Urban Transportation Systems Planning
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Lecture - 29
Intervening Opportunities Model

Module D lecture 9. In this lecture we shall discuss about another type of synthetic model called as intervening opportunity model.

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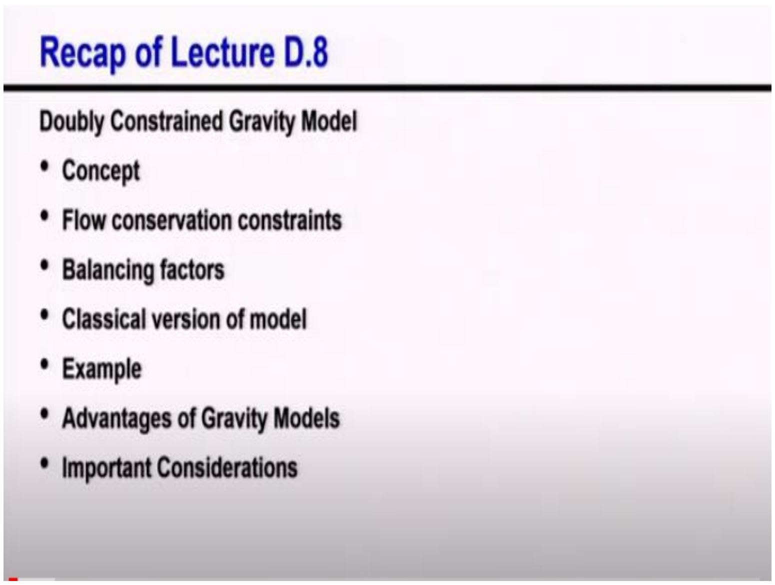

In lecture 8 we discussed mainly about the doubly constrained gravity model. What is really doubly constrained gravity model, what are the flow conservation constraints, how we use the balancing factor, then the classical version of the doubly constrained model and then we took an example to explain you how this model can be applied. Then we also talked about the advantages of gravity model and some important considerations which one has to keep in mind because otherwise they may act as a limitation or disadvantage of the doubly constrained model.

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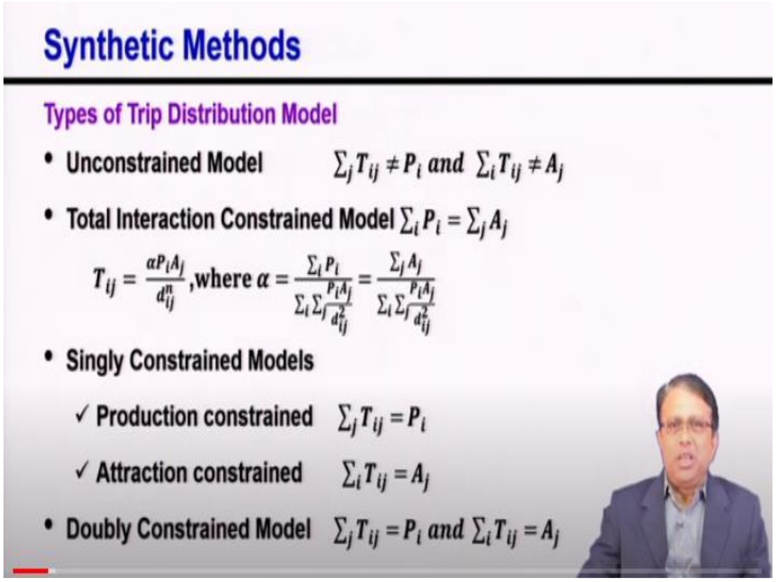

So, with this background, today we shall discuss about another synthetic model. But before I proceed further, I would like to briefly discuss about the various types of trip distribution model within the different categories. Already we discussed about this. You know what is singly constrained model what is doubly constrained model. But I will once again like to briefly mention and then talk about the intervening opportunity model.

Trip distribution model may be unconstrained also. So, far we have not mentioned this one. We mentioned only singly constrained and doubly constrained. But it could be unconstrained that means where we shall not satisfy this T ij sum over j equal to P i. So, you take the cells of a trip distribution matrix and all the cells in a row that should give ideally the production that constraints will not be satisfied automatically by the model.

Also the attraction constraints that means if I take a column in the trip distribution matrix then all the cells in a column if you add that may not give you A j automatically, you know based on the model form or model equation. So, once none of these two constraints are satisfied or none of these two constraints is satisfied automatically by the model form. Then we shall call that model as unconstrained model.

That means row total, column total I mean both ends will not be satisfied automatically by the mathematical formulation of the model. So, then we shall call it as unconstrained model. Then the total interaction constrained model means there the model will ensure all this has to be anyhow ensured. But the question is that whether the model form will ensure this or not. So, the model form in this case will ensure that sum over P i, sum over all zone, the total productions from all the zones should match with the total attractions of all the zones.

So, sum over P i sum over i should be equal to sum over A j. j means all the destination zones. So, sum over all this destination zones. So, generally as T ij equal to alpha into P i A j by d ij to the power n. That is the general form. So, in this case alpha will be equal to as I have written here sum over P i sum over i divided by sum over i sum over j P i A j by d ij to the power 2 or the d ij to the power n in general.

And same way this is equal to again sum of the A j for all the destination zones divided by sum over i sum over j P i A j d ij to the power 2 or d ij to the power n as the case maybe. So, then it is called that the total interaction constrained model. So, model ensuring that what is happening. Then single constrained model which may be again production constrained model that means only that T i j sum over j should be equal to P i that will be ensured automatically by the model form.

And in attraction constrained model only T ij sum over i equal to A j that constraints will be met. The other one will not be satisfied automatically. And doubly constrained model is something where both the constraints will automatically get satisfied by the model form itself.

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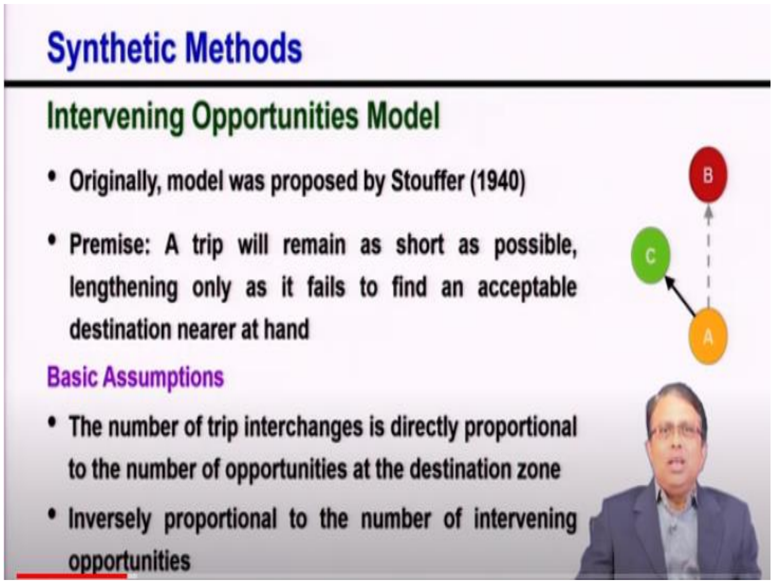

So, with this now let us talk about this intervening opportunity model. What is intervening opportunity model? Now, this was originally actually proposed by Stouffer. And the basic premise is like a trip will remain as short as possible lengthening only as it fails to find an acceptable destination nearer at hand. I think two examples I could remember immediately. One is maybe there is a cyclone or hurricane and you know some kind of natural calamity like that and such kind of things will pass through certain areas.

So, people need to be maybe evacuated. So, where do you want to take them? Would you like to take them to a far distance place? Probably the answer is no. We would like to shift them, maybe if possible and if there is a suitable location, of course, then maybe immediately to the next village which is just outside this area. Or if a suitable place is not available immediately outside that influence areas then you try to take them little away.

So, you will only take those people away when you do not get a suitable destination a suitable place near us. So, that is what is said that a trip will remain as short as possible lengthening only if it fails to find an appropriate destination nearer in hand. If we are not able to find anything nearer then we will take it further. We can take those people further. The other example I can give you can think of like the residential choice locations.

That is again a kind of distribution model in a way. So, you are working in the city and in most cases there are several cities, say for example, Bombay or Mumbai or Kolkata if you take such cities ideally what people would like to do generally speaking if possible people would like to stay in the same building itself. That may be the third floor is the office and people would like to stay in the fourth floor. But people cannot stay. Why?

Because it is so expensive that people most cases will not be able to afford. So, now just think they can stay anywhere along a suburban line. In abroad, metro lines are also connected like that. So, people will probably find out some location in the suburb and then stay there and commute to office. Now, obviously if they can stay somewhere nearby so maybe the main station which is in that (())(09:16)) they would probably like to stay somewhere maybe just which is 4 stations away from the main station.

And if they cannot get a location then only probably they will think of going to a station which is 5th station or 6th station or 7th station. And as you move further actually you are travelling from a distant place. So, the trip length is increasing. So, ideally people would like to locate themselves nearer as nearer possible. So, that means a trip will remain as short as possible in exactly in the same manner lengthening only if it fails to find an acceptable destination near will help.

You want to stay probably but you have to find the suitable accommodation there. If you do not find it you say, okay, let me go little far. You still do not get there then again you travel some more distance may be another one or two stations in this suburban line away from the CVD. So, that is the basic premise. So, assumptions are the number of trip interchanges is directly proportional to the number of opportunities at the destination zone.

So, far in the gravity model what we said? The number of trip interchange is directly proportional to the attraction of that zone. Here something very similar but we are saying it is the number of opportunities proportional to the number of opportunities at the destination zone. So, giving this example of working in the CVD and locating a residential location somewhere in the server, of course where higher chance of settling down or finding a residential place.

Obviously if there are more housing opportunities say just imagine a near a suburban railway station lot of new housings have come up and you can easily get probably a flat in rent. Obviously where more such flats are available more opportunities are available in general. I am speaking at in that given content. More will be that trips will more trips will terminate there. So, the number of trip interchanges is directly proportional to the number of opportunities at the destination zone.

More the opportunities in the destination zone, more trips are likely to get terminated there. Second it is inversely proportional to the number of intervening opportunities. Now somewhat similar to gravity model again but also different in some sense. What is similar because there we say inversely proportional to distance or cost or time. Here we are not saying directly inversely proportional to cost, time or distance but here we are saying inversely proportional to the number of intervening opportunities.

That means what? It is another way of measuring indirectly as we are saying the deterrence we were trying to estimate or trying to quantify in case of gravity model. Here we are in the same manner we are trying to say what are the opportunities in between intervening opportunity? Inversely proportional that means probably you are more likely to, you will likely you are getting settled maybe in the 5th suburban station from the CVD.

So, what will be your probability or chance that you will get settled down in the 5th suburban station? That will inversely get proportional to the number of opportunities in between. That means how many opportunities are there in 1, 2, 3 and 4. Or considering the 5 also that will decide what is the probability of you locating in a catchment which is around the suburban station 5.

So, that means if I have more opportunities in between then I have less chance that I will go up to suburban station five. So, that is the thing that in between if there are a lot of new housings coming up. Naturally instead of going to zone or station 5 people will probably try to settle down more or more people will settle down probably in zone 3 or zone 2 wherever such opportunities are coming up.

So, we can easily say the number of trip interchange is directly proportional to number of opportunities at the destination zone and inversely proportional to number of intervening opportunities. Just think that the same example maybe I could that is what I could remember now. Maybe there are so many other examples can be given that you are trying to locate yourself. What is the chance that you will locate yourself in the 5th suburban station?

It will depend on how many opportunities are there in the fifth suburban station. The more the opportunity the more likely the trip will terminate there and also it will depend on how many opportunities that they are in between intervening opportunity. That means how many housing opportunity it will be there in station 1, station 2, station 3, station 4? And naturally if more opportunities are there then people would like to locate themselves closer as close as possible.

So, then there will be less chance or less number of people will actually go and settle down in suburban station 5. So, very logically we can understand or we can relate such kind of things.

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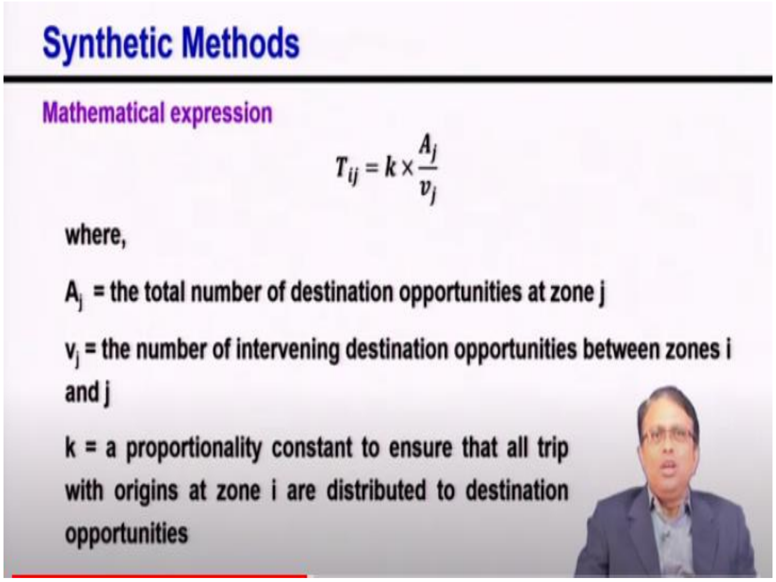

Mathematically we can write then T ij is proportional to A j. What is A j? A j is the total number of destination opportunities at destination zone j proportional to that and inversely proportional to intervening opportunity. So, what is inversely proportional to v j where v j is the number of intervening destination opportunities between zone i and zone j. Remember we are talking everything this i and j in order of distance.

That is the catch of it and that is very very important when you are talking about this intervening opportunity model. Just zone 1 is closer then zone 2 then zone 3 then zone 4 then zone 5 something like this then in order of the distance in order of distance. So, that is what is very very important and of course k is proportionality constant. Why? Because this will ensure that all trips with origin zone as i are distributed to destination opportunities proportionality constant. So, that is what is the general formulation?

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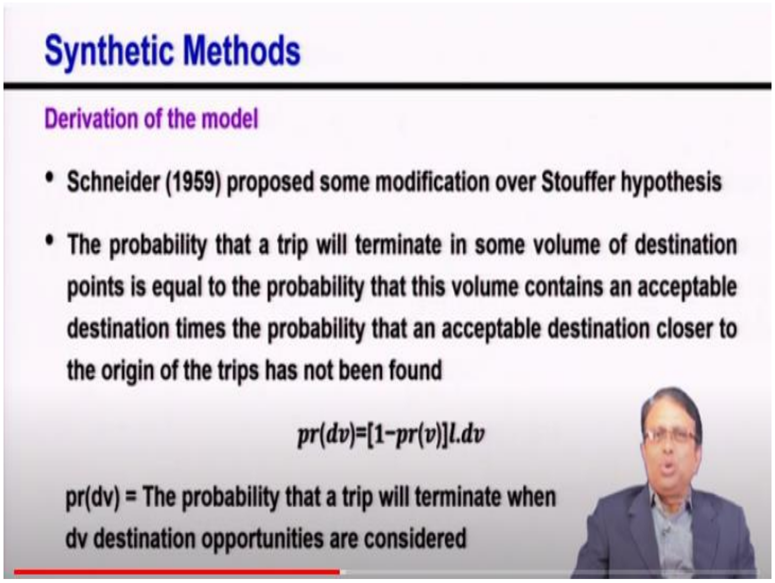

Now Schneider proposed some modification of the Stouffer hypothesis and we are not going into details. It is not within the scope of the present lecture may be. But what was shown that the probability that a trip will terminate in some volume of destination points is equal to what? The probability; that this volume contains an acceptable destination. That means I was giving you about the example of 5th suburban station.

So, what is the probability that a destination can be found out in around that 5th suburban station times the probability that an acceptable destination closer to the origin of the trip has not been found. Means what? Multiplied that the probability that; a destination could not be found out in suburban station 1, 2, 3 and 4. So, we can write like this probability of dv, dv you just consider a band or a ring around the production zone i.

We can consider many rings around i and as the i or j is increasing that means they are going away or the distance wise higher time wise higher from zone i. So, just consider a small ring of dv at a distance v from the origin zone i. So, then as I said it is what? It depends on two things. One is that probability that an acceptable destination closer to the origin of the trip has not been found out.

That means we can say 1 minus probability of v because at a distance v this small band or ring of d v exist. So, within this v what is the probability that a destination could not be located that is 1 minus probability of v into l dv. So, probability of dv is what? First it is that the probability that a trip will terminate when dv destination opportunities are considered.

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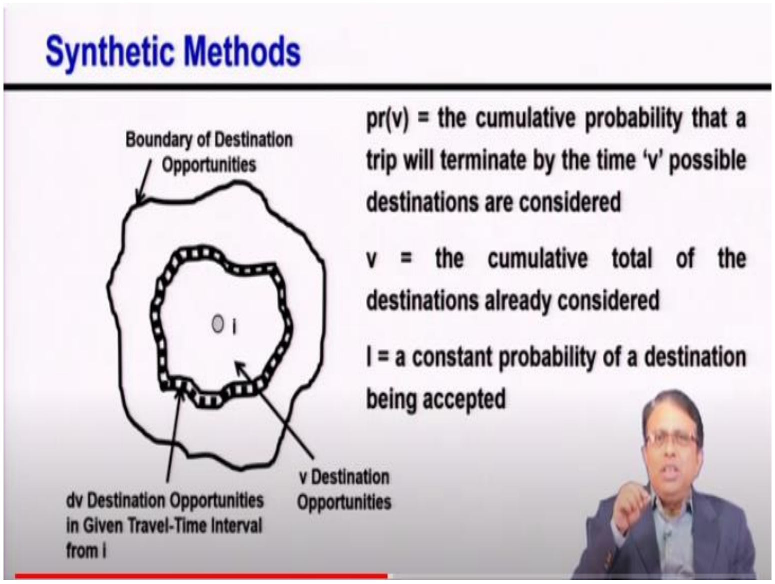

And probability of v is that the cumulative probability that a trip will terminate by the time v such rings or v such possible destinations are considered in order of distance or time. So, you can see i is the center and around that at a distance v in between there are v destinations and then you are considering the dv destination just outside v. So, v is the cumulative total of the destination already considered and l is what a constant probability of a destination being accepted.

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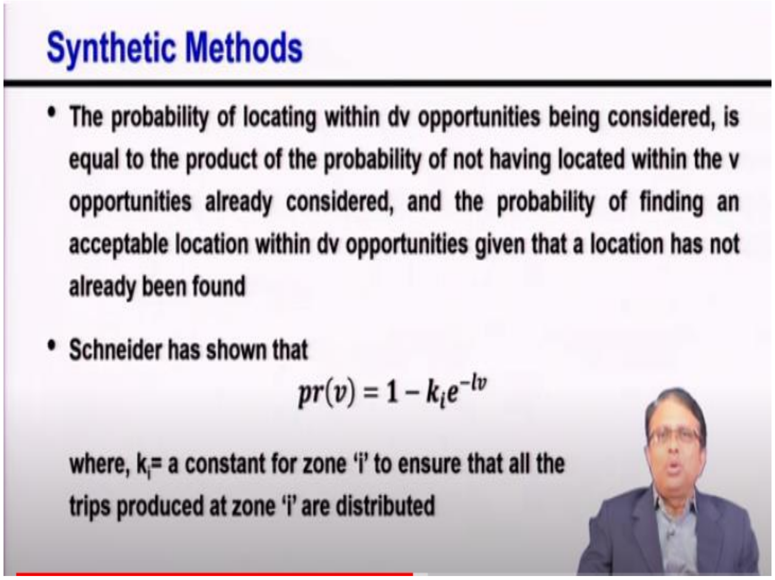

So, for that is so what we said? I am trying to repeat it again in a slightly different form not very different. The probability of locating within dv opportunities being considered the probability of locating within dv opportunities being considered is equal to the product of the probability of not having located within the v opportunities 1 minus probability of v. That is what I say the same thing.

And the probability of finding an acceptable location within dv opportunities given that a location has not been already found out. So, into l v. Schneider also has shown that probability of v can be expressed as 1 minus k i into e to the power lv. The lv all meaning remains the same k i is what? k i is a constant for zone i to ensure that all the trips produced at zone i are distributed. You can relate it very easily with various types of distribution models I mentioned once again today in the beginning.

Unconstrained model and then production constant model, attraction constant models. So, these are basically bringing back all those things.

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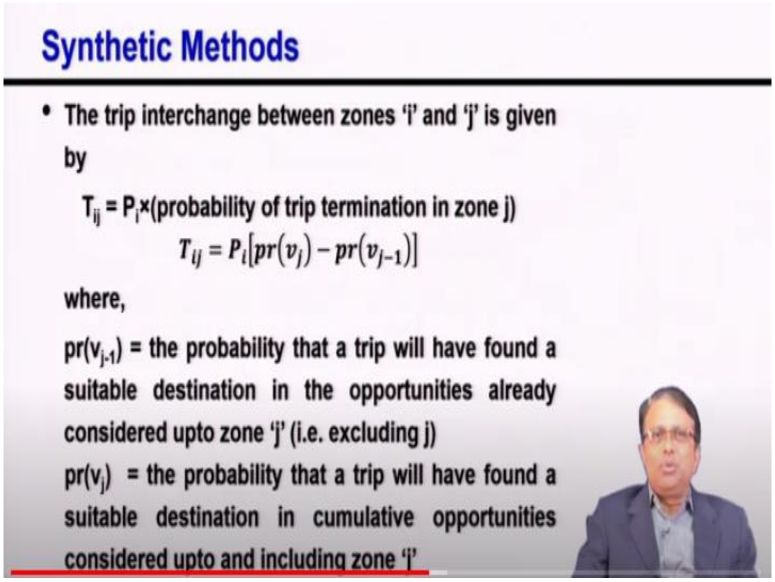

Now the trip interchange between i and zone j is given then by this formula T ij equal to P i total trips produced in zone i into what is the probability that a trip termination will happen in zone j. Now, we are no more talking about v or d v but we are talking zone j exactly in the same way you can think of like dv small band or a small ring away from the production zone i. So, what is the probability of trip termination in zone i?

One is the probability of trip terminating in zone j within zone j the whole band or whole width or whole distance minus probability of locating into v j minus one. That means we have 1, 2, 3, 4 like that, we are talking about the jth zone in order of distance or time. So, what we are saying probability of v j minus 1 means the probability that a trip will have found a suitable destination in the opportunities already considered up to zone j but not including zone j.

It is actually excluding zone j. What is the probability of locating a trip within that distance or within that many zone? So, number of zones will be what j minus 1 because we are not including jth zone. And probability of v j will be what? Same thing. The probability that a trip will have found a suitable destination in cumulative opportunity is considered up to and including j now.

The earlier one excluding j so up to jth zone this case and previous one the probability of locating a trip up to zone just outside j up to that excluding jth zone. So, up to j minus 1th zone. That is what it is. So, that is the difference. Cumulative probability difference in cumulative probability that trip will terminate in the jth zone or jth ring or jth band, whatever you say.

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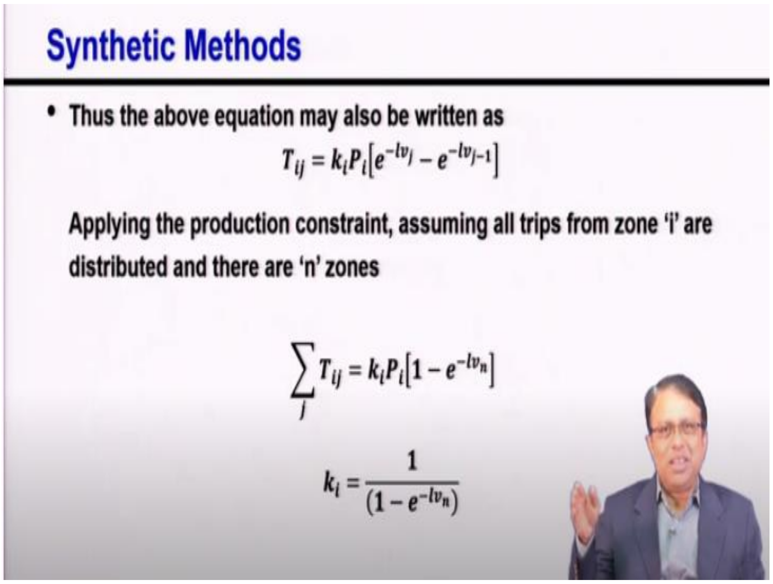

Now considering that probability of v equal to 1 minus k i into e to the power lv that way if you put then you can put T ij equal to k i P i e to the power minus lv j minus e to the power minus lv j minus 1. Now applying the production constraints if we apply the production constants means what? T ij sum over j should be equal to P i. That is what let us do. Then in that case what you find k i into P i into e to the power minus lv j minus e to the power minus lv j minus 1 equal to P i.

Sum over this equal to P i. So, then what you find? You get P i will be there. P i will cancel and then you get k i equal to 1 by 1 minus e to the power minus lv n. Why you are getting 1? Because you say 1 to 2 and then 3 then 4. Sequentially it is coming. So, the term will cancel out and you will finally get only what will remain 1 minus e to the power minus lv n. Because all intermediate zone you can see here e to the power minus l v minus e to the power lv j minus 1. So, what will be the earlier one?

e to the power lv j minus 1 minus e to the power l minus lv j minus 2. So, plus minus will get cancelled out for all zones. So, what will remain is only 1 minus e to the power minus lv n. So, here you can find out the value of k i.

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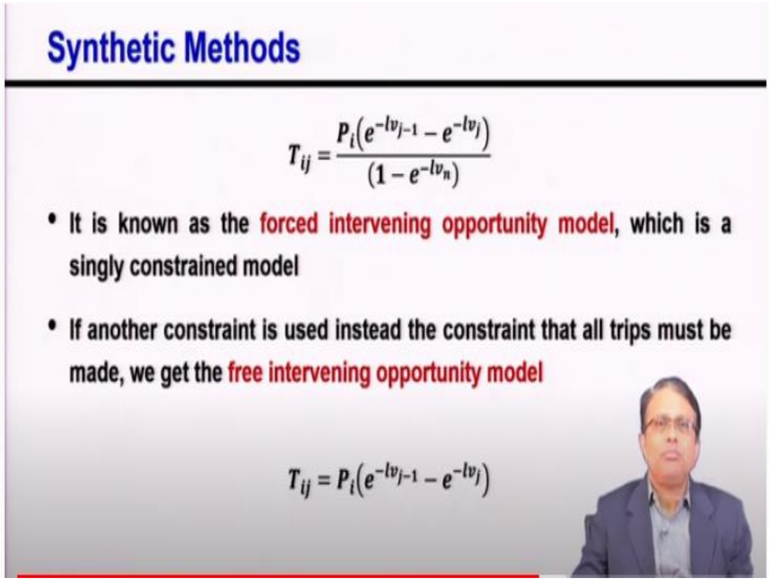

So, once you have got this that is the equation you get as it is shown here. So, this is a forced intervening opportunity model, which is singly constrained model. Production constant so singly constrained and because this is constrained so it has to match the production. So, you can also call it as forced intervening opportunity model. If you add another constant instead of the constant that all trips will be made then you get free intervening opportunity model.

So, what will happen? That k term will not come in the previous one? What we say? That k term will not come into picture. So, it will be simply P i e to the power minus v j minus 1 minus e to the power lv j. This k equal to 1 minus 1 minus e to the power minus lv n. That v j that will not come. This is called as free intervening opportunity model. That means this production attractions will never match. They will not match even the total number of trips also we are not forcing.

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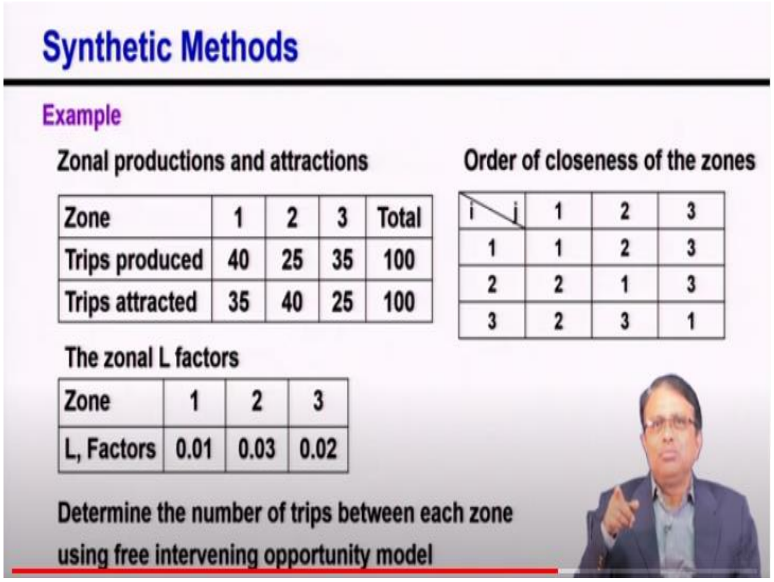

Let us take an example. I have given three zones here trips produced. In this three zones trip attracted to this three zone and then order of closeness. Remember this order of closeness is very important in this case. So, what is the order of closeness like the column indicates the first 1, 2, 3 indicates what is the closeness of zone one? So, one if you consider the closest zone is 1 then next is 2 next is 3. For zone 2 the closest zone is actually 2 then 1 then 3. The closest one is 3 then 1 then 2. That is the order of preference and here it is the L value for zone 1, zone 2, and zone 3.

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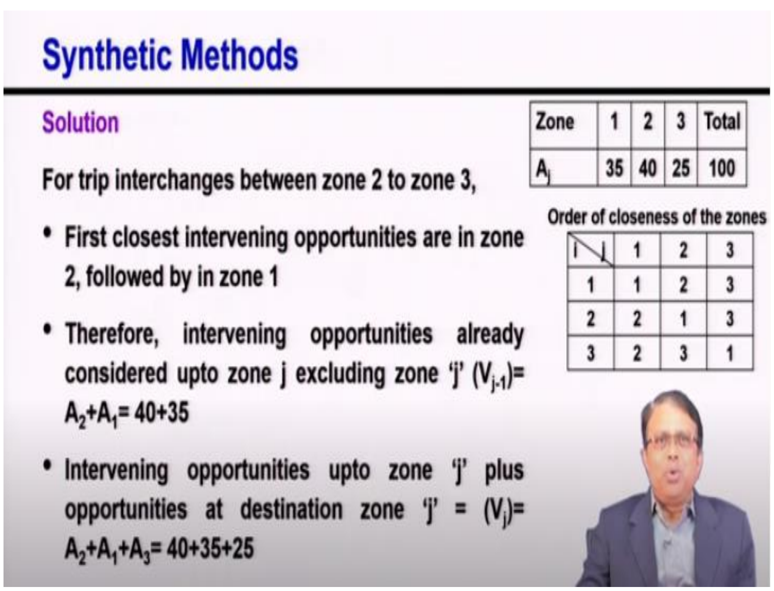

Now if we want to try to distribute this thing let us clearly understand this part. This is the very important component. Otherwise we will get confused. So, for let us say example, we want to explain you the trip interchange between 2 and 3. So, from 2 up to 3. So, with two as origin, zone 3 stands where? Zone 3 is, so first closest point intervening opportunity closest to 2 is what? First 2 then what 1 as you can see and then 3. So, the intervening opportunity up to if you are seeing zone 3 means v j minus 1 means not including zone 3.

So, up to zone 3 but not including so upto zone 3, what will be there? Zone 3 is the third zone in order. So, before that just before zone 3 zone 1 and just before that zone 2 itself. So, attraction of zone 2 and zone 1 will be there 40 plus 30. Then up to zone j means along with this we are talking about zone 2 to zone 3. So, j minus 1 whatever you got earlier. Now the jth zone that is the zone 3 also will be added.

So, attraction of zone 3 also will be added. So, you just simply add now also 25 with that. So, for t plus 35 earlier up to v j minus 1 and v j will be 40 + 30 + 25. That clearly explain the whole thing.

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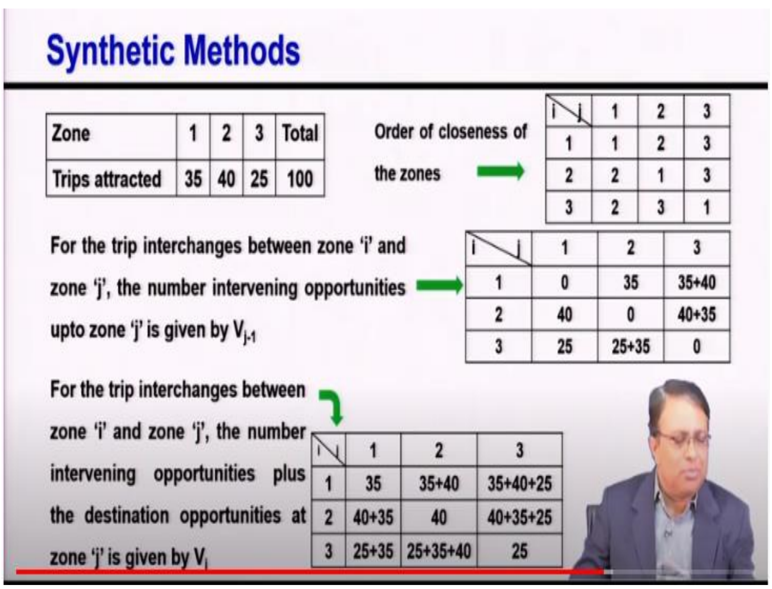

Zone	1	2	3	Total
Trips attracted	35	40	25	100

i \ j	1	2	3
1	1	2	3
2	2	1	3
3	2	3	1

i \ j	1	2	3
1	0	35	35+40
2	40	0	40+35
3	25	25+35	0

i \ j	1	2	3
1	35	35+40	35+40+25
2	40+35	40	40+35+25
3	25+35	25+35+40	25

So, like that; if you consider the trips attracted 35, 40 and 25. So, order of closeness of the zone I have just reproduced it from the previous one as it was given originally so that you understand clearly. Then two things I am showing here. For each origin zone and for each of the destination zone j, each origin zone i is distinction zone j considering the order of closeness what you will consider when you consider up to v j minus one and then what you consider when you consider up to and including jth zone.

The basis is exactly same as I have explained earlier for one element from 2 to 3. Exactly the same way I have shown the value that what you can opportunity is you should consider when you talk about up to j minus one. That means up to j but not including jth zone in order of closeness and when what you would consider up to v j. Both I have shown.

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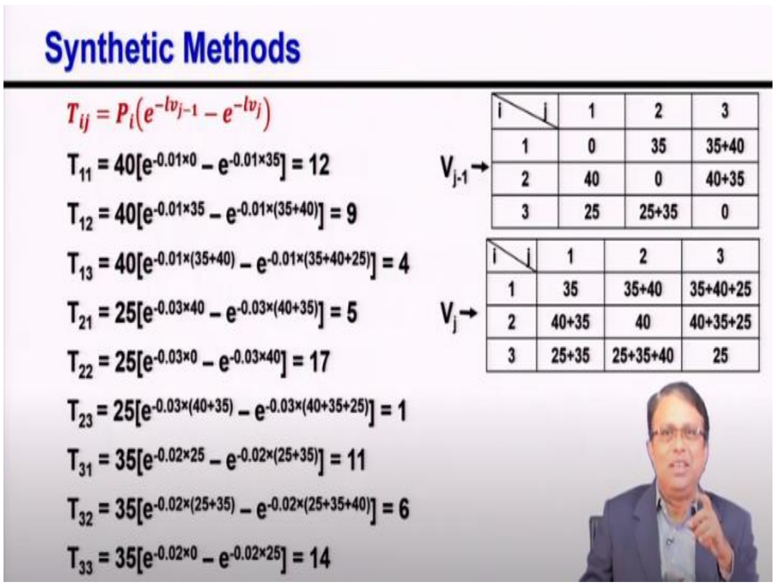

So, accordingly once you have done that then this basic equation is known. Remaining thing is not so complicated. The only complicacy is that order of closeness and accordingly to understand clearly what are the zones and their opportunities I should include in what calculation which I explained clearly in the last two slides. So, here you will use the equation T ij equal to P i into e to the power minus lv j minus one minus e to the power minus lv j. It is unconstrained.

So, we are not putting any constraint. So, accordingly you calculate T 11, T 12, T 13 and like that 2 1 2, 2 2 3, 3 1 3, 3 2 3. Remaining calculation is very straightforward. And here also I have said then from the previous one I have borrowed these two tables for showing that what you really need to consider as the opportunities when you are talking about various j's and then opportunities up to j minus 1 and opportunities up to j and up to means including j.

Those tables are also referred here so that easily you can understand how the calculations are being done.

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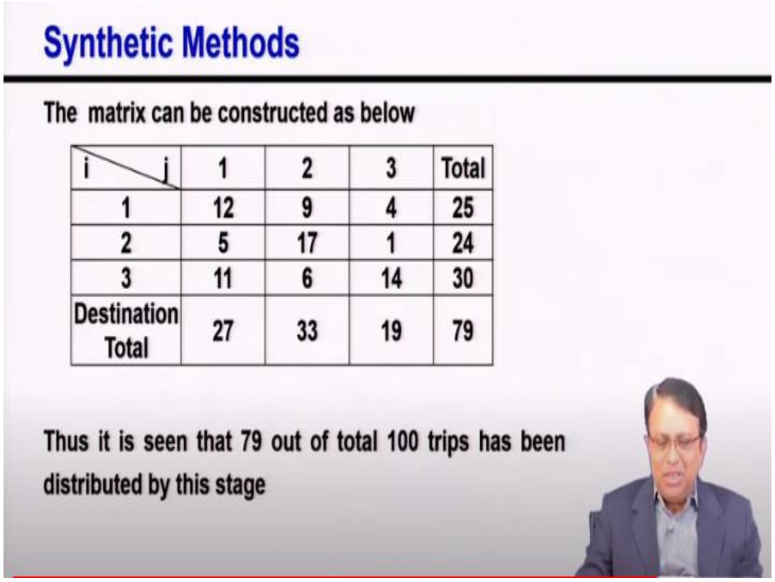

i \ j	1	2	3	Total
1	12	9	4	25
2	5	17	1	24
3	11	6	14	30
Destination Total	27	33	19	79

So, now if we see that trip distribution matrix what we find here attraction wise zone 1 25, zone 2 24, 30 and 79 is the total number of trips. That means we wanted to distribute 100 trips but because this is an unconstrained model. So, how many trips have been distributed? Only 79 instead of 100. So, all trips have not been distributed because it is an unconstrained model. So, the model automatically will not ensure that.

But then shall we leave it like this? No, we shall not leave it. So, what we can do? The answer is again simple and known to you. You remember the singly constrained gravity model. When we took the production constrained models the attractions were not matching. So, what we did? We want this attraction to be this when we target this we got this. And that same example you want 80 when you target 80 you get 70 marks.

So, what does it indicate? You should then target 90 or more than 80 definitely. More than 80 you should target. Then probably you will end up getting somewhere around 80. But if you only target 80 you are not going to get an 80. So, same kind of thing I have shown you earlier when I talked about how these adjustments are required to be done for singly constrained gravity model. The same way you can do it here.

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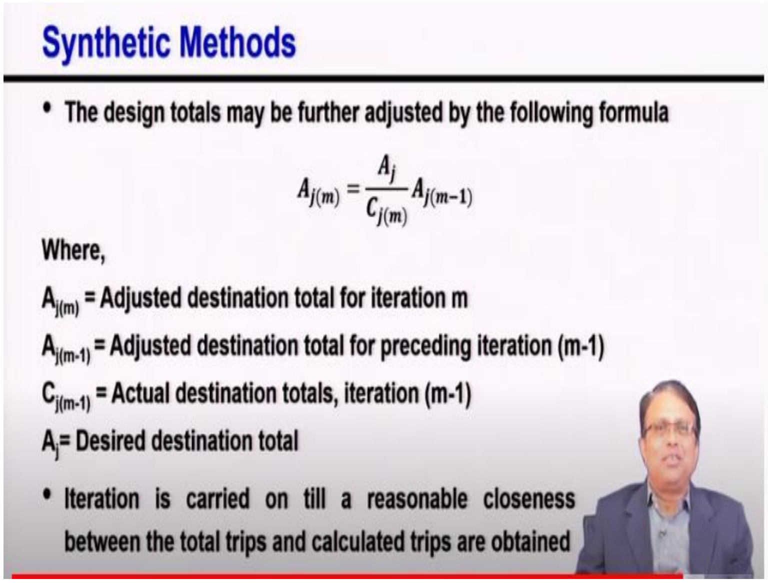

So, I have only shown you the formula the design totals may be further adjusted using the following formula. So, now you will think that my attractions are different. Modify the attractions and then exactly productions will not change, order of closeness will not change, the procedure for calculation will not change but with the revised attraction values what we used in this model. So, the revised attraction values will come. So, what you will get here is basically the target will be different.

And then with this revised target you will modify your target as I have shown you there and remember that a model could be you can think little carefully. A model could be production constrained model, a model could be attraction constrained model. What kind of model and accordingly you have to keep the do the adjustment. Here also similar kind. The target could be different.

So, accordingly the procedure will not change. The way the order of closeness will not change. But the other things will change. I am showing you A j values. What A j values you have used? So, this A j values you need to modify. And then do iteration and 1, 2, 3 iterations you need to do and then finally you will get something which will ensure that you have actually distributed all the trips.

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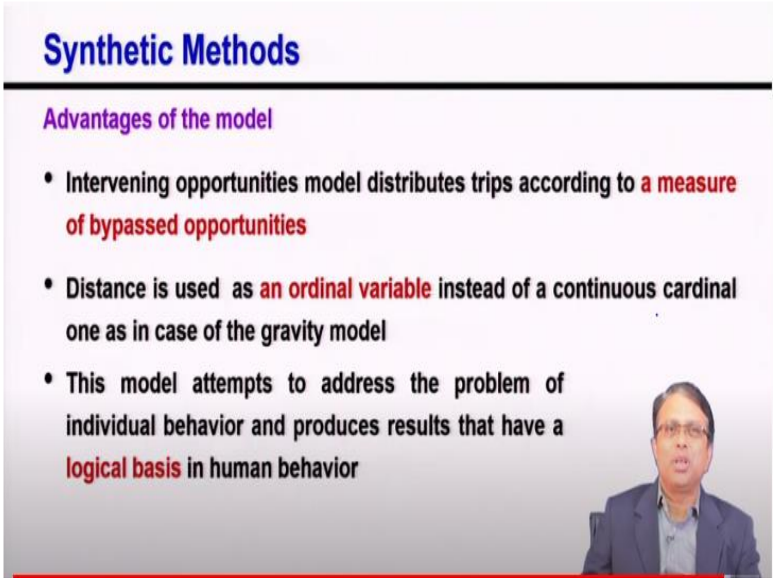

And with this I would say some of the advantages as you know that intervening model opportunity distribute trips according to measure of bypass opportunities or consider the intervening opportunity. Distance is used as a ordinal variable and then this has got a logical basis consideration. As I give you an example that 5th station or if there is a natural calamity, you want to shift people you want to shift to a nearby area only which is safe.

Of course if it is possible. And there are opportunities you would like to shift them near or rather than shifting to a far distance place.

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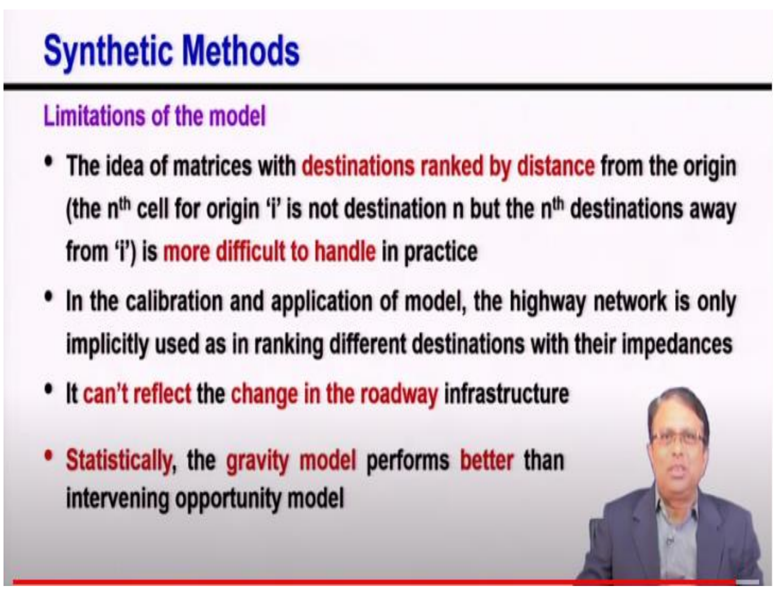

So, there are limitations as well. As they said the data with the destination rank by distance from origin is more difficult to handle in practice because the order is very important. And not like simply any i, j gives the distance and I will use a gravity model, that kind of thing you cannot do. So, this order closeness is very important and sometimes it is confusing as well and difficult. So, in the calibration and application of the model the highway network is only implicitly used. We are not directly using the travel time or so.

But yes indirectly there are considerations that we are talking about intervening opportunities there in some form or other we are considered. It cannot reflect the change in the roadway infrastructure. You cannot say simply I modify the transport network how it is going to change. And generally gravity models are found to perform better than this intervening opportunity model.

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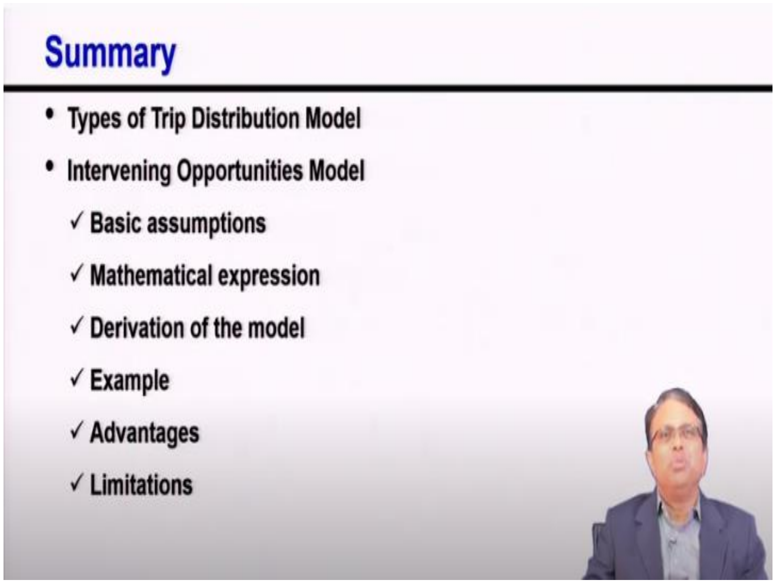

So, altogether what we discussed here about the types of trip distribution model and in details about the various aspects of intervening opportunity model including an example and talking about their advantages and limitations. So, with this I close this lecture, thank you so much.