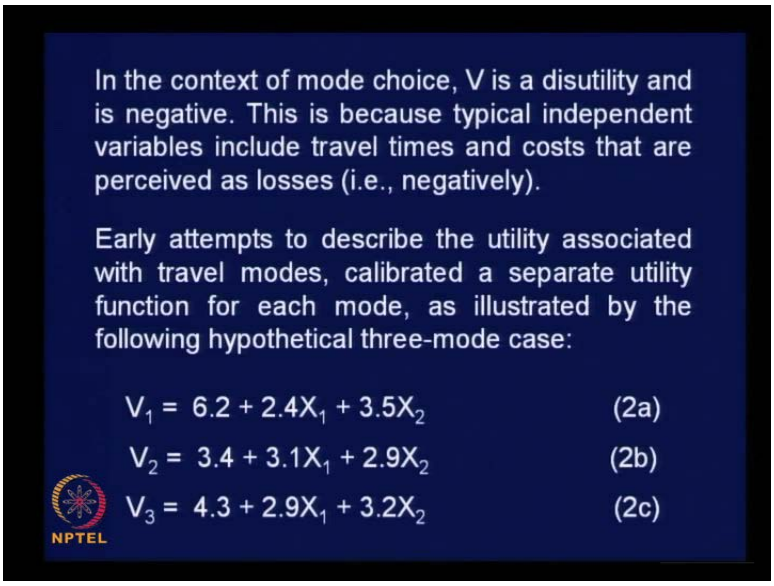

In the context of mode choice, V is a disutility and is negative as I said. This is because typical independent variables include travel times and costs that are perceived as loses by travelers. Early attempts to describe the utility associated with travel modes calibrated a separate utility function for each mode, as illustrated by the following hypothetical three-mode case. We just saw one equation representing utility of travel modes, but in the beginning, they developed separate utility functions for each of the alternative modes available.

Let us say, there are three alternative modes available in a particular situation. This is how the utility functions were developed. This is a calibrated utility function, why do you say that, it is a calibrated utility function because values of the parameters are given here, values of a 0, a 1, a 2, etcetera are known. So, that we get only through calibration, that is have, we can understand these equations as calibrated utility functions right.

And you can see the coefficients for the same factor or attribute of a mode X 1 could be a particular attribute may be travel time, but the coefficient are different for different modes, travel time has got a weight age of 2.4 in the first case, 3.1 and then 2.9. Let us say this second X 2 is travel cost, for example then the coefficients are varying 3.5, 2.9 and 3.2 because these functions are developed independent of the alternative modes competing for one another for the travel market and this is how initially, utility functions were developed

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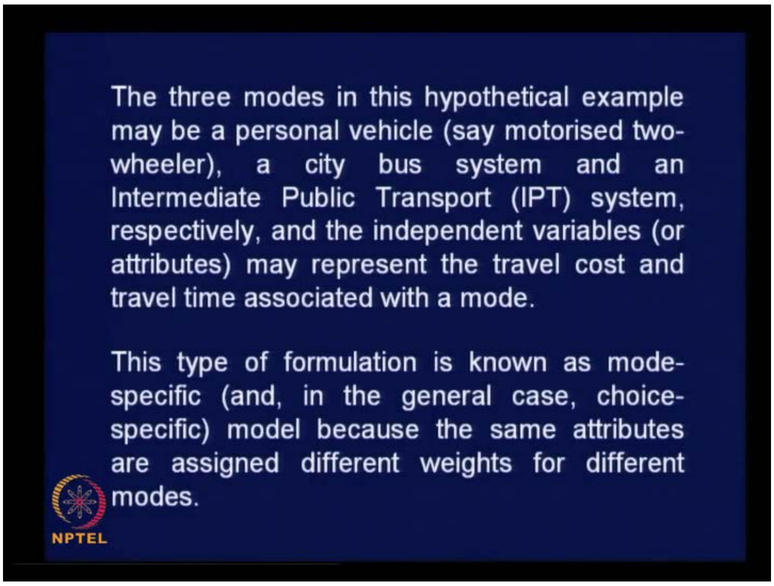

The three modes in this hypothetical example, let us say, may be personal vehicle, say motorized two wheeler pertaining to our condition, a city bus system and intermediate public transport system, taxi, auto rickshaw and so on respectively and the independent variables or attributes may represent travel cost and travel time for example, X 1 and X 2 associated with each of these three modes. This type of formulation is known as mode specific, I repeat mode specific model because the same attributes are assigned different weights for different modes, as I indicated to you right, same attributes X 1 has got different weights for different modes. That is why, this formulation is known as mode specific formulation, utility functions are specific to a particular mode.

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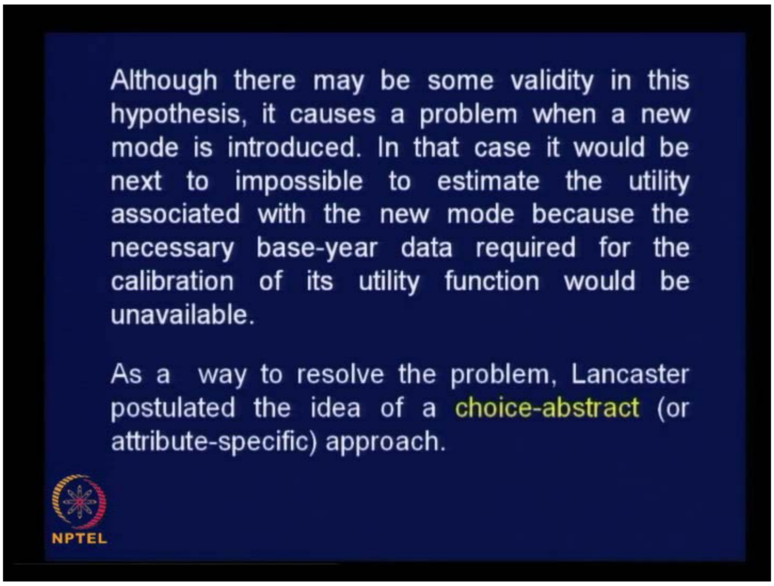

Although, there may be some validity in this hypothesis, it causes a problem when a new mode is introduced because as (( )) as, we will be working for a mode choice scenario in the horizon year. At that point of time, it may be likely that we propose a new system itself, a medium size city where in the base-year condition, we have only bus service I P T service and personal vehicles and the city might grow to a larger metropolitan city after twenty years, you might think of introducing light weight or metro rail system which is totally a new mode of transport for that particular urban area, when a new mode is introduced.

In that case, it would be next impossible to estimate utility associated with the new mode because the necessary base-year data required for the calibration of its utility function would be unavailable. We may not know, we will not be able to get the values of the parameters involved. Therefore, this difficulty is inbuilt in the process of mode choice that we have just now seen, when we have independent utility functions for each of the modes introducing new mode in the future might create problem because we will not be able to calibrate utility function for the new mode.

And how to solve this problem, as a way to resolve the problem, Lancaster a researcher postulated the idea of choice-abstract or attribute specific approach, instead of making utility functions specific to modes, you make the functions specific to attributes like speed, cost and so on across modes. Then you can cover any possible new modes when it is being introduced. So, that is the suggestion given by Lancaster and we will see the details of this particular utility function in the next class.

To summarize, what we have seen in this class, you may recall, we started our discussion, recollecting the different aspects related to trip end mode choice model then we discussed in detail about trip interchange type of mode choice model involving different factors like travel time ratio, travel cost ratio, travel service ratio and then dividing the travelers into different socio economic groups to take into account, socio economic characteristics of travelers.

And we found that even though, these are just graphical representation of the mode choice process, these are also very important significant mode choice models at that point of time. However, we found that, there were few limitations of the earlier models, like non segregation of captive and choice riders (( )) a problem. And then, they could not treat individual travelers as independent entities entities, they considered zonal averages as the basis for mode choice analysis. Then finally, how we discussed about disaggregate type of mode choice model, the basic theoretical aspect, and then the principle involved in development of utility function for various modes based on (( )) principle with this we will conclude our discussion for today, we will continue in the next class.