Urban Transportation Planning
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Lecture No. # 36
Transport Related Land-Use Models Contd.

This is lecture 36 on urban transportation planning. We will continue our discussion on transport related land use models, and complete the discussion in this class itself. You may recall in the previous class, we finally discussed about a basic principles related to Lowrys land use model, and then the important steps involved in the application of Lowrys model in land use prediction. What are the four important steps in the application of Lowrys model in land use prediction?

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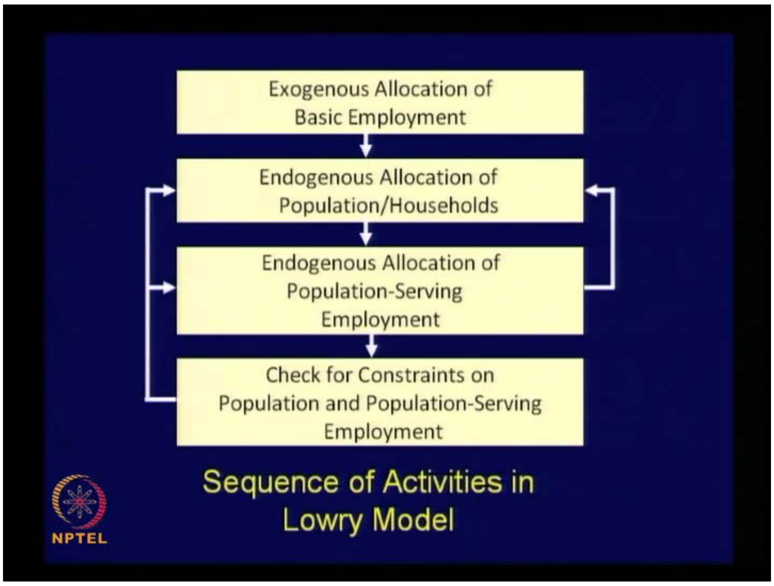

I will just show you the same flow chart that we have seen earlier to illustrate the four steps. Step 1, exogenous allocation of basic employment, we do not make use of a model to allocate basic employment, these employment locations are fixed based on other data collected from various sources. Then, endogenous allocations of population slash households, this is done using the model right. And then, endogenous allocation of population-serving employment, this is also done through the modeling process. And finally, check for constraints on population, and population-serving employment zone wise; that is what is to be done as a last step in the application of Lowrys land use model.

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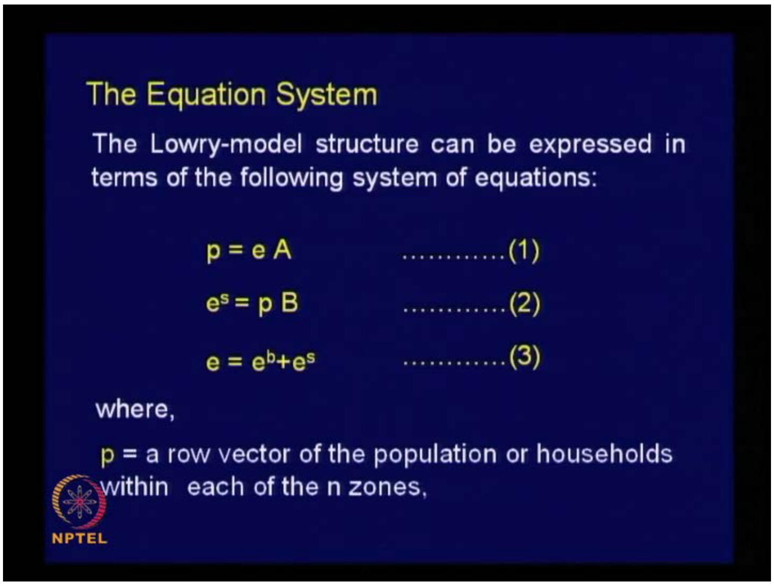

Let us just recollect the set of equations related to Lowrys model the equation system involves the following equations. p is equal to e into A and e s is equal to p into B and e is equal to e b plus e s of course, p is nothing, but A row vector of the population or households within each of the zones considered say n zones and e is A row vector of total employment and e s is again A row vector of service employment and e B is the row vector of basic employment in different zones of the urban area. A is an n by n accessibility matrix giving information about the probability of an employee living in j a, but working in i and B is also an n by n matrix giving probabilities of service type or they use by people living in j whereas, service type r is located in i. So, this is basically accessibility related matrices A and B.

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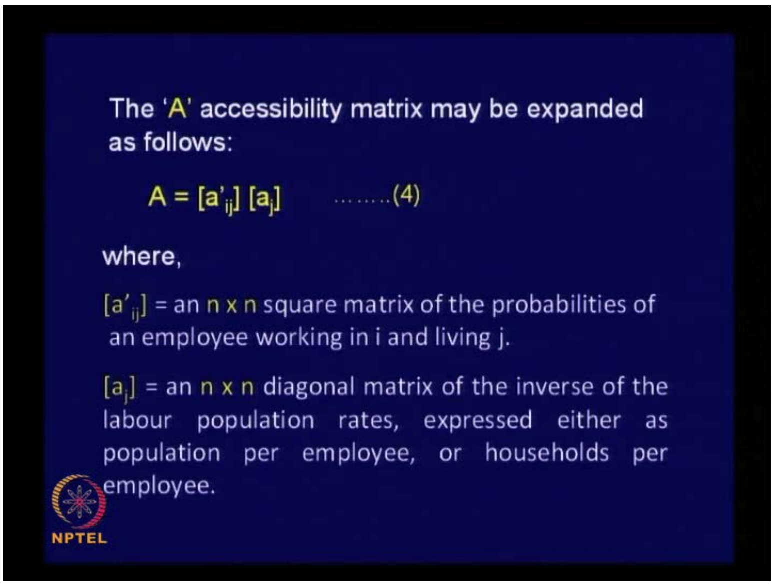

And please recollect how we calculate the value of A? a is obtained as a dash i j into A j as you may recall and a dash I j as I said is n by n square matrix of the probabilities of an employee working in i and living in j and A j is again n by n, but diagonal matrix of the inverse of the labour population rates as employees per household or employees per one thousand population. So, on expressed either as population per employee, or households per employee.

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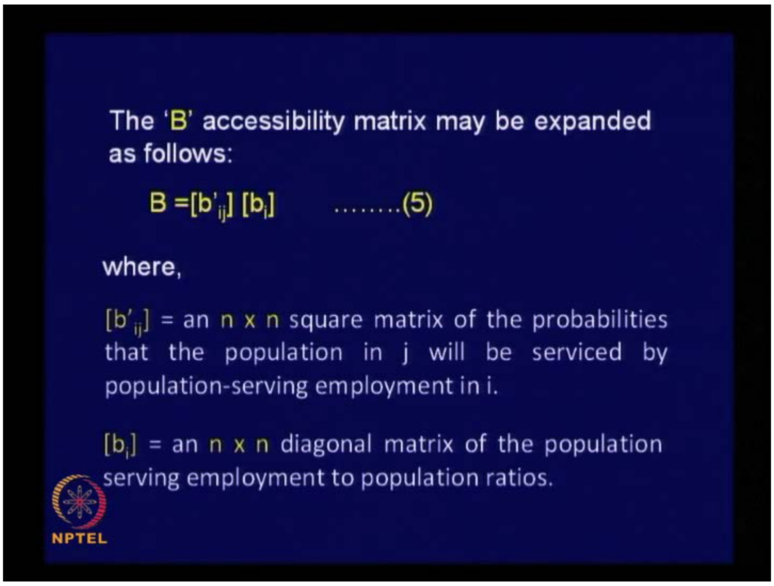

Similarly, the B matrix is given as b dash i j into b i where, b dash i j is an n by n square matrix of the probabilities that the population in j population in j will be serviced by the population serving employment in i, b i is n by n diagonal matrix of the population serving employment to population ratios. Certain number of service employment per given population value per one thousand. So, on please remember this equation while we take up a numerical example to understand the application of Lowrys model.

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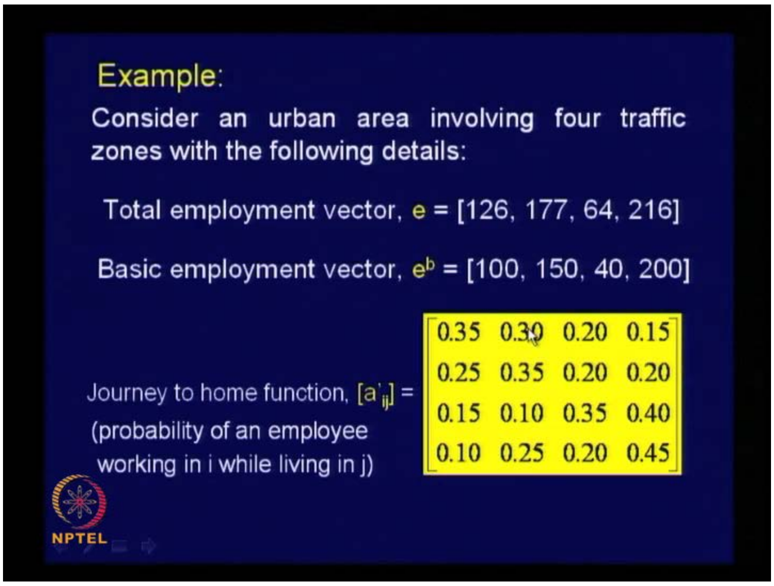

Let us consider, a simple numerical example involving just four traffic zones in an urban area the following are the details given to us. Total employment vector e is given as 126 177 164 216, it simply a row vector of employment details in the four traffic zones. A similar vector giving information about basic employment 100 150 40 and 200; obviously, these numbers pertaining to e b will be slightly less than e, because is the total and e b is part if e and these numbers are fixed by the planner; these numbers cannot be obtained through the modeling process.

Because, it is related to basic employment, journey to home function a dash i j is given like this is A 4 by 4 square matrix and how do you understand the cell value point B in the first row and how do you understand the cell value 0.3 in the first row. Anybody, maybe I have to provide you this information this is nothing, but probability of an employee working in I, while living in j. Then this 0.3 means probability of an employee working in zone 1, but living in zone 2 that is, it and 0.35 obviously, is working in zone 1 and also living in zone 1.

That how we need to understand these numbers, the other related question is this how do we get this numbers in practice? Nobody will give this numbers to us, when we plan or when you try to predict the population distribution for the horizon year for an urban area we have to get this numbers. Is it possible to get this numbers for base year condition? This is base year data only. We are using base year data to predict the future population distribution. We conduct different types of service including home interview survey, where in we get detailed information about all the characteristics for each of the trips made. So, trip horizon destination trip purpose etc is known to us.

Definitely we can find out of a total of say x employees in A particular traffic zone how many are employed in given zone, living here working in another zone. Because, total employment is known to us trip horizon destination is known to us and trip purposes is also know to us. So, these numbers can be easily found for base year condition. So, these proportions are given as probabilities 0.35 is nothing, but thirty percent of the total of the trips made for basic employment is within that zone itself that is the meaning.

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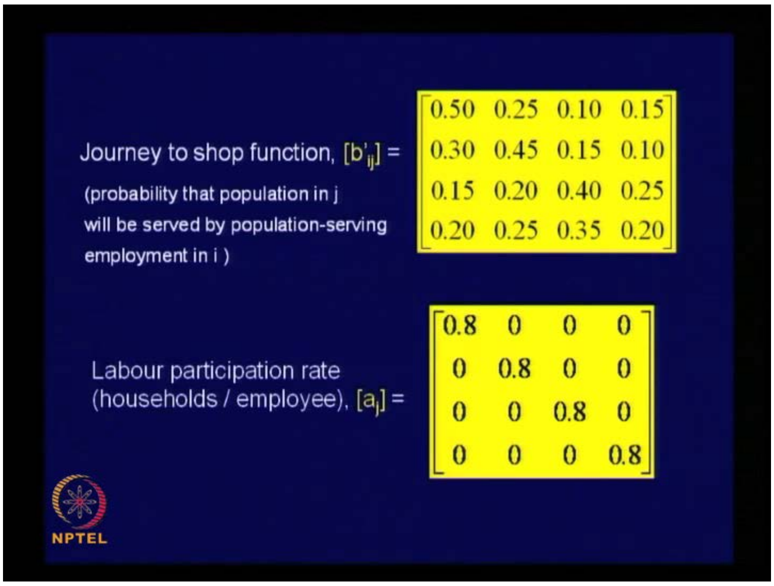

And similar information related to employment in service related industries, population serving employment, probability that population j will be serviced by population serving employment in i, for example 0.45 means what. Probability of population serving employment in zone 2 being served to the population living in the same zone, that is how we need to understand this numbers. Labour participation rate households slash employees a j is a diagonal matrix. Why it is a diagonal matrix? After all this information pertains to only four traffic zones so, you can have only four entries and rest of the cell values will be zero. But, still we want to have a same number of rows and columns. Because, it is a diagonal matrix we cannot just have a diagonal matrix with 4 entries without entries in the other cell, because it should be A 4 by 4 matrix.

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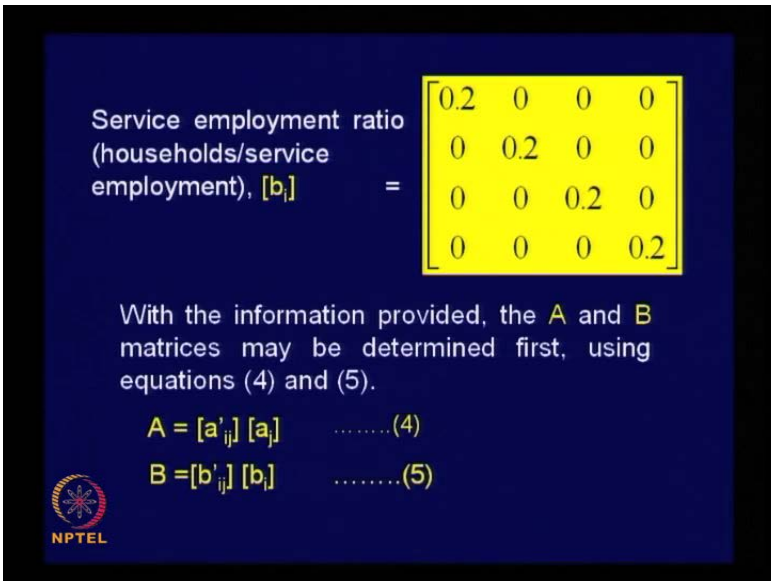

And similar information related to service employment ratio, they expressed as households per service employments b i like this. Again these are just four entries pertaining to the four traffic zones, again a diagonal matrix values or 0.2 in all the four cases. So, it is very direct in case, but in practice it need not necessarily could be lesser. Now, with the information provided A and B matrices, may be depluming first using equations 4 and 5 equations, 4 and 5 just now we have seen. Equation for A and equation for B i will again show you the same equations. So, that we just follow closely A is equal to a dash i j into A j the values are given to us now. We know the value of a dash i j in A matrix form, A j is also given in the form a diagonal matrix.

And b dash i j value is given in the form of A square matrix and b i value is given in the form of a diagonal matrix. So, it is going to be multiplication of matrices, this means you should be able to recollect your matrix algebra knowledge for the benefit of those who may not be able to recollect quickly or the required information for this purpose. Let me just give you brief on the relevant aspects of matrix algebra. So, that you appreciate this subsequent analytical steps.

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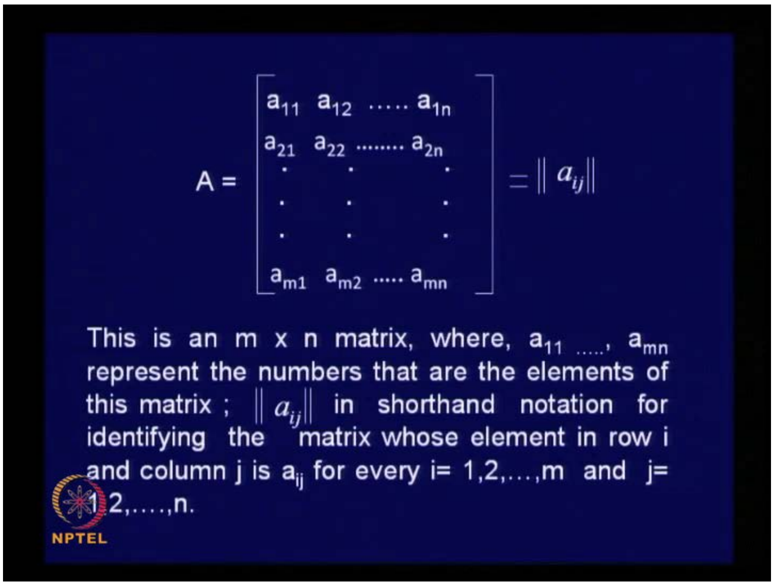

This is an m by n matrix. There are m rows and n columns. Symbolically, matrices can be represented as shown on the right hand side. So, where a 1 1 to a m n or the cell elements represents a number that are the elements of the matrix. Obviously, and for identifying the matrix whose element in row i and column j is a i j for every i is equal to 1 to m and j is equal to 1 to m. That, how we designate the cell elements as a i j, i refers to row elements and j refers to the column elements.

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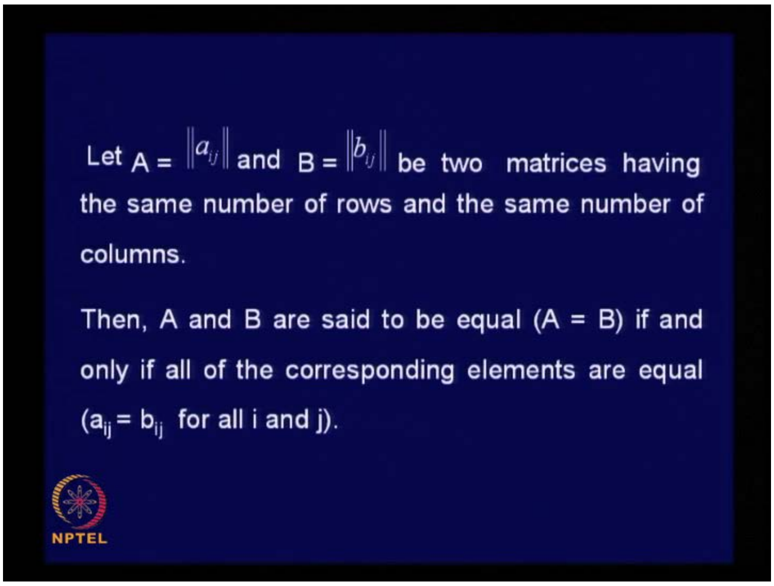

Let A and B be two matrices having the same number of rows and same number of columns square matrices. Then A and B are said to be equal only when or only, if all of the corresponding elements are equal, element corresponding to 1 1 in a should be same as 1 1 in b. So, all the cell elements should be same on the corresponding cell element should be same. Then, we can say both the matrices are equal otherwise they are not equal.

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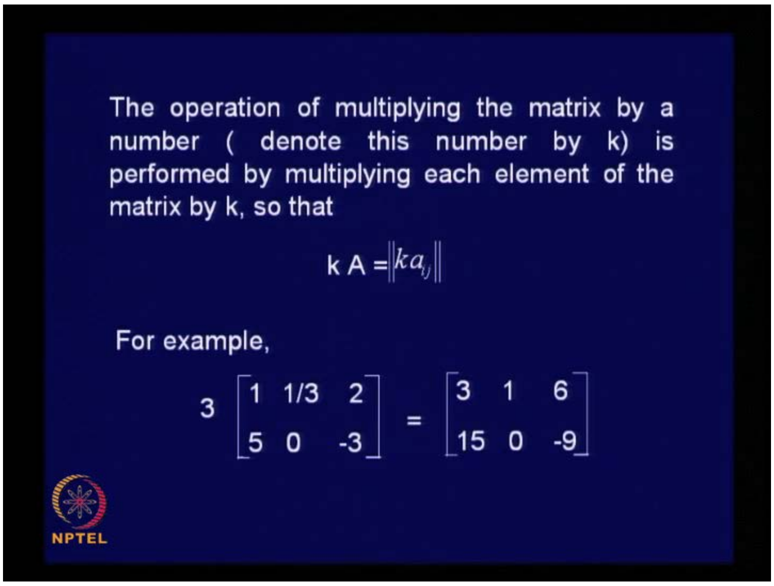

The operation of multiplying the matrix by a number denote this number say by k, is performed by multiplying each element of the matrix by k, that is how we need to understand multiplication of matrix by constant. Let us say, we need to multiply matrix A with k. So, this implies A goes in and gets multiplied by each of the cell elements. If you take this numeral example, of A small 2 by 3 matrix with cell values of 2 1 by 3 2 5 0 minus 3 being multiplied by 3, you can see simply multiply the cell elements by 3 to get the product of 2.

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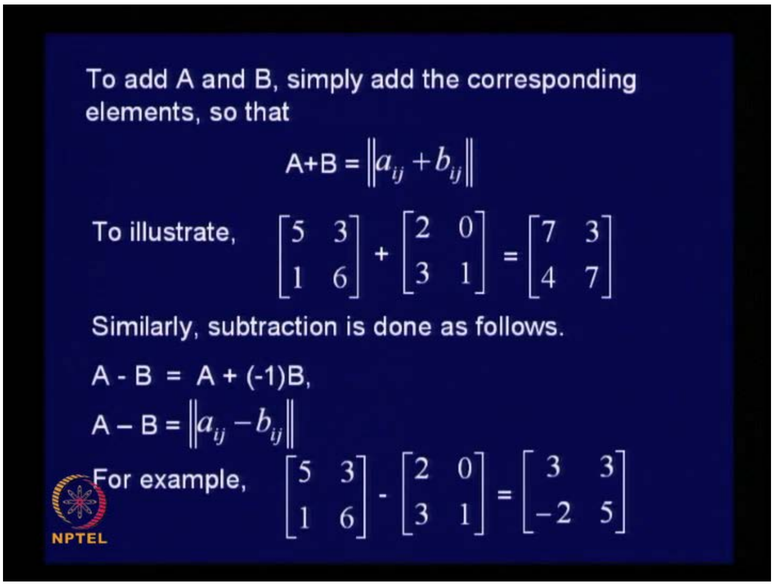

Then about addition of matrices to add A and B, what do we do we simply add the corresponding elements of the value of 1 1 in A is added to be corresponding value 1 1 in B and do the addition. A plus B is obtained as A matrix with cell values as a i j plus b i j. To illustrate let us consider, this simple matrices 2 by 2 matrices A and B in cell values of 5 3 1 6 2 0 3 1. So, we simply add the corresponding elements 5 plus 2 7, 3 plus 0 3, 1 plus 3 4 and 6 plus 1 7. How do we subtract one matrix from the other? We do subtraction indirectly through addition; we just assign negative value for the entire cell elements matrix which is to be subtracted fully other one. Simply do again addition of the two matrices A minus be is treated as A plus minus of B. Let us consider the same set of matrices 5 3 1 6 2 0 3 1 one is subtracted from the other. So, simply we subtract 2 from 5 five minus 2 3, 3 minus 0 3, 1 minus 3 minus 2, 6 minus 1 5.

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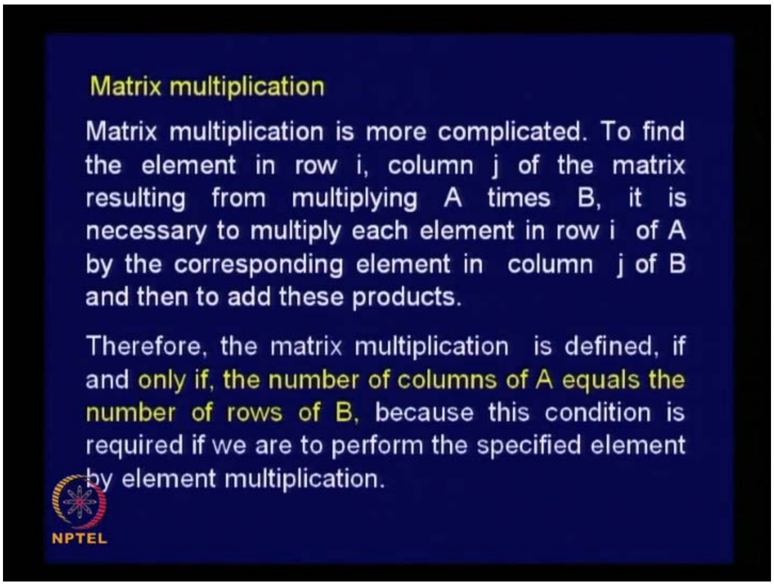

So far, things were much easier and with matrix algebra, but multiplication is little complex. Matrix multiplication is more complicated. To find the element in row i, column j of the matrix resulting from multiplying A times B or multiplying matrix A with B. It is necessary to multiply each element in row i of A by the corresponding element in column j of B and then to add this product. So, the columns of one matrix are related to the rows of another matrix. Unless, there is some connectivity between these columns and rows will not be able to do really multiplication. Therefore, the matrix multiplication is defined, if and only if, the number of columns of A equals the number of rows of B, because this condition is required. If your to perform the specified element to element multiplication, because its column to row multiplication. So, we need to have these conditions satisfied for matrix multiplication.

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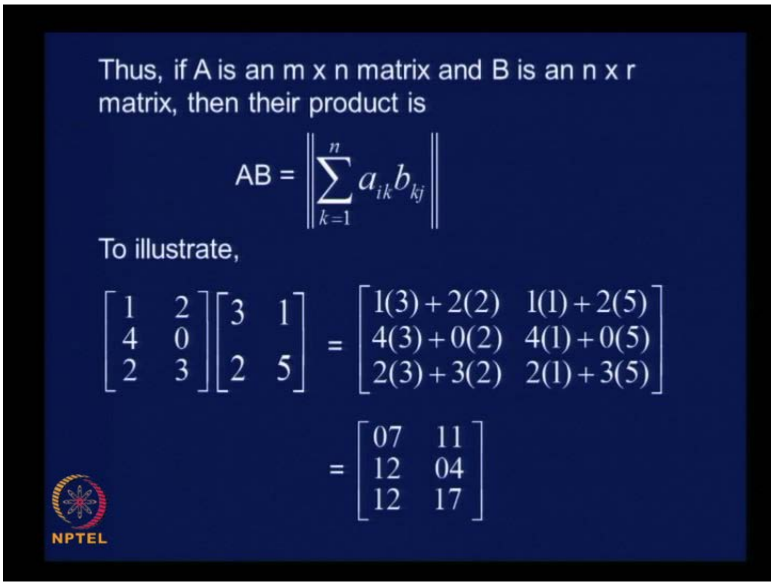

Let us take a small example and see how this multiplication can be done to understand the concept better. Thus, if A is an n by m by n matrix and B is n by r matrix then there product is symbolically represented like this. i and j vales are involved. Let us consider this numerical example. We need to multiply a 3 by 2 matrix 3 rows and 2 columns 3 by 2 matrix by 2 by 2 matrix. 3 by 2 by 2 by 2, is it acceptable? It is A 3 by 2 matrix and 2 by 2 matrix. So, we can do multiplication what did we do, we just consider the row first row of the matrix and then the corresponding column is the first column. We multiply 1 and 3 plus 2, second element of the first row and second element of the first column. So, this summation use you one cell value or a product. Then we consider the same first row, but the second column 1 into 1 here plus 2 into 5 the corresponding element.

So, this is another cell value and similarly next we take a second row here and then multiply is at the columns of the other matrix, 4 into 3 plus 0 into 2 4 into 3 plus 0 into 2 and similarly this is one cell value and then 4 into 1 plus 0 into 5 is another cell value. And finally, considering the third row 2 into 3 plus 3 into 2 one cell value and then 2 into 1 plus 3 into 5 another value. So, the result is 4 we get A 3 by 2 matrix again 3 by 2 multiplied by 2 by 2 gives to 3 by 2 again. 3 by 2 matrix the cell values are 7 11 12 4 12 17. We will do a similar exercise, while getting the values of the accessibility matrices namely A and B in the application of Lowrys model.

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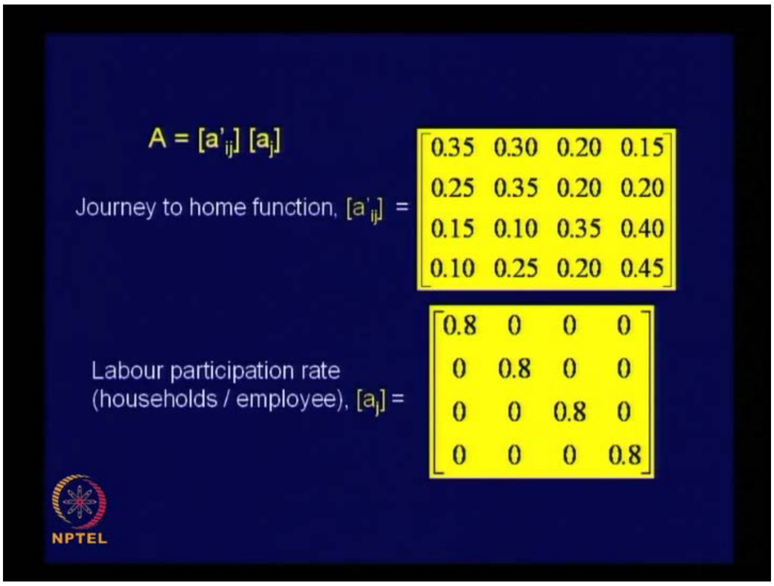

Now, let us try to get the value of A, a dash i j into a j, a dash i j value is this given to us A j value is this and product of these two.

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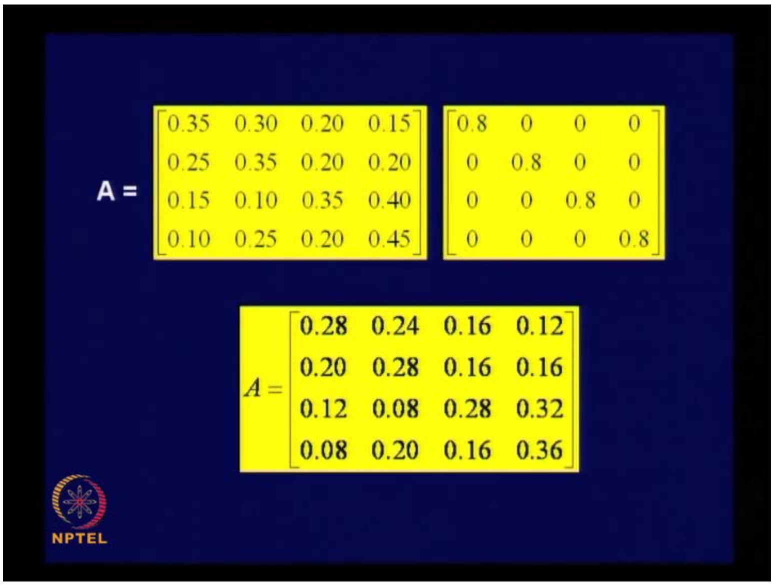

So, we are multiplying 4 by 4 matrix by another 4 by 4 matrix. So, the condition is satisfied, satisfied or not satisfied. So, we can multiply and we can get the result as shown here same rule is applied, I am directly giving you the result.

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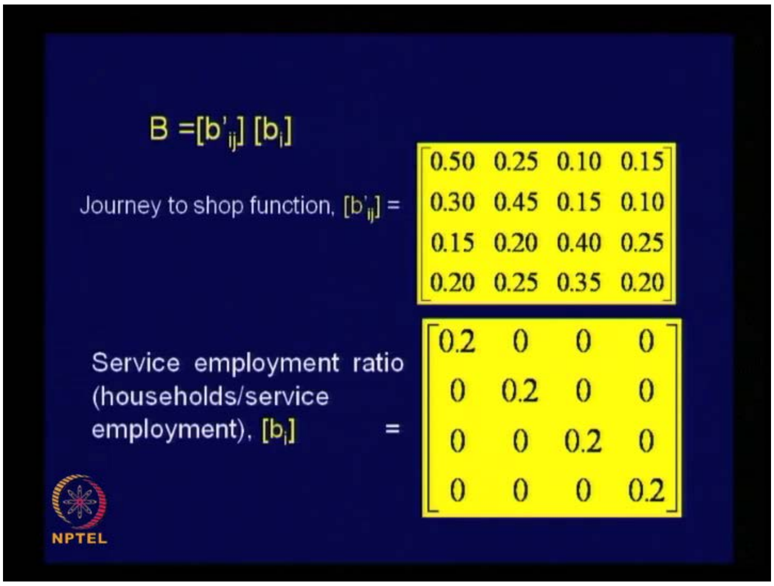

On the same lines, get the value of B as b dash i j into b i, b dash i j value is given to us and b i value is also given to us. Multiply the two matrices to the value of b.

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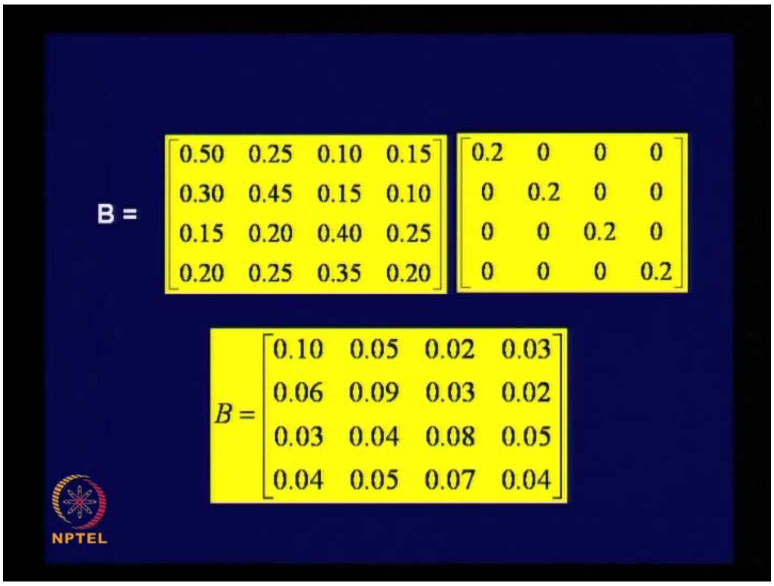

And the value of B is this. So, we have the accessibility value is both as A as well as B matrices. Now we are ready to use the basic equations of Lowrys model to get the required values.

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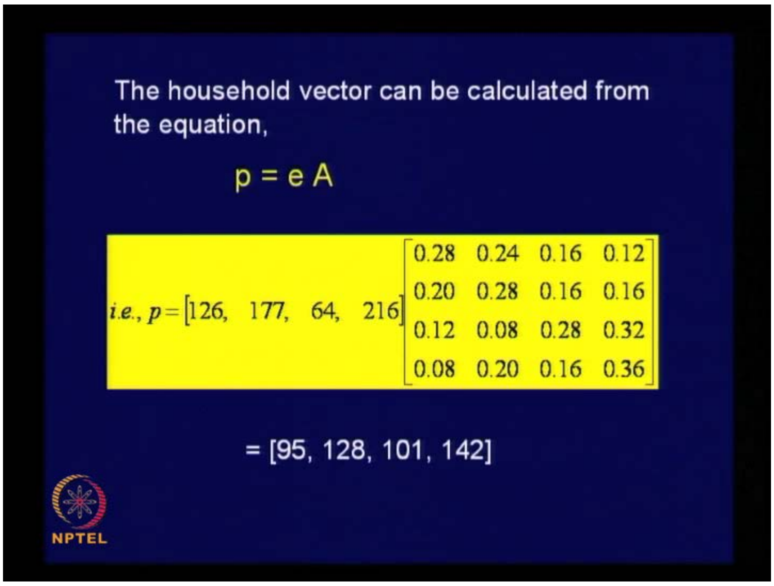

The household vector can be calculated from this equation, p is equal to e into A. The value of p is given to us. Do we know the value of p? No. p value only is being calculated e and A is known to us. Total employment vector is given and A we have calculated. So, we have to calculate the value of p. p in this case is taken as households not population; p refers to number of households in each of the traffic zones. Again we are multiplying what is the size of this; it is row vector. If you want to express this in matrix form how you designate this as a matrix, 1 by 4 matrix. 1 by 4 multiplied by 4 by 4, what will be the result? You will be getting only 1 by 4 matrix and this is the result. So, you get values of 95 128 101 and 142, these are the predicted number of households. In each of the 4 traffic zones as for Lowrys land use model. Then use the value of p to get the other values.

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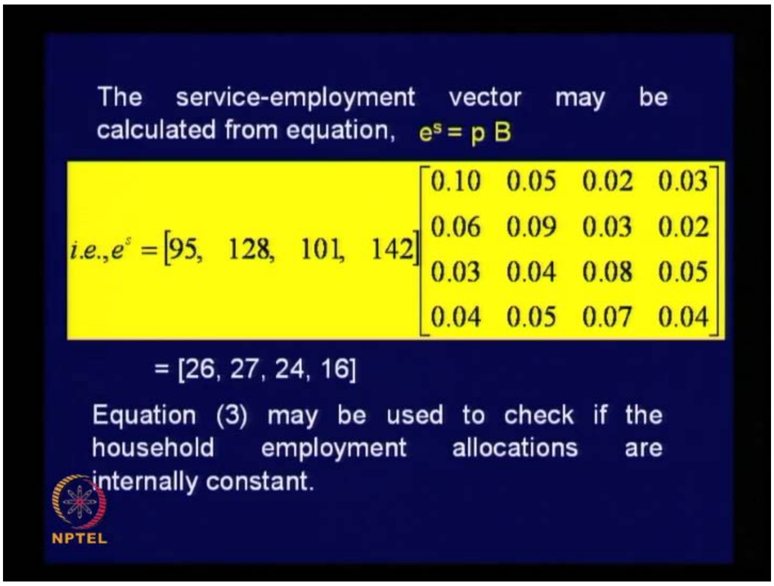

The service-employment vector may be calculated from this equation e s will equal to p into B, and we know the values of p now, as well as B is known, and get e s value as p multiplied by B, again we will get 1 by 4 matrix; 26, 27, 24, 16. So, these are the number of service employments that will be located in each of this traffic zones.

Yes please.

Sir, we can (( )) the e s vector by in the formula e c equal to e B equal to e s.

Yeah.

So, e s e minus so, we can directly find.

We can directly find that is also possible. This is also that that will because bringing it and then we can get it because e is known to us e B is also known. So, you can get e s value that is also possible. Equation 3 you may recall what are the equation 3 was, may be use to check the household employment allocations are internally constant.

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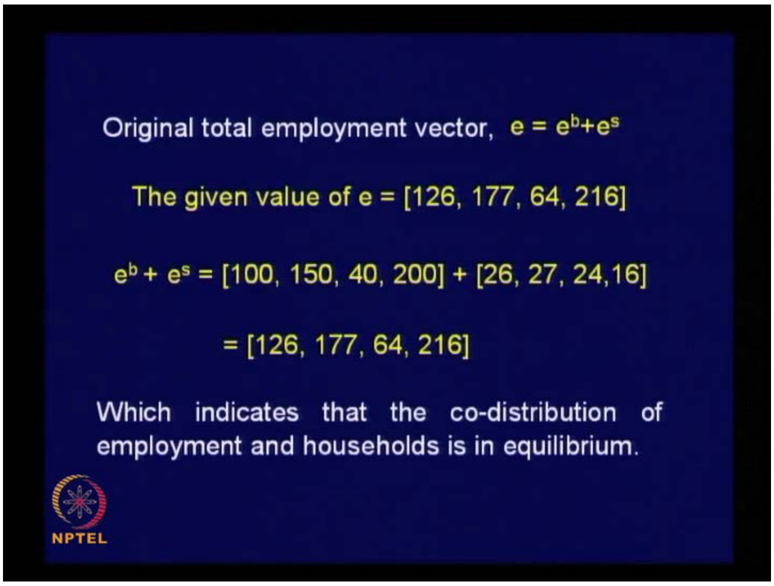

This is what we do; we do this for just checking. We estimate e s value differently and then sum up both and check whether it is matching with the total employment value, which we already got. So, the given value is this 126, 177, 64 and 216 that is known to us and now let us add these values e B and e s and if you add this the simple addition of the cell. Obviously, get the same numbers 126, 177, 64 and 216. So, you are predicted value is matching with the actual observed value of e. So, we can say that the calculation of A B as well as e s is logical. Suppose, this indicates that the code distribution of the employment and the households is in equilibrium.

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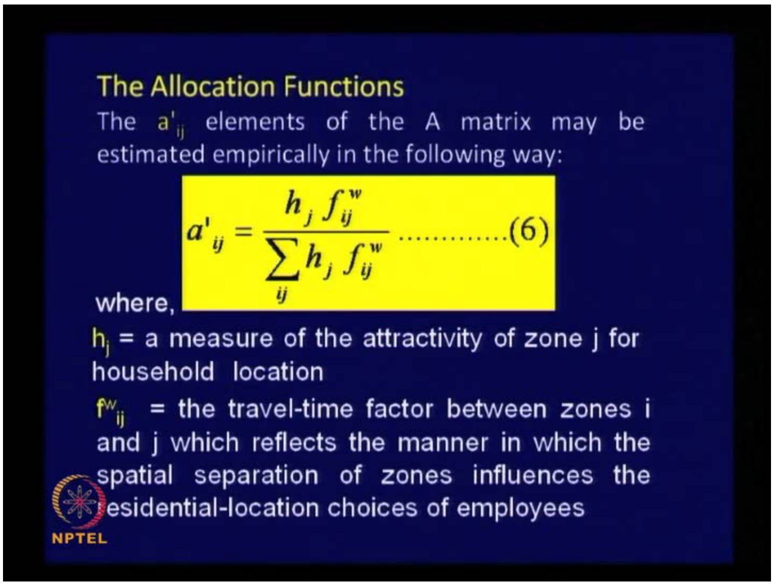

Now, there are certain issues. If there is no match between your calculated and actual observed values while you are checking, we should know how to tackle such situations. In that context, let us look at this allocation functions. The a dash i j elements of A matrix may be estimated empirically in the following way. I have already shown this equation in the previous class itself. It is a gravity type of equation to get the value of a dash i j. Please, remember in this just now we have seen a dash i j values are directly given to us, that this is the way a dash i j the values are actually estimated. h j is what? It is a measure of the attractivity of zone j for household location.

How to get some value for h j? Any suggestion. So, measure of attractivity of zone j, I will show the explanation for the other term also. So, that you will be able to think comprehensively and respond. f w i j is the travel time factor between zones i and j, travel time factor will normally express as a function of the actual travel time. We do not take the travel time itself represent the resistant to mobility just express, it as a function and get some number. f here also represents the friction for mobility between the zonal pairs, which reflects a manner in which the spatial separation of zones influences the residential location choice is required with respect to their work place. That is a meaning here, w stands for work.

So, with the explanation given here you will be able to suggest methodology to get the value of f j. F i j we can get because travel time can be measured easily between zonal pairs and there are standard functional forms available to express spatial separation between zones, as in terms of friction travel resistance or friction factor we can get some value for f i j. But how did you get the value for f j is just related to the attractivity of zone j for household location. How do you measure the attractivity of zone j? Household location means of course, it should be first suitable for construction of houses the zone self. So, first it is related to topographic and even geographic condition of that particular location in an urban area.

Normally, you can assume that topographically and geographically most parts of urban area will be suitable for house construction of course, adhering to the zonal guidelines. If a particular area is designated as a residential zone, the planners would have looked into the suitability of that area for housing purpose and designated that portion as a residential area. So, we can basically assume that topographically and geographically the designated areas for housing will be already fixed.

But still we need to have some value of h j based on other factors. What are the other factors? Because as plan as we should know or fix some value of h j, otherwise you cannot get the value of A dash h j. It is again A very important to get you are A matrix value of A. What are the other relevant factors to get some measure of f j which is nothing, but attractivity zone for household location.

Yes.

The reach of a work place can also be a measure of attractiveness for the zone in a residential location.

Yes. Her point is the accessibility to work place could be one of the factors governing the attractivity of a zone as a residential area. Is it acceptable?

Yes or No?

Yes, it is acceptable. So, we fix our residence in an urban area based on several factors what are the factors that we have in mind while fixing our residential location. Let us say you are just transfer to a new city and you want to fix a suitable location for housing first, work place and residence then that is the only activity in which you will involve, you will just go work and then come home and sleep.

There should be nearby schools, they took for the nearby schools and hostel facilities shopping facilities, shopping facilities and so on.

So, that is how we need to understand the value of or fixing the value of h j or please simply think of the different purposes for which we make trips what are the purposes for which we make trips starting from work, education, shopping, social recreational, personal business, like visiting post office, bank and so on.

Yes.

(( ))

So, we keep all these things in mind and then fix a particular location as suited for our housing, other related question is how we get the value of s j for all the zones in the urban area. It should be relatively acceptable value, when you say that zone 100 is better for housing then zone 90, there should be some indicative to compare.

We should arrive at some numbers, how do you get this numbers? So, think of the ease of access to all these activities trips made for all the purposes. Then rank a particular zone based on ease of accessibility for all trip purposes and within that you can give weightages for certain trip purposes. For example, educational work you can give a higher weightage and access to health service may be, you may not do it regularly occasionally, you can give a lesser weightage. You cannot give equal weightage for all activities. So, it is a detailed process of accessing suitability or attractiveness of each of the traffic zone for the purpose of housing and it is very difficult to really arrive at very accurate value of h j for all the value of zones in an urban area. You should do a thorough analysis of accessibility to all activities and assign suitable weightages aggregate all these things to get the value of h j. So, is how we need to get the value of a dash i j.

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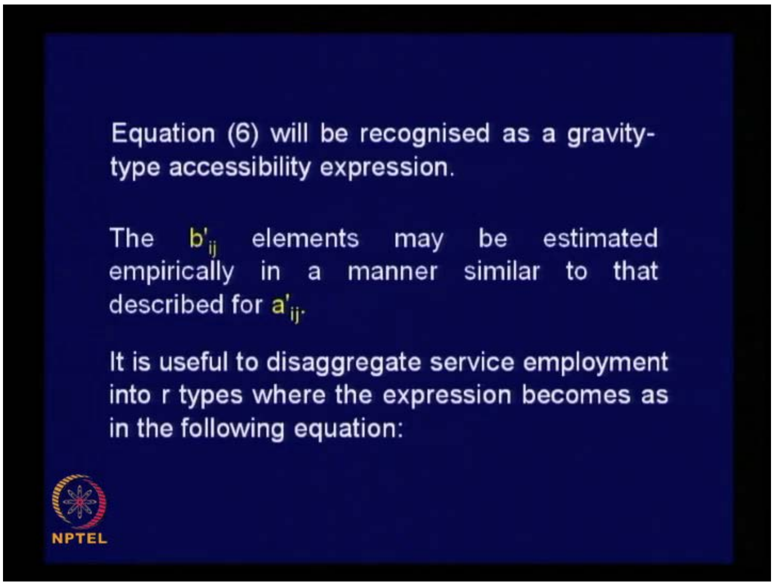

Of course, the equation 6 will be recognized as a gravity-type accessibility expression, as I said earlier and similar exercise as to be done to get the value of b dash i j also and this is related to suitability of a zone to fix what? Population serving employment location and of course, for this purpose we disaggregate service employment into all types as I indicated to you earlier because, you cannot just consider all types of services as similar in nature we have to disaggregate them based on the frequency of access required by the residents.

Some services are accessed on regular basis, daily basis; some services are accessed may be once in a week or alternate days and things like that based on the necessity for accessing services. We can categorize the services into different types as well as based on the other the intensity of activity related to different services also we can categorize if we take education services, as I mentioned to you earlier kinder garden an elementary school, middle school, high school people might access these type of services every day. But still you cannot ah there is no need to locate a high school at frequent intervals, whereas there is a need to locate kinder garden at frequent intervals. So, it is also related to the nature of the service being provided.

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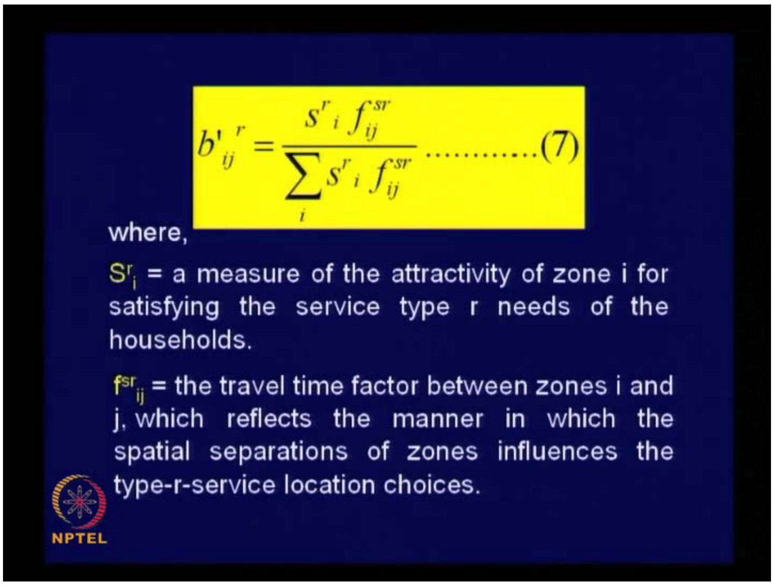

So, this is the equation about you familiar. So, S i r is a measure of the attractivity of zone i for satisfying the service type r needs of the households and f i j s r is a travel time factor between zones i and j, which reflects the manner in which the spatial separation of zones influences the type-r-service location choices. So in this context, can you suggest a methodology to get value of s i r? Let us say r first to educational service in the form of middle school. How will you fix the measure of attractivity of a particular traffic zone to fix a middle school, to locate a middle school. The whole discussion is based on the assumption that the employment opportunity is and population should be spread logically in such a way that the services are accessed easily by the residents.

That is the concept based on which we distribute these two endogenously using the model. How do you find the attractiveness of a zone to locate a middle school? They are locating this facility using the model.

Yes please.

We can do that by the having the number of estimating the number of kids, who have I mean getting a middle class education in an area with that survey we can get to know the attractivity of the students being occupied, I mean occupied in the school and also with the amount of bus services available this is available. So, that how many people can use bus service to reach the middle school?

Yes, to some extent the point is right, but while fixing the service related facility, you must keep in mind the type of facility and its horizon. The (( )) area accessibility is obviously, one factor and then the coverage by a particular service that is also important. By fixing a middle school in zone 100, if you are able to cover more traffic zones than fixing it in 99 then 100 becomes a better zone for fixing the service than 99. So, of course obviously, you consider accessibility and other related aspects.

Yes please.

You have some point; I have one question like as in news we all see that there is a survey for the best cities in the world and all. So, it is the more attractive city for the rejection. So, do the studies come into picture and that is how it is determined to you that which is the best city like today, they say Sidney and Malvern is the best city to stay yeah. So, do the questions and what is the real applications are (( )) applied there sir.

Do not think that way this models very in a religious manner. I would say that those statistics are based on stated preferential approach. They interview sections of the people urban dwellers in different parts of the society belonging to different socioeconomic groups and they assign ranking weightages things like that arrive some number. Because this kind of detailed exercise for macro level comparison is difficult, because it is data intensity unless you get detailed database for all this calculations it may not be working. Mostly the livable cities for the statistics that is given out or based on state preference might be residence or of the respective cities, as well as opinion from general urban transport system planning or urban planners in general experts all over the world.

That is how they get these ranking based on the attractiveness of cities for living. That is how the point to be understood here is getting correct value of s i is crucial, which is a detailed process. As we saw in the earlier case getting the value of h j s i value only will govern the value of b dash i j r, if there is some error here then there will be an error reflected in the value of b dash i j or which in turn will reflect in the value of B and finally, we will be interrupt while checking the correctness of the prediction of the distribution of population and service employee.

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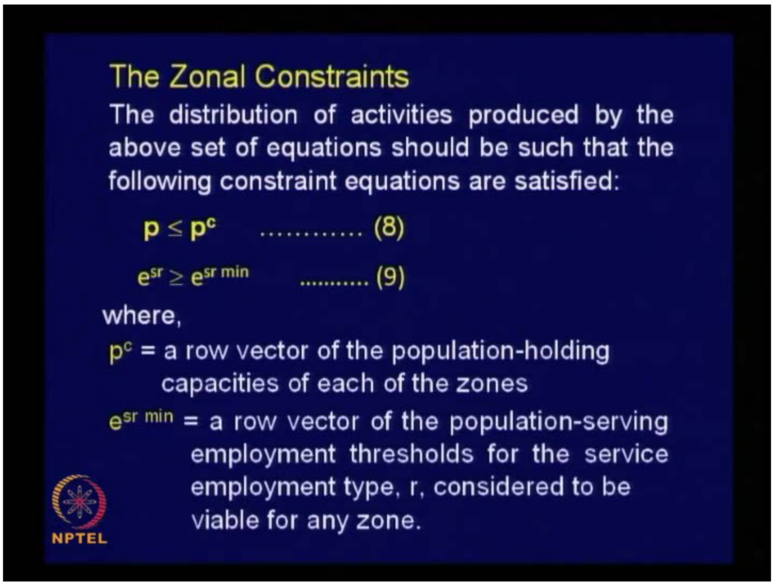

Please remember in this context the zonal constraints, while applying and predicting Lowrys model predicting the horizon year values. You should see that household or population distribution for various zones should be less and are equal to the zonal capacity in terms of number of households or the population for each of the zones and another important factor is e s r should be greater than and equal to e s r minimum. You should provide minimum required service for any traffic zone, this are all zone wise details service type r. Service type r may be available in some other zone by it should be accessible to the other zone, which is associated with the other zone which is associated with the particular service that is how we understand e s r and e s r main. Let us say unfortunately when you apply Lowrys model.

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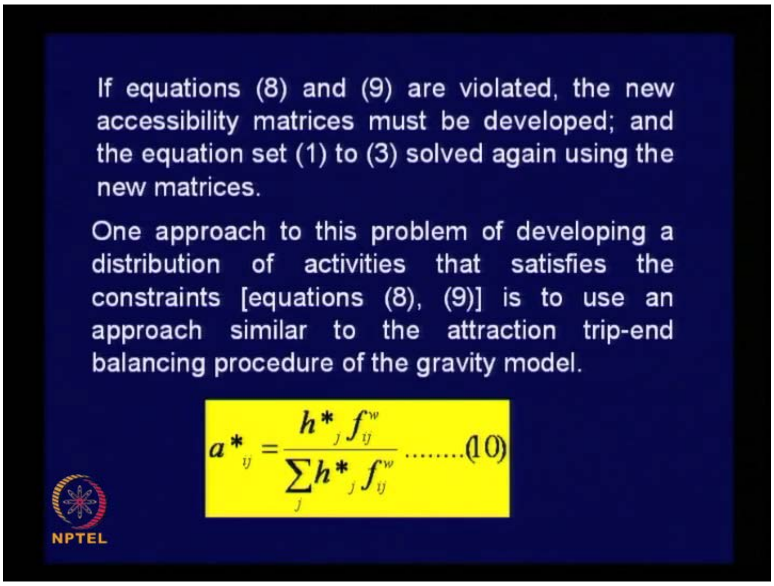

Of course, the explanations are known if equation 8 and 9 are violated not satisfied. What do we do? The new accessibility matrices must be developed fresh values of A and B are to be calculated. First calculating the correct values of a dash i j and b dash i j and the equation said 1 2 3 again, the first 3 equations solve again using the new matrices. How it is being done? One approach to this problem of developing a distribution of activities that satisfies the constraints equations 8 and 9 is to use an approach similar to the attraction trip-end balancing procedure of the gravity model. When they are matching its fine, when they are not matching follow the same procedure. I am just giving you the essence of it, we calculate a new value a star i j is the new value using modified formula, the only modification that you find here is instead of s j we are writing S star j and similarly in denominator its S star j.

That means the problem lies there in accessing the attractivity of traffic zones for residential location in this case. That is the detailed exercise where we are likely to commit mistakes f i j is normally estimated reasonably correctly. So, we must go back and check for the correctness of the estimation of the value of s j, the ranking procedure, weighting methodology, all those things you must check and come back with the new value of a i j and use this a i j value to get value of A.

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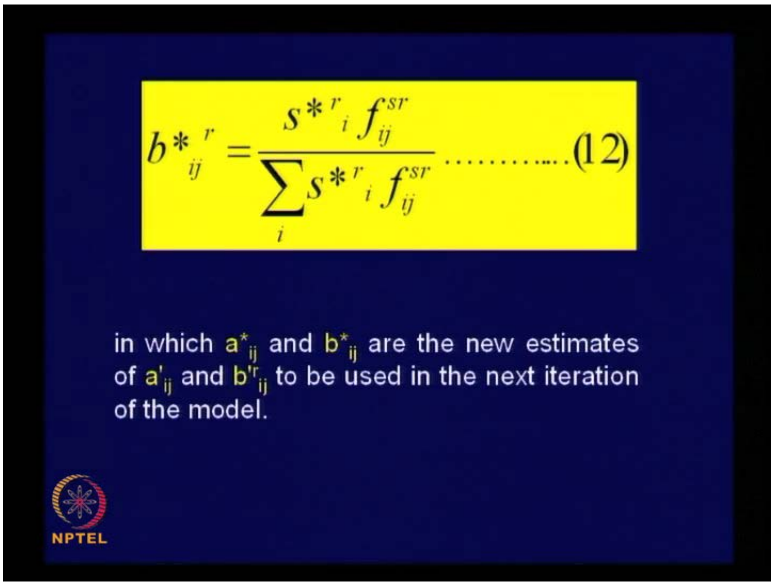

Similarly, to get the new value of b dash i j or for r service b star new value as to be calculated. Here again you can see that s i is the culprit and we have to get an acceptable or corrected value of s i rework the attractivity of so once for locating service type employment service type activities. And then rework or recalculated value of b dash i j r then substitute this values in and the basic equation for B and get new values of B. That is what is given here in which a star i j and b star i j are the new estimates of a dash i j and b dash i j to be used in the next illustration of the model. So, we need to understand that application of Lowrys model of land use prediction is going to be iterative process in practice.

Even though, in the given numerical example it was very direct and satisfy the required improvement in practice, it may not happen. In most cases, you may have to do it iteratively and there is a match between predicted and actual estimated values. This completes our discussion on land use related or transport related land use models. Summarize what we have done today. We just recollected the different steps involved in the Lowrys land use model, then we took up a numerical example to understand the application of Lowrys model and while taking up the numerical example we find that the analysis involves matrix algebra knowledge. So, then we discussed basic aspects, which are relevant to this exercise in respect of matrix algebra involving addition of matrices, subtraction of matrices and multiplication of matrices.

Then we just did the calculation related to the given example, to check whether we are able to apply a Lowrys model systematically to get the predicted values of the population or households, and service employment zone wise. Finally, we discussed about the possibility of the predicted values not reflecting the actual observed values, in that case we have to rework on the attractiveness of traffic zones for residential location as well as attractiveness of zones for location of service related (( )) right. So, with this we will complete our today's discussion, in the next class we will discuss about urban structure which is a new topic right..