Urban Transportation Systems Planning
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Lecture - 54
Land Use and Transportation – IV

Welcome to module G lecture 4. This is the last lecture of this module and we shall continue our discussion about the land use and transportation.

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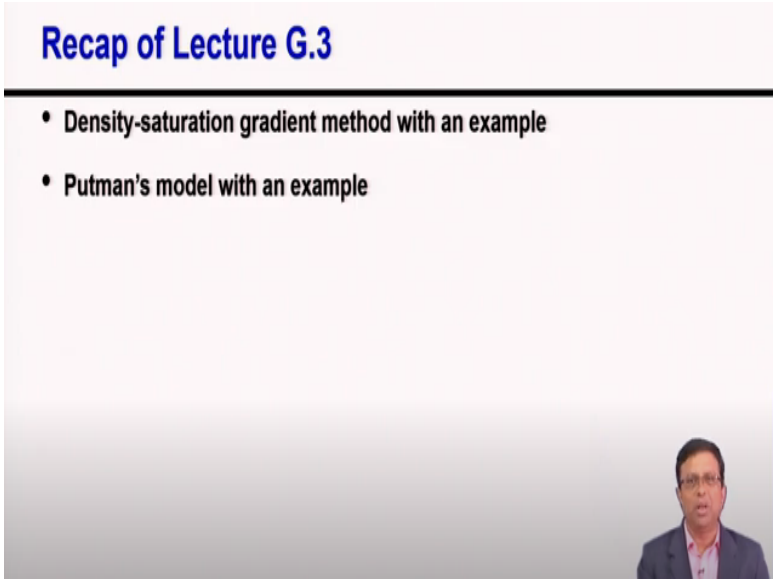

In the previous lecture we discussed about density-saturation gradient method and took an example to explain to you how it works. Also we discussed about Putman's model and took an example to again show how the model can be applied to get the distribution of residential population.

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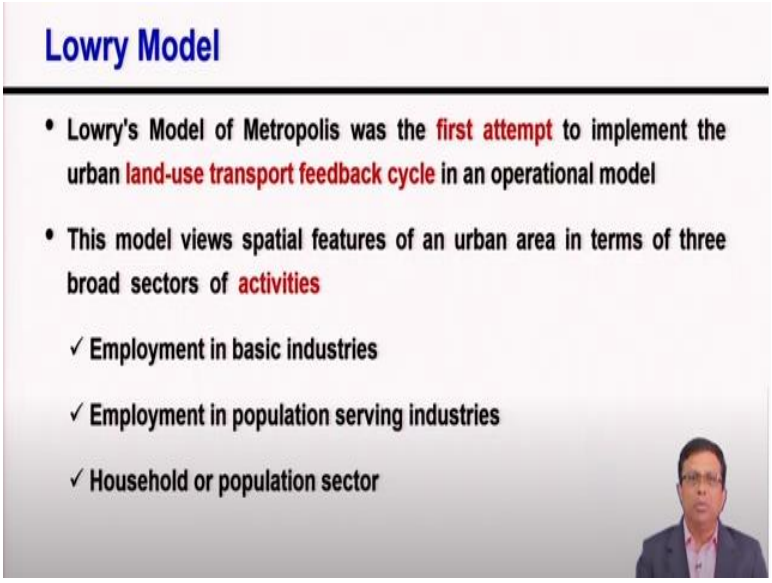

In continuation to that discussion today we shall talk about Lowry model. Now this Lowry's model of metropolis was the first attempt. So, you can call it an intermediate era model to implement the urban land use transport feedback cycle in an operational model. And this model views special features of urban areas in three broad sectors of activities first employment in the basic sector. So, again this also starts with employment like the Putman's model also.

We exactly started with employment then employment in the population serving industries. The first one was basic industries. This is employment in population serving industries. I shall explain you the difference clearly in the next slide then the household or population sector. So, starts with employment, two types of employment we are considering. The first one is employment in the basic sector then employment in the population serving industries and then finally we are coming to the household or population sector.

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What is basic employment? Basic employment is the employment in those industries whose products or services depend on the market external to the study area. Say for example, a steel plant is developed in one area. So, it happens sometimes. A completely new area, nothing was there and a steel plant is set up in that area. Now obviously the products from the steel plant are not going to be sold there only.

The product is outside the study area and it is called the basic industry. It can be a good example of basic industry. Then next is location of service employment depends on population distribution in the region. So, first what we are doing we are considering the basic employment. So, let us say an industry setup which is a basic industry. So, we know that how much or how many population, how many employments will be generated because of that and those employments how they will get distributed.

Now this employment each in simple terms let us say x number of employees. Now this x number of employees will have their families. Now those families will again have to see how those residential populations or households will get distributed not necessarily that if the employment is in a particular zone. That means the residence will be in that particular zone only. There is no guarantee like that.

So, based on the employment distribution we have to get the population distribution. But this population distribution is now with respect to the basic employment. Now people come from outside and they were employed there. So, they will require all sorts of services. I mean they need to go to the market to buy things, they need to go to the bank, they need to go to the post office probably children will need to go to school.

So, all you know services will be required. So, to serve this basic population we shall require service employment. Now again this population is distributed or you know households are distributed in different regions. Now those households will be required to be served by service employment. The service employment is not that if I am residing in a particular zone I will use the services only in that zone.

That service also; I am living in one zone, I can go to another zone to avail a service. That is also possible. So, how the service employment will get distributed? Now the service employment those people they will also have their family. So, the overall population now increases where you know they also will be located in different areas. So, we know that how the population changes. Now there are more people altogether living in that area.

So, the service employment or the requirement of service will be higher. So, now you need more service employment, overall total population also will change. So, after some iterations we shall find that the changes in the requirement or the change in the population distribution in different region is not that significant or maybe rather negligible. So, we can say that the whole thing has reached to a kind of equilibrium or stable condition. So, that is the difference between the basic employment and the service employment.

So, basic employment is the employment in those industries whose products or services depend on the markets external to the study area and employment then gets converted to households or population. Now to serve the population within that study region you need service employment. So, location of service employment depends on the population distribution of that region. Then special distribution of basic employment is allocated exogenously as I said. Also we know how many total employments will be there.

Basic employment will be there in a basic industry and then how those employments will get distributed to different zones. So, the special distribution of basic employment is allocated exogenously that means from outside the model. But the other two activity sectors that means employment to households or population and basic employment to the requirement of service employment.

And eventually service employment means we have to consider total employment and then convert them to the household or the population. So, these two activity sectors are calculated by model within the model by applying an iterative procedure until two constraints are satisfied or keeping in mind two constraints. One is the maximum number of households for each zone that could be a limit.

And then minimum population serving employment for any zone the requirement of population serving employment and keeping in mind these two or satisfying these two constraints.

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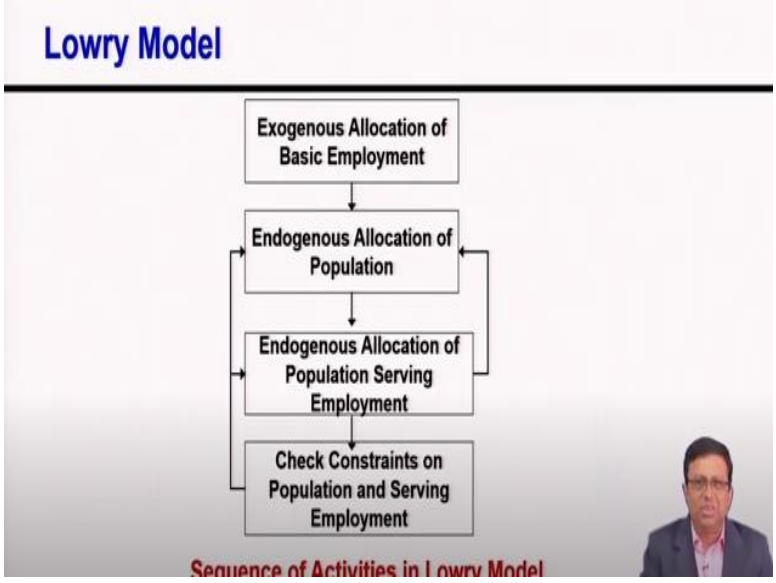

So, this is a simple flowchart which is explaining how this Lowry model works with a feedback cycle. We are saying that it is an exogenous allocation of basic employment. As I said we know that total employment, basic employment because of the setup of this industry or maybe a motor

vehicle manufacturing industry or a steel industry. So, we know how many people are directly working there.

Now, and then within that study area how those basic employments are likely to get distributed that is decided externally. So, we are saying exogenous allocation of basic employment. That is the starting point. Now the moment we know that initially what we will do? We will do endogenous allocation of population. So, first it is only the total employment that may be considered only as the basic employment in the beginning.

And then we know employment to the household population and then how those populations will get distributed. That will be decided then once that is known then endogenous allocation of population serving employment. So, we know how the household population will get distributed in different zones and then to support those people or households how many service employments will be required. Now we will estimate the service employment.

Now the service employment also; that is the employment now. So, this service employment also we shall require the household that the population change will happen because of that. So, the revised, again allocation will happen, allocation of population or allocation of households and this will keep on happening. And also we need to check the constraints on population and service or serving employment.

And you can see that depending on that it can go back to again endogenous allocation of population serving employment or endogenous allocation of population. And then one more iterative loop you can see that endogenous allocation of population to endogenous allocation of population serving employment and then service employment to again population. So, the overall population distribution is known now.

So, you check whether the service employment allocation is adequate or not and then once that loop is stabilized or settled then you come and check whether the constraints on population and service employments are satisfied. If not then again we go back and repeat the process. I shall explain it again further.

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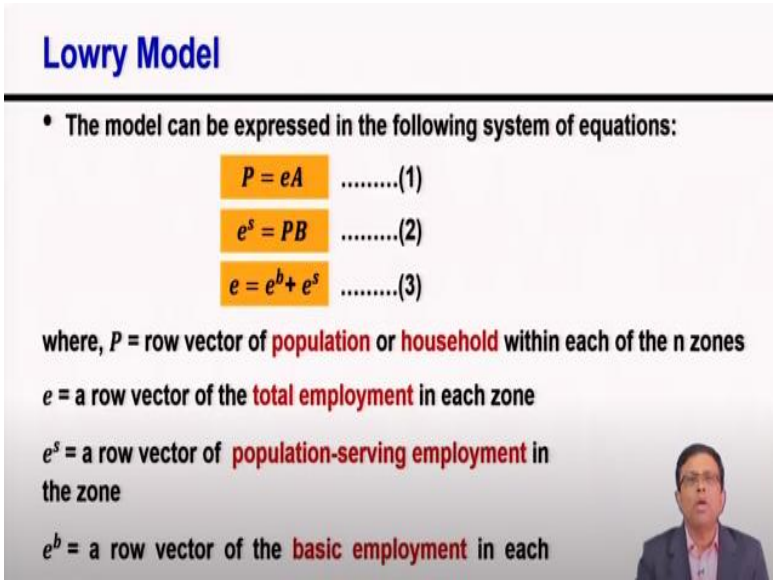

So, mathematically the model can be expressed in the following system of equations. Simple equation, first P equal to eA. What is the P? P is the row vector of population or household. Where from the population is coming? Population is coming from the employment. So, P equal to eA is the row of total employment. So, the employment is now getting converted to population. Not just only is employment getting converted to population.

But we are also deciding that if the employment distribution in different zones is something then what will be the corresponding distribution of households or population? So, that A is very important to A. Now what is A? A is basically an n by n matrix workplace-to-household accessibility. So, e is the employment. Employment getting converted to population rather I should say employment distribution is known.

So, that employment distribution from that we are getting the population distribution or distribution of household let us say population distribution. Because that also is getting inside this A matrix in this form.

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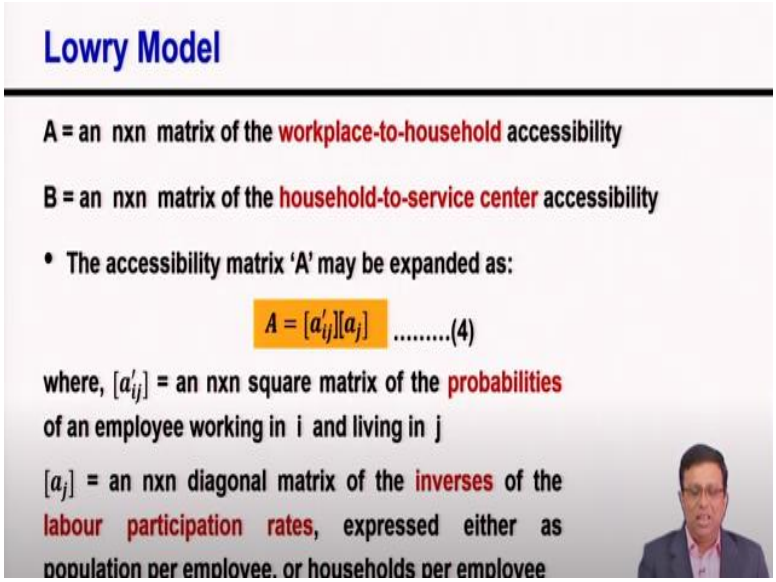

If you say that A is actually a ij dash into a j. What is a ij dash? a ij dash is basically n by n matrix of probabilities of an employing employee working in i and living in j. So, if I take every zone i we know that how many employment are there, how many people are working in that zone. Then we are finding out in each zone j what is the probability that those people working in zone i will live in zone j?

That we are getting that probability for every j for a given i and then for every i. So, if I have 10 zones I know the distribution of employment then I am getting if each of these 10 zones so many employments are there then how they are going to decide their residences. That means if a person is working in zone i then what is the probability that he will actually stay or this residence will be located in zone j?

So, that helps us to get employment distribution to household distribution. The other is a j is an n by n diagonal matrix of the inverses of the labour participation rate. What is that? It is expressed either as population per employee or household per employee. So, we got the household only if i take a ij dash. That means n by n matrix of the probabilities of an employee working in i and living in j then we are getting number of households.

But number of households to population how many people that is coming households per employee or how many, population per employee. So, that inverses of the labour participation

rate is helping us along with the a ij dash that is the probabilities of an employee working in i and living in j. So; together that A matrix n by n matrix helps us to convert the employment distribution to population distribution overall.

So, that is the first matrix. Now this employment is the total employment. Now when we are starting we do not know the service employment. We only know the exogenous allocation of the basic employment. So, we start with that. But then subsequently we work out that given a population, given the population b what is the requirement of service employment? So, e s service employment e s a row vector of population serving employment in the zone or rather in different zones.

So, that is getting calculated based on the population distribution. But then it is population to service population to service so that matrix B is helping us to get that. What is the matrix B? Matrix B is n by n matrix household to service center accessibility. That is we are getting it.

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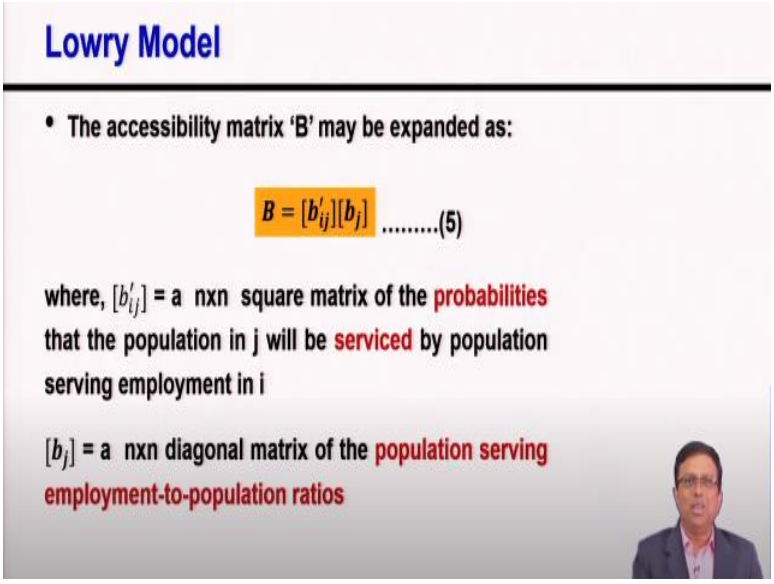

Now that again comes from two matrices b ij dash and b j. What is b i j dash? An n by n matrix of the probabilities that the; population in zone j will be served by population serving employment in i. That means as I said that people living in zone j not that all of them will be served by the service serving employment only in that zone. No, they can be served by the population serving employment in other zones also.

So, you live in one area but you can take the service from an adjacent zone. You can go to another place and take the thing within the same study area not outside the study area. So, b ij dash is that n by n matrix square matrix of the probabilities that the population in j will be served by the population serving employment in i and then multiplied by b j. What is b j? b j is obviously an n by n diagonal matrix of population serving employment-to-population ratios.

At what rate? If so many people are to be served then for a particular serving employment or particular service how many people will be required? So, how many shops you require to serve say a given number of population or households? That we are getting. So, overall what this b matrix is doing? It is helping us to know once we know the population distribution it is helping us to get then the corresponding serving employment distribution what will happen.

That is the e s. So, every zone I know different zones how many serving employment will be there. Now the equation, third equation is getting the total employment, how the total employment is distributed? Then it is the basic employment plus the serving employment. So, e b plus e s and then you start with first only the basic employment. So, your total employment is only basic employment. Accordingly you get the population distribution.

Once you get the population distribution then you get that serving employment distribution. Now you know the total employment you can go back so you get your revised population distribution using equation one. Like that in an iterative manner you go satisfying the other two constraints. So, here I have said what is P, what is e, what is A, what is B, what is e s, what is e b. All are explained and then also I have explained what is this A matrix and what is this B matrix and how you calculate.

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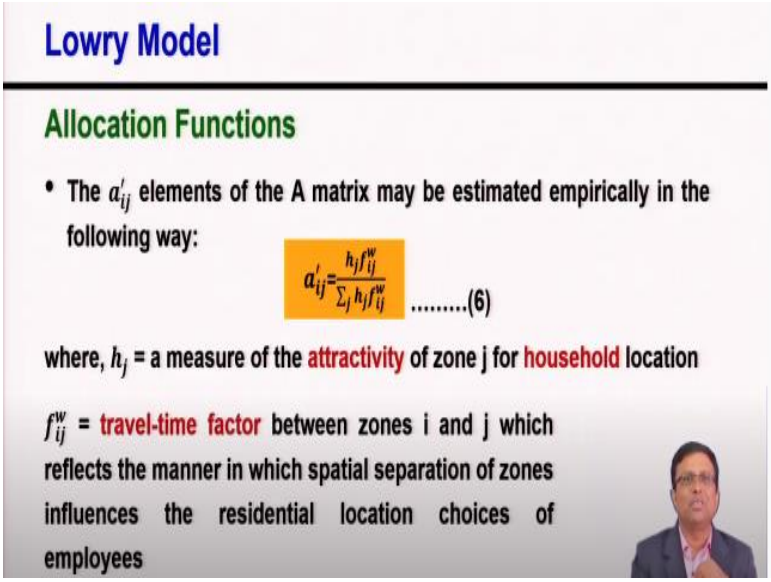

Now this a ij dash elements of the A matrix how we estimate? What is that? What is a ij? Please look at it again. It is an n by n square matrix of the probabilities of an employee working in i and living in j. So, people who are working in i they can live in any of these zones within that study area of course, not external. So, how many of them will live in a particular zone j? Here all the zones all the j's are competing with each other to get that population.

Get a share of that employment in zone i that you are working in zone i. But all other zone j's are competing to get them in their respective zones. So, how do we get this probability? We can get this probability with this one. h i multiplied by f ij w divided by sum over h j f ij w and sum over what? Sum over j because all j's are competing people are employed in zone i. It is all over time trying to get what is the probability that the person will get located in a particular zone j in terms of its residence or household.

So, here all the j's are competing. So, h i j f i j by sum over h i j f i j, something like the gravity equation. So, what is f i j? f i j is the friction factor between i and j depends on the travel time, travel cost. You are very familiar. I have discussed all these in great detail when we discussed about our gravity model and even when we discussed about the Putman's model in the previous lecture.

Putman's model was also similar very very similar, slightly different form maybe but conceptually very, very similar. So, the travel time factor between i and j. So, that is the way they are getting. So, employed in zone i how many of them will stay in a particular zone j and like that j has n number of zones. If there are total n number zones in the study area the j also varies then from 1 to n. So, all j's are competing to get that share of that employment or employees who are actually working in zone i.

So, like that for every i whoever is employed all j's are competing with each other and getting a fraction from each i and then that decides how many total are going to reside in zone j. So, you get a distribution of that.

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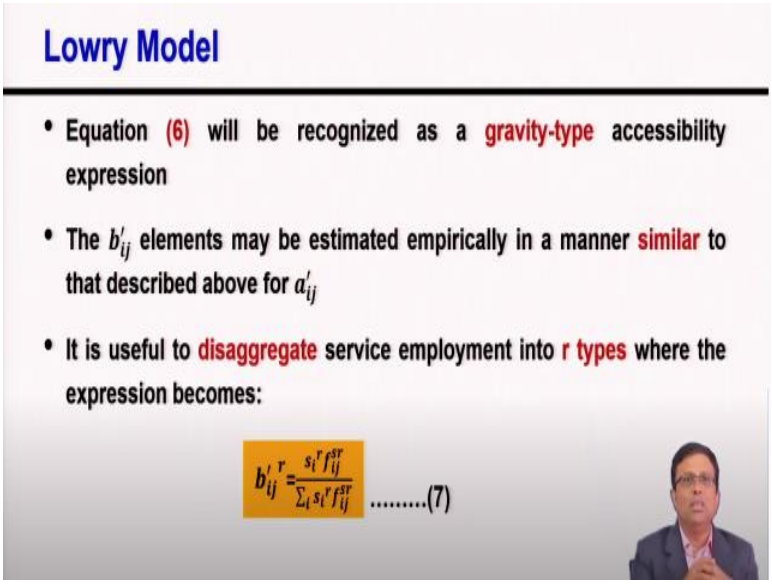

Similarly this as I said that this allocation function this equation 6 will be reorganized as a gravity-type accessibility expression. b ij similarly can be expressed also like as you have seen the previous equation. The b ij is also the same way. It is the same concept that is used here. It is useful to disaggregate service employment into r types. You can further disaggregate different types of service employment.

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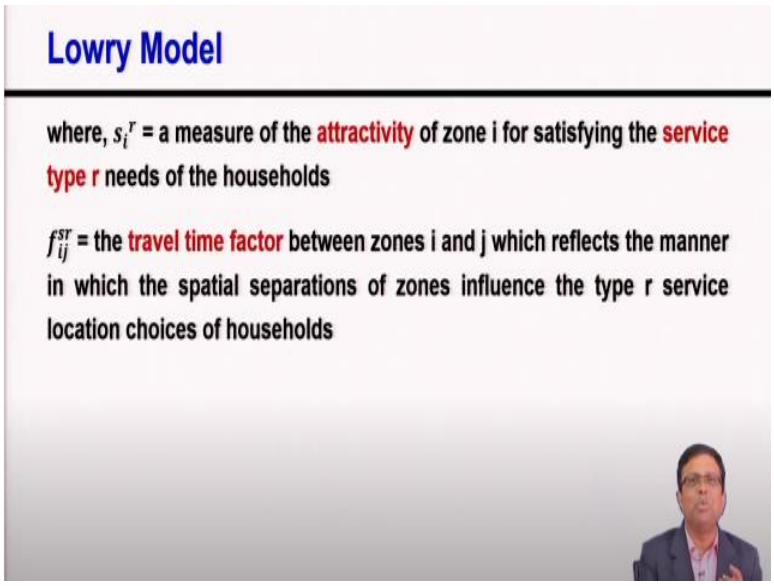

And then you can adapt all together.

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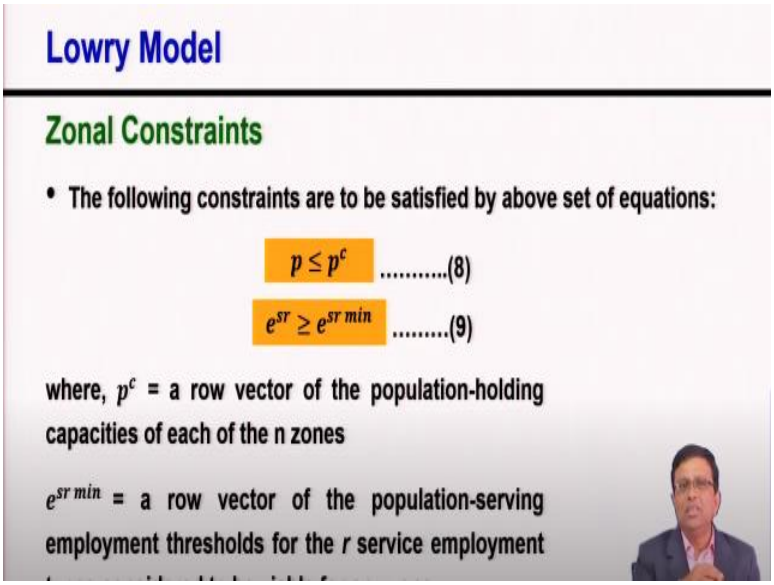

And these are the two zonal constraints. The following constraint p has to be less than p c and e sr greater than e s r minimum. So, p c is a row vector of the population-holding capacities of each of n zones. That is one constraint and e sr minimum is a row vector of the population-serving employment threshold that the minimum this has to be satisfied in terms of service employment for the r service employment types considered to be viable for any zone.

So, there are different types of you can even consider different multiple types of service employment. Or for simplicity maybe consider all of them together as you will see. We shall consider like that only one type of service employment in that next example.

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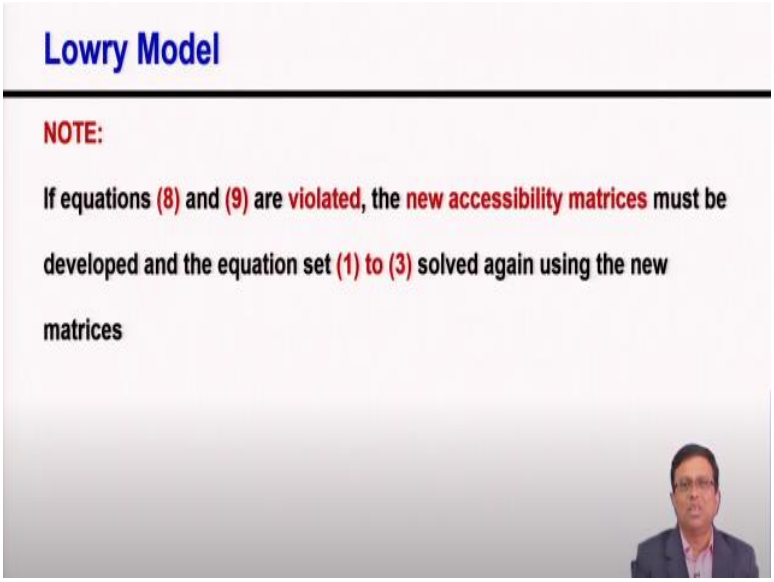

So, if equation 8 and 9 are violated then the new accessibility matrices must be developed. That a ij, b ij all those, the new functions are to be developed. New accessibility matrices are to be developed and the equation 1 to 3 to be solved again. So, new accessibility matrixes are to be developed. What I say, this is what we say that A workplace-to-household accessibility, B is the household-to-service center accessibility.

So, if this constraint is not satisfied you have to work out again come back and work out this A and B matrix again and then the whole thing will get repeated. That is what we explained also in that feedback. If you can see if the; constraints are not satisfied then what you do? You go back, start again. So, now let us take a small example. Before that let us talk about the limitation.

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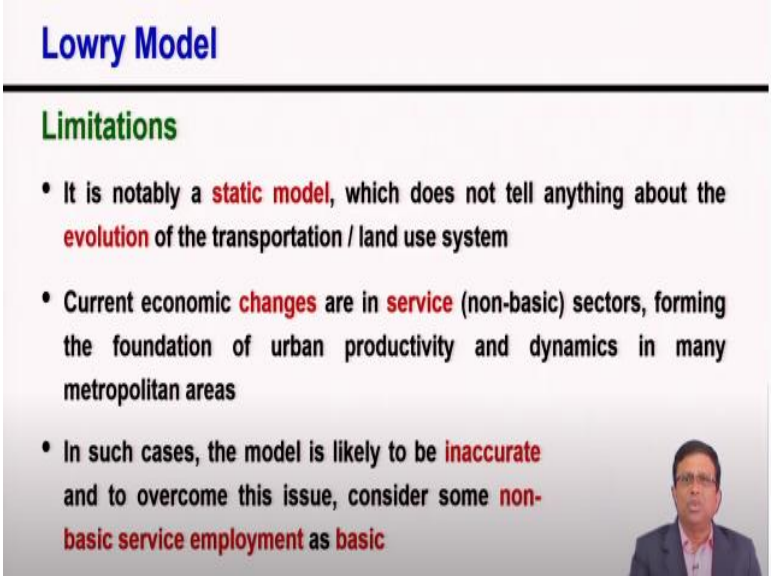

Limitation is notably a static model which does not tell anything about, it considers but it is finally a static model. It does not tell anything about the evolution of the transport land use system. The second problem is if you look at the current time the changes are happening in the service sector because these days the basic employment is really less. So, mostly it is the service sector that is dominating.

So, therefore forming the; foundation of urban productivity and dynamics in many of the metropolitan areas. So, in all such cases the; model is likely to be inaccurate and because everything starts here with the basic employment. Rest is supporting. Service employment is supporting. But what we are finding is that the current economic changes are basically in the service sector which is the non-basic sector.

So, one can assume to overcome this problem. Maybe some of the non-basic employment may be assumed as the basic employment. But then you know overall some level of inaccuracy that we shall incur.

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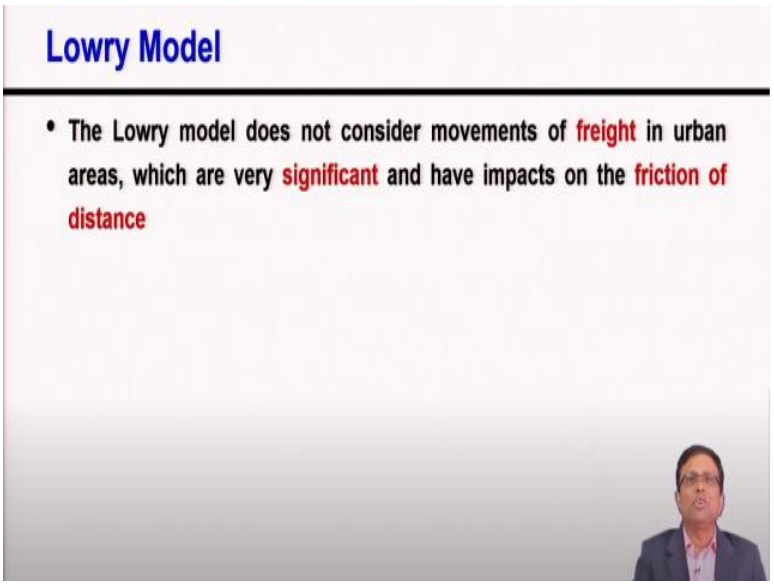

And the Lowry model does not consider movement of the freight in urban areas which is again a very important thing of course. Many other models also do not consider the freight. So, those are as well limitations for other models. But of course it is also a limitation of this model and because these have also significant impact on the friction of the distance.

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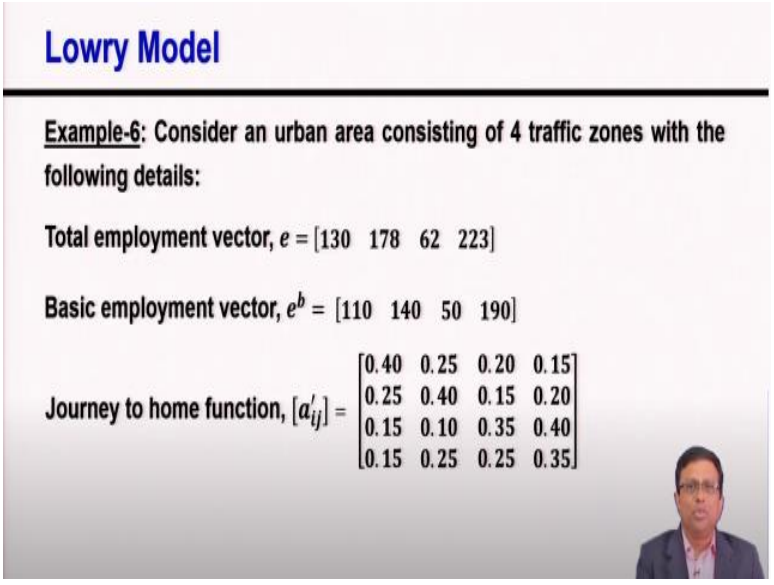

So, now let us take a small example. So, this is a very simple example. Consider an urban area consisting of four traffic zones and the employment total employment vectors are known. Now we do not get total employment exogenously. We get only basic employment. But this is just an example. Suppose the total employment is given, also the basic employment is given. The journey to home function a ij dash that probability matrix is given.

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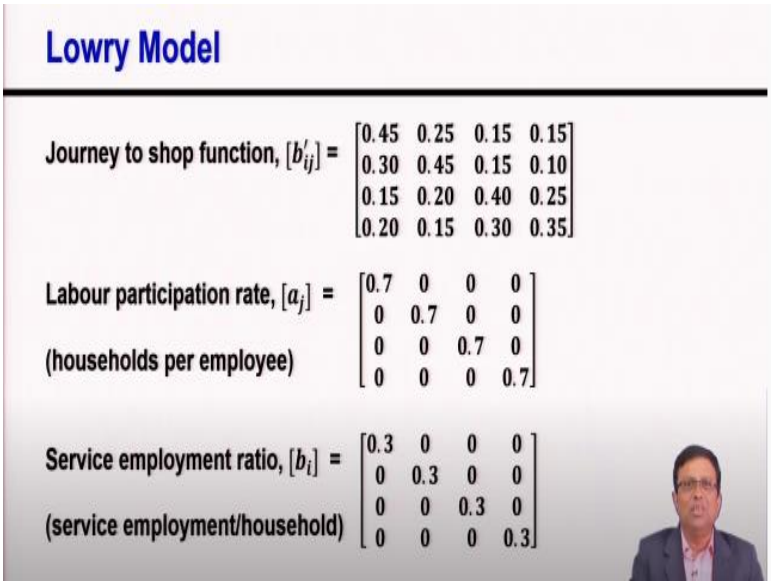

Journey to shop function b i j dash is also given. Labour participation rate is given that means household per employee. Service employment ratio b i is all given. So, I can calculate A matrix, I can calculate B matrix and I know the basic employment. So, I can calculate the service employment, I can also then come back and say what is my total employment and then here what we want is to check.

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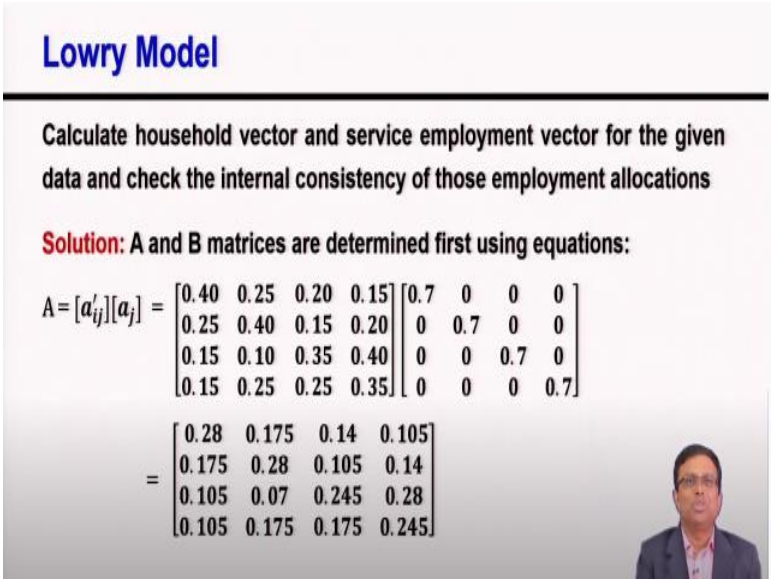

That is what we say, calculate household vector and service employment vector. So, you can get this matrix A, matrix B and all other calculations you can do and check the internal consistency of those employment allocation. That means finally my basic employment is the starting point. I

will calculate the service employment or total employment is also given. So, from all these I have to get the service employment.

And then I will check if my service employment plus basic employment whether it is giving me this total employment vector. What is given whether that is matching or not. Ideally it should match. So, if everything is in order it should match. So, what we do? The solution we first get the A matrix. It is very straightforward because I know this a ij dash, a j both are known. So, simply take the product, you get the A matrix.

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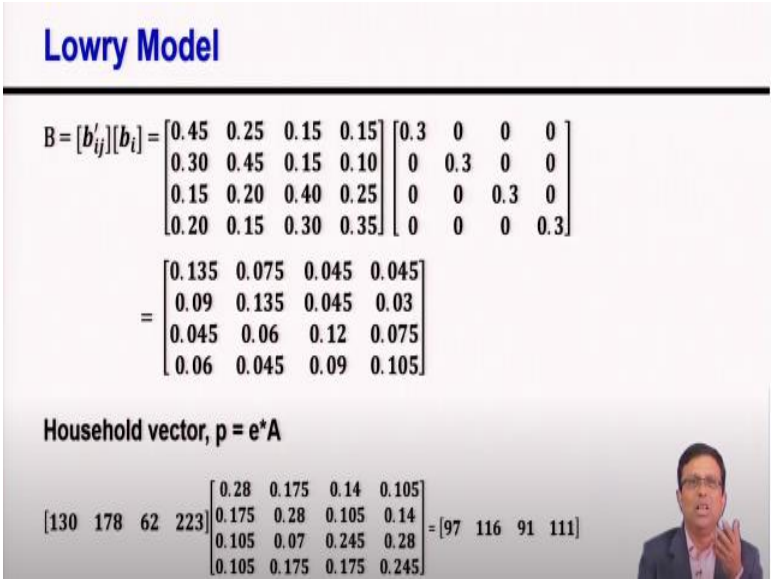

Similarly b ij dash and b i also are known, b ij and b i are also known. So, that is also known, the b j is also known. So, we get that B matrix. So, then we know p equal e into A. So, total employment is known. That is again given into A. So, we get the population or the household vector p.

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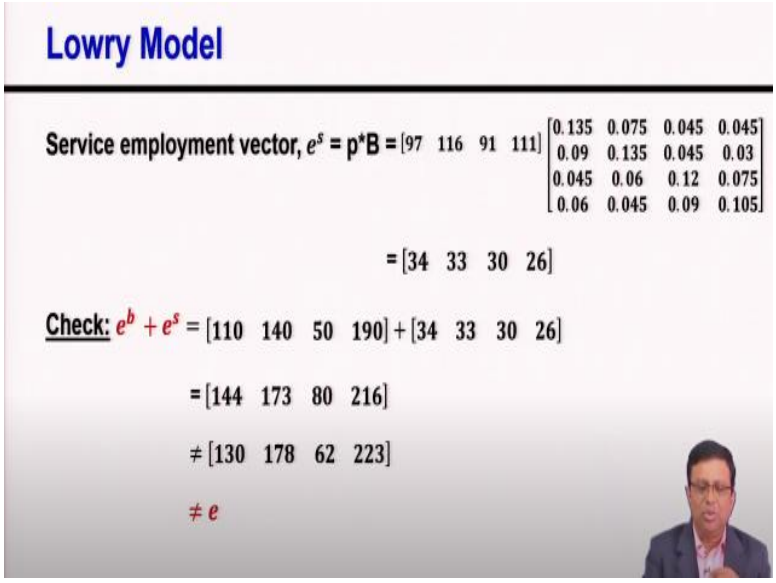

Once we know the household vector we can calculate the service employment, simply p into B. That is the second equation what I have shown in the beginning. So, you get that service employment distribution. Now we know then what is the total employment in each zone? Or in different zones, what will happen in each zone, what is the basic employment plus what is the service employment. Take the total.

So, we have taken that. We know the basic employment distributions in four zones are 110, 140, 50 and 190 and the service employment is 34, 33, 30 and 26. So, you add them. What do we find? We are getting then the total employment distribution as 144, 173, 80 and 216 which is not the same as whatever is given as my total employment because total employment is given as 130, 178, 62 and 223. So, when I check the internal consistency I find it is not matching.

Otherwise if everything would have been correct this total employment should have matched with the total employment what is already given. So, internal inconsistency is there.

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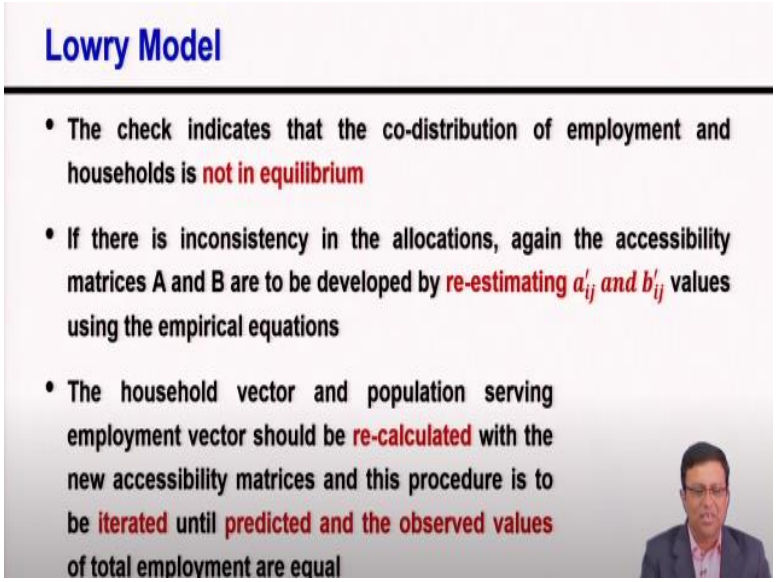

So, what is happening? The check indicates that the co-distribution of employment and household is not in equilibrium. If there is inconsistency in the allocations, again the accessibility matrix A and B are to be developed by re-estimating a ij dash and b ij dash values using the empirical equations. So, we have to go back and get the revised matrix A and B the household vector.

And population serving employment should then be recalculated with the new accessibility matrices and this procedure is to be iterated unless predicted and the observed values of total employment are equal. But remember that in this case we said this is just an example problem we said the total employment given. But actually total employment cannot be known. Total employment will get calculated from the exogenous allocation of the basic employment.

And endogenous calculation or allocation within the mode l whatever we will get from that. So, I would like to go back to this flowchart again. Remember that everything should actually start from exogenous allocation of basic employment. Rest everything is happening internally. So, although the problem is just an example I have said that can you check the consistency. That was the problem taken as an example here.

But remember that nobody will give you directly the total employment. So, we are starting only with the basic employment. Initially the total employment will be only the basic employment and

later on will work out and will calculate the service employment and then keep on iterating the things matching all the constraints. So, that is what it is. So, that is what is to be done actually.

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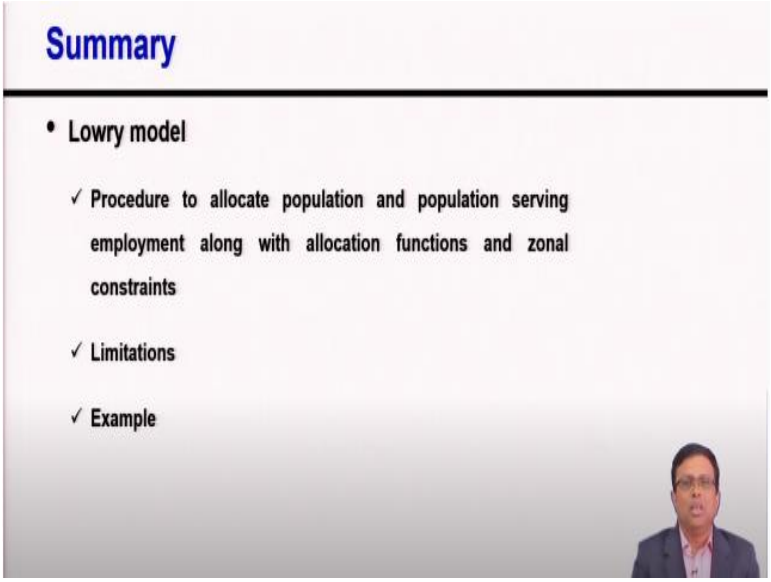

So, in summary what we discussed here we give you an introduction to this Lowry model. Lowry model again further have been developed by other researchers, have been developed further means little bit modification has been done. And you know as I said that we could discuss only a little bit. Because land use transport interaction and land use transport models are really the model model and so many further developments are there.

And there are full courses available on this topic. So, here in this course we wanted to only give you a brief introduction to the basic concept of land use transport interaction and wanted to mention two or three very basic and very simple kinds of models. Thank you so much.