Traffic Engineering
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Lecture 35
Operational Analysis of Signalized Intersection - I

Welcome to Module E lecture 9. In this lecture, we shall talk about the operational analysis of signalized intersection.

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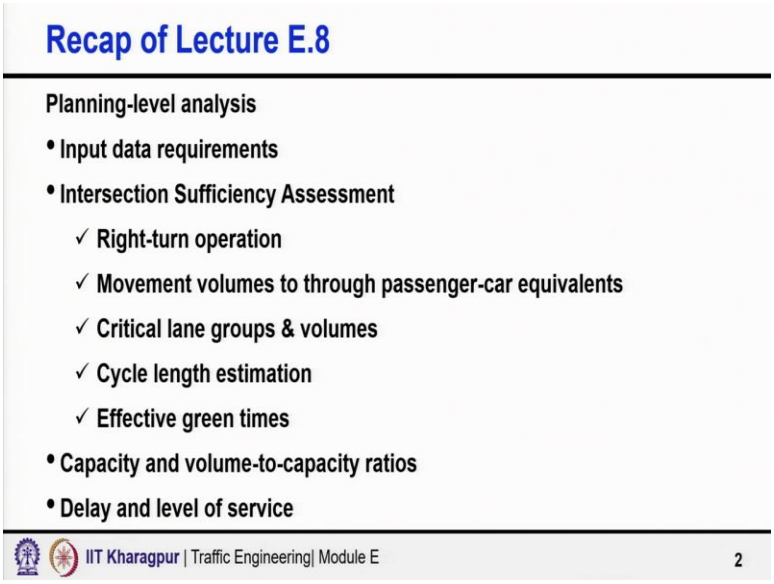

In lecture 8, we discussed about the planning level analysis, I mentioned to you about the data requirements, I mentioned to you about the input data requirements, the procedure to carry out intersection sufficiency assessment, different steps namely deciding about the right turn operation, movement volumes to through passenger car equivalent, then identification of critical lane groups and volumes, estimation of cycle length calculation of effective green time, then calculation of capacity and volume to capacity ratios and finally, what is the resulting delay and therefore, the level of service.

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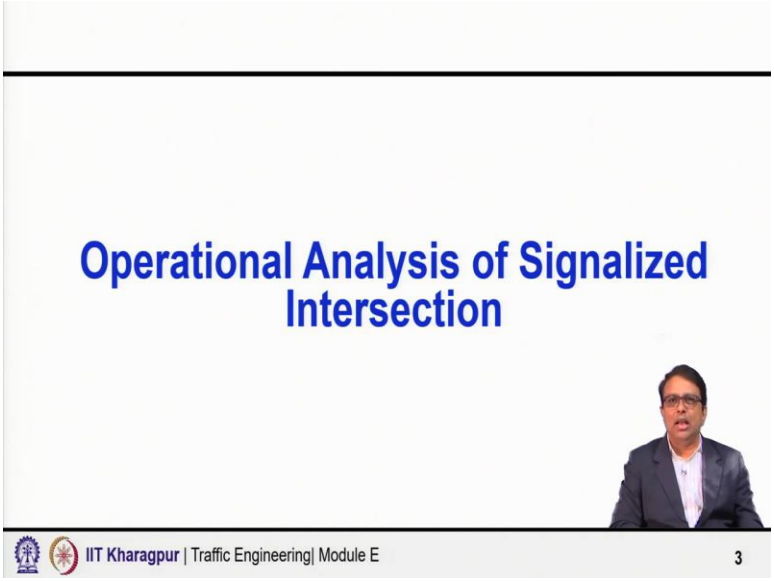

Now, today, we shall start our discussion about the operational analysis of signalized intersection. So, the previous lecture was on planning level analysis and today we shall focus on operational level analysis.

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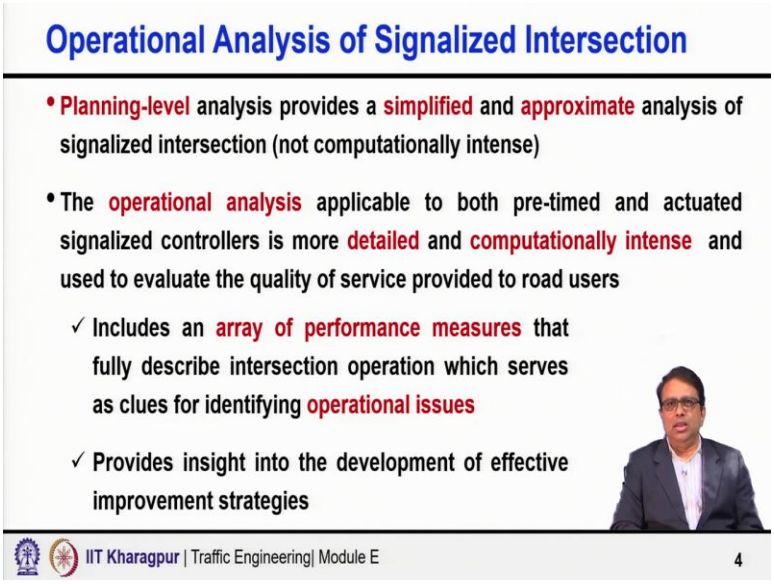

Now, planning level analysis was actually simplified and approximate analysis, which was not computationally intense. And what we are going to discuss today maybe today and also the next two lectures. The operational analysis is applicable to both pre-timed and actuated signal controller

you are aware of what is pre-timed signal, what is actuated signal controller or operation and these operational analysis is more detailed and computationally intense.

And this is used to evaluate the quality of service provided to road user. So, this operational analysis includes an array of performance measures that fully describe the intersection operation and is helpful to identify the operational issues also this provides an insight into the development of effective improvement strategies, what improvement is really necessary.

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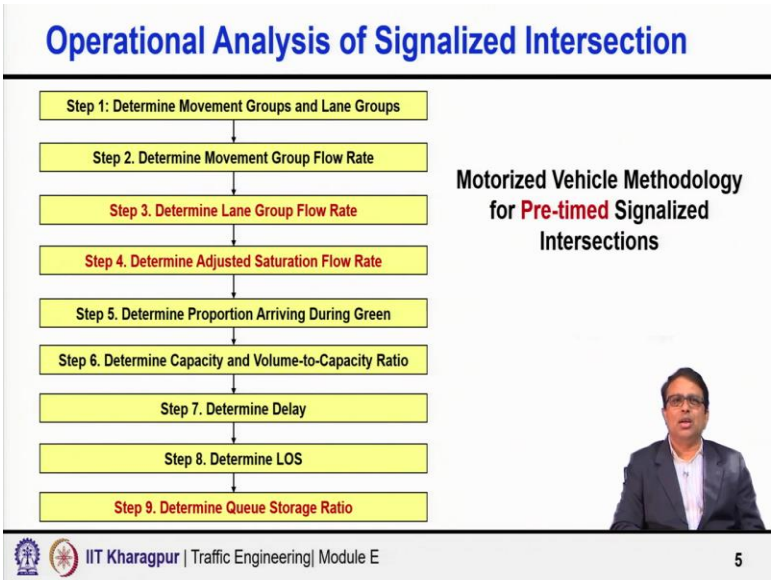

Now, like the planning stage analysis, this operational level analysis also is carried out following these 9 steps and this is actually for motorized vehicle and for pre-timed signalized intersections. So, remember that we are actually targeting here the motorized vehicle and for pre-timed signalized intersections.

Many of the steps are somewhat common to what we have discussed earlier. For example, step 1 determination of movement groups and lane groups you are already familiar with this terminologies, what is movement group, what is lane group and then determination of movement group flow rate this is also known to us we have discussed earlier.

But step 3 and step 4 are somewhat different more detailed, and we have not discussed earlier. So, this will be something new and something important for you in this operational analysis. How to determine the lane group flow rates? And also how to determine the adjusted saturation flow rate?

Now, in today's lecture particularly we shall discuss in details about step 3, but not about step 4 step 4 will be covered in the next lecture. Then step 5, determine proportion arriving during green, determine then capacity and volume to capacity ratio, the delay and finally determination of level of service. Also in step 9, we shall talk about how to determine queue storage ratio. Now, some of these things will be dealt in today's lecture, while other things will be dealt in continuation to today's lecture, maybe tomorrow and some of the team again in the subsequent lectures.

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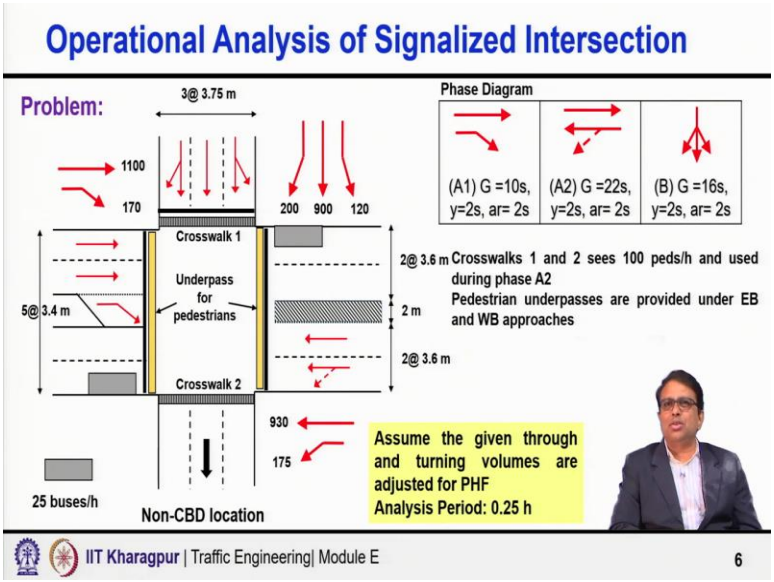

Let us, take an example problem, because we shall explain and we shall discuss the methodology step by step methodology. But it will be easy for you to understand and appreciate the calculations if we take the take a problem also. So, we pick up a problem, this you can see a four arm intersection there are four approaches north south and east west north south approach is one way, the other direction movement is not happening movements are always happening from north to south in that direction along the road.

So, it is one way, the east west movement is two way. Now, this is an intersection where pedestrians are present, but the east west corridor which is a two way corridor there, the pedestrian crossings are provided with grade separated facilities. So, there are underpasses on both sides of the intersections to take the pedestrian.

So, pedestrian vehicular conflict is not there on the east west corridor. But on north south, yes, there are at grade pedestrian crossings so at I have shown it here as crosswalk 1 and this is the

crosswalk 2. So, at grade pedestrian crossing is happening. But this two ends of the east west corridor shown as yellow bar these are actually indicating underpasses for pedestrians.

Now, the traffic movements are shown here you can clearly understand now the there are exclusive lane for right turns on eastbound approach and there are all exclusive lane westbound the straight is exclusive, but then the left side lane straight and left are shared. So, it is a shared lane and the left turning vehicles they have to yield to the pedestrians which are using the crosswalk 2. So, this is actually a permitted turn not a protected one. And therefore, it is shown using the dotted line.

Now, the southbound movements are happening in three lane protected the turning movements are protected that is why because there is grade separated facilities for pedestrians so underpasses are there. So, they are shown as solid lines the left and right turns and their left and right is happening from the shared lane.

So, looking at this and based on all previous discussion, it is easy for you to accept that maybe we can operate this intersection with three phase signal. In phase 1 or phase A or A1 what we are doing Phase A1 we are, what we are doing? We are allowing this straight and the right turn for the eastbound approach.

Then in phase A2 it is both are called A A1, A2 because the straight towards east that movement is continuing the right is stopped and then the westbound movements are allowed. So, westbound both straight and left both movements will happen. Then in phase B actually we are stopping all the movements from eastbound and westbound approaches. We are allowing the movements to occur or to happen on the southern bound a southbound approach and all movements are allowed from the southbound approach and all are protected the left and right turning movements. So, that is what is the phasing for this.

Now, crosswalk 1 and 2 sees 100 pedestrian per hour and use during phase A2 quite logically, and pedestrian uderpasses are provided as I mentioned under eastbound and westbound approaches. Assume that the given through and turning volume are adjusted for peak hour factor. So, we do not have to do any adjustment. Normally what we do hourly flow to peak hour or peak 15 minute, hourly flow rate that is what we convert. So, here that is not necessary because what I am saying that assume that the giving through and turning volumes are adjusted for peak hour factor and the

analysis is period is 0.25 hour this will be used subsequently may not be used today, but we shall continue our lecture tomorrow also. So, that time it will be required.

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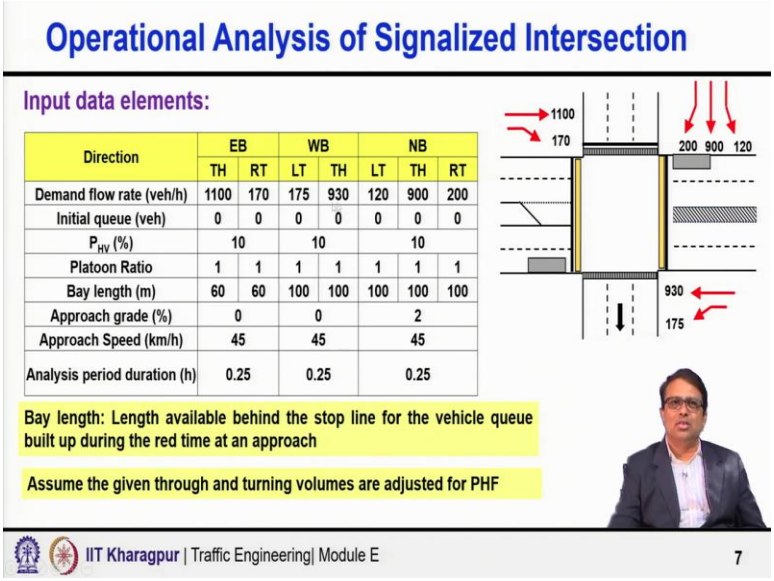

Now, coming to the input data elements therefore, we have eastbound, westbound and northbound through and right and for northbound through left and right. Eastbound, westbound and rather it is south bound to northbound because that is what is basically southbound approach. So, it will be southbound.

Now, the demand flow rates are given you know 1100, 170 and then 930, 175 and then 120, 900 and 200. Then the initial queue is assumed as 0 for this particular example problem, initial percentage of heavy vehicle is taken as 10 percent on all approaches, platoon ratio, you already know it is taken as 1 bay length is given. Now, bay length is something new to you, bay length is basically the length available behind the stop line.

So, if this is the stop line, what is the queue length that is acceptable maximum. So, length available behind the stop line for vehicle queue built up vehicle queue built up during the red time at an approach. So, it tells you when this is red, then vehicle will stand in a queue, how much or how long that queue can go, it can go up to the bay length that means up to that 60 meter or 100 meter as given here, up to that length the queue may be accepted during the red.

This is decided based on otherwise it will start affecting the operation of the upstream signals. So, there are other considerations. So, the bay length is important. Assume that the given through and

turning vehicle volumes are adjusted for peak hour factor this I have mentioned in the previous slide as well. Approach grade is taken as 0, 0 and 2 percent and approach speeds are 45, 45 and 45 all cases 45 kilometers per hour and the analysis period is 0.25 hour in overall.

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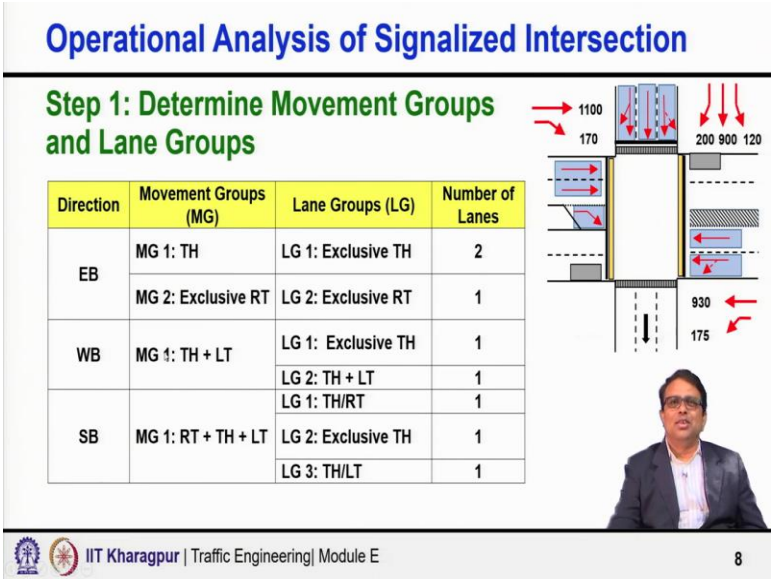

Direction	Movement Groups (MG)	Lane Groups (LG)	Number of Lanes
EB	MG 1: TH	LG 1: Exclusive TH	2
	MG 2: Exclusive RT	LG 2: Exclusive RT	1
WB	MG 1: TH + LT	LG 1: Exclusive TH	1
		LG 2: TH + LT	1
SB	MG 1: RT + TH + LT	LG 1: TH/RT	1
		LG 2: Exclusive TH	1
		LG 3: TH/LT	1

So, we this data our first step is to determine the movement groups and lane groups, with whatever understanding you have developed already you can easily do that. So, you can say if we considered the eastbound approach, then obviously exclusive lane all are exclusive lane, 2 through lane and 1 right turning all are exclusive lane.

So, obviously there are two movement groups and two lane groups one to one correspondence movement group and lane group similar because no shared lane. For the westbound approach left lane is a shared lane straight and left and the next one is a straight. So, the movement group will be only 1 but lane group it will be 2. So, lane group will be 1 for exclusive through the other is through and left.

Southbound left and right most lane are straight and left and straight and right together and the middle one is straight. So, a through traffic movement. So, it will be one movement group only. But lane group will be 3. One will be through and left through and right and other will be exclusive through lane. So, that is what and here I have indicated how many number of lanes are there as per this diagram.

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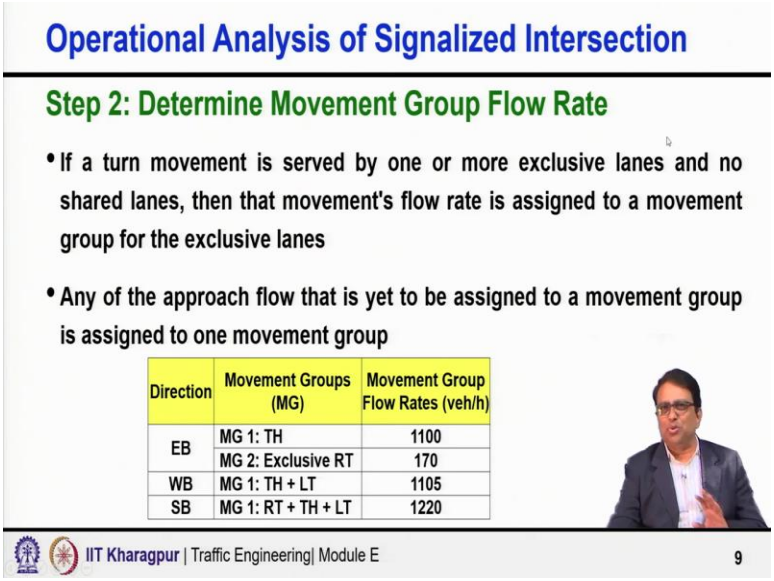

The step 2 is determination of movement group flow rate, this is also fairly clear, you can do that very easily, say movement group 1, 2 and for westbound movement group 1, for southbound also 1 movement group. So, knowing that these traffic volumes which are given and shown in this diagram, we can easily calculate that what will be the through movement eastbound 1100. So, that is the through movement and turning is shared is exclusive right is 170. So, like that movement group for westbound and southbound approach.

So, the basic idea is if the turn movement is served by one or more exclusive lane and no shared lane, then the movements flow rate is assigned to the movement group for the exclusive lane and any other approach flow that is yet to be assigned to a movement group will be assigned to one movement group, that is what is the basic principle and this we have discussed earlier.

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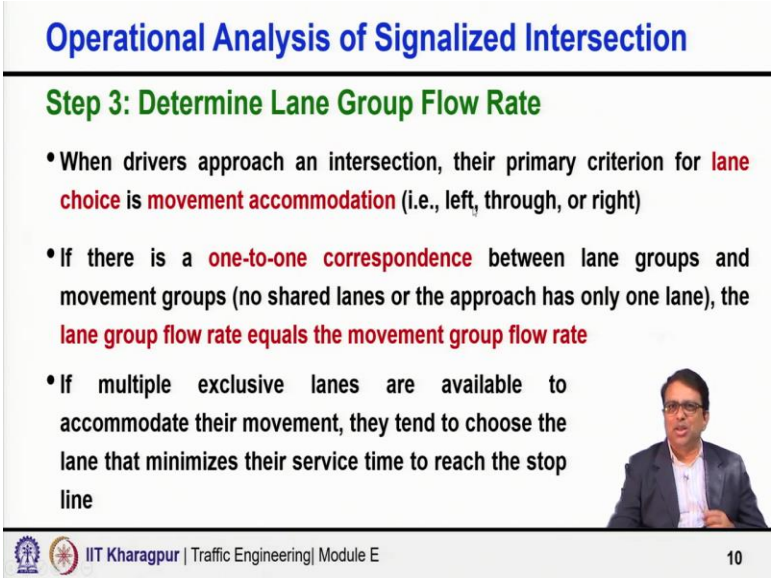

Step 3 determine now lane group flow rate. This is something little bit different than what our understanding you have developed so, far. Now, when drivers approach an intersection, their primary criterion for lane choice is movement accommodation that means, if I am approaching an intersection and I want to turn left so, I will try to choose lane accordingly. If you are turning want to turn right you will choose lane accordingly so, on so forth.

If there is one to one correspondence between lane group and movement group that means, when it will happen when there is no shared lane and the approach has only one lane. Then it will happen. So, no shared lane or the approach has only one lane that time it will happen. So, one to one correspondence between the lane group and movement group.

Go back to this diagram, you can see here the lane group and the movement group is same for eastbound approach. Because they are all exclusively lane, no shared lane. So, when there is no shared lane, then one to one correspondence is there. The lane group flow rate equals to the movement group flow rate there is no difference. And when there are multiple exclusive lanes are available to accommodate their movement.

Now obviously, vehicle tend to choose lane in a manner that will minimize their service time to reach to the stop if you are traveling whatever direction and if there are multiple lanes, if you are supposed to go straight, it is a through movement. Obviously, will try to select a lane where you

can reach faster up to the stop line that will be the general tendency or that is the behaviour that is expected.

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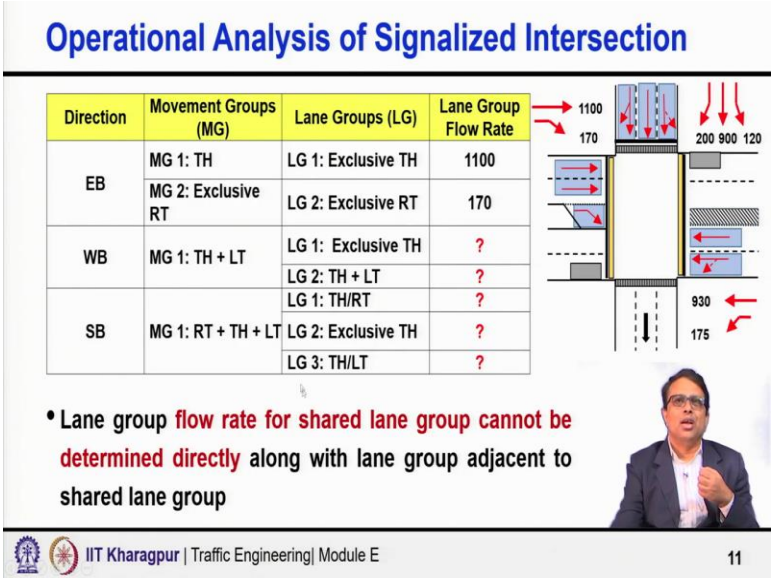

So, considering that when there is one to one correspondence as I said, the lane groups and movement groups are same and that will happen when there is no shared lane or the process only one lane. So, here for the eastbound all exclusive straight and right. So, obviously the movement group and lane groups are same and therefore, the movement group flow rate will be assigned as lane group flow rate. So, this is simple.

But then the westbound and southbound they are all with shared lanes. So, shared lanes will it be just simply equal distribution? No. So, how to calculate this lane group flow rate for westbound and southbound approach or similar situation where there are shared lane. Now, lane group flow rate for shared lane group cannot be determined directly along with lane group adjacent to shared lane group.

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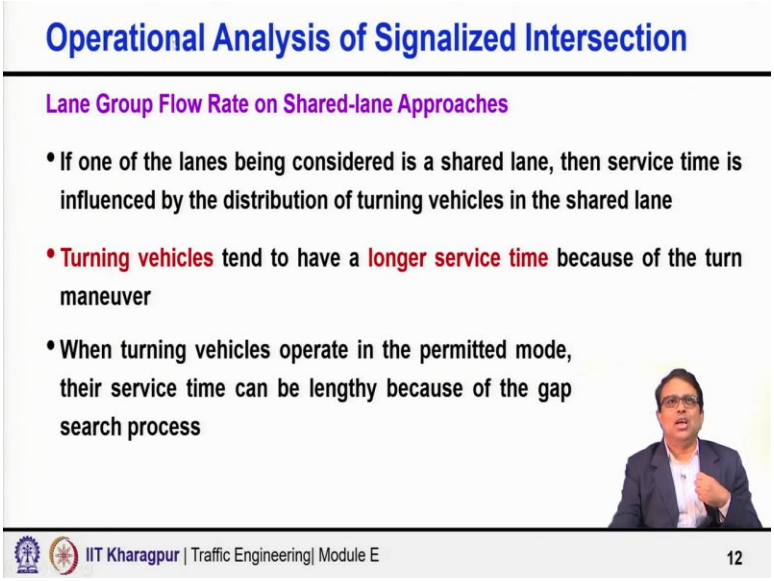

So we need more discussion and now it is something a little bit new. So, let us try to understand what understanding what methodology we follow to determine the lane group flow rate under such situation. Now, if one of the lanes being considered is a shared lane, then service time is influenced by the distribution of turning vehicles in the shared lane.

Suppose, you have straight and left and then straight. Now, the because in one lane, it is a shared lane and there is turning traffic. So, naturally the service time is influence by the distribution of turning vehicle in the shared. Now, normally turning vehicles they will tend to have longer service time because of the turn maneuver.

So, a vehicle is going through straight vehicle straight going whatever will be the service time if a vehicle is to take turn either left or right then the turning vehicles because the vehicle is turning it will take longer service time also, whenever there is a turning vehicle and if it is a permitted one, then one more factor will come which will also influence the service time, what is the factor? Because the turning vehicle then has to yield to the pedestrian movements or to pedestrians.

So, the when turning vehicle operated or when traveling vehicles operate in permitted mode their service time can be lengthy because of the gap search process, pedestrians are there, priority is higher for pedestrians. So, the turning vehicle has to look for suitable gap, then only can be discharged.

So, all these will tell you clearly or all this tell you clearly that movement on a through lane and movement on a shared lane even for the straight going vehicle it is not the same thing. The shared lane obviously, because of turning vehicle will have longer average service time and if the turning vehicles have to yield to pedestrians, then it will be even longer. So, we cannot just simply consider it is a 50-50 distribution that is not proper.

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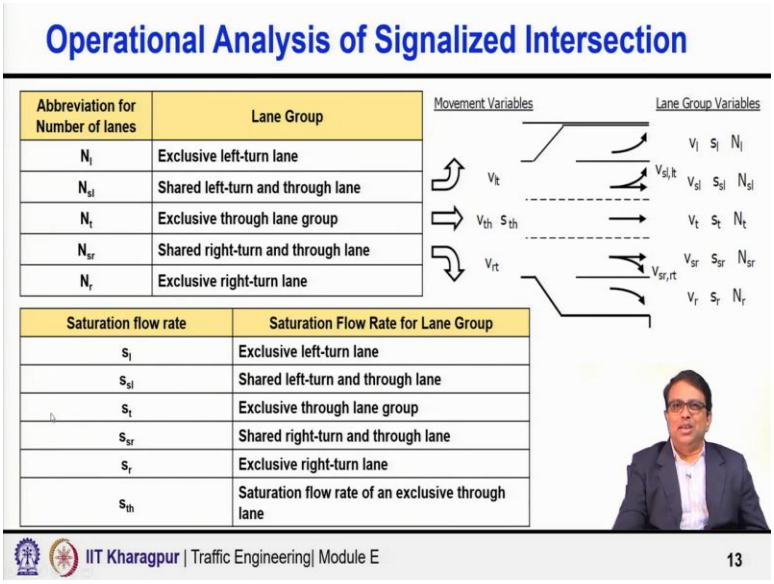

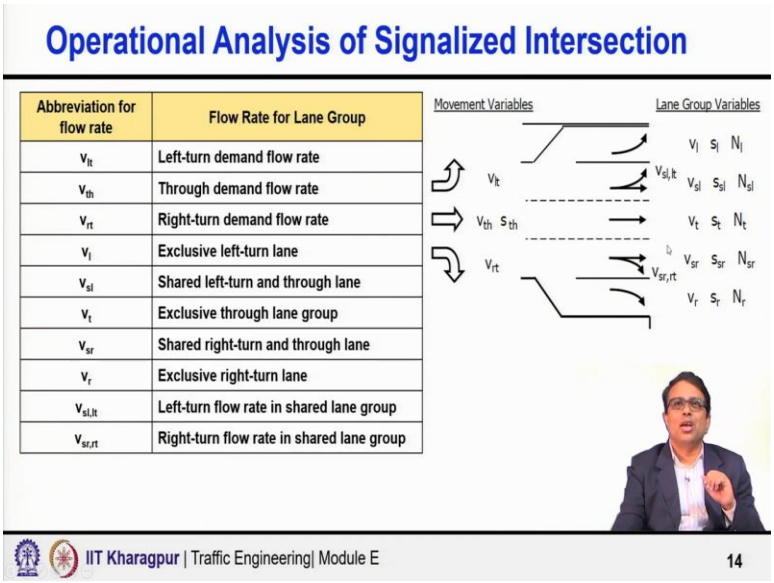

Now, then how to do it? Now for the movement I will stop about the example problem. I will stop that example problem. And let us try to understand generalized scenario which may happen and

our particular problem is one special case of that generalized scenario and what procedure we need to follow to get the lane group flow under such scenario.

Now, here you can understand I am showing an intersection approach where you have Vlt is the left turning volumes V through Vth is the V through traffic volume Vrt is the right turning traffic volume and let us assume that it is a most general condition that there is one exclusive right, one exclusive left, one shared right, right and through one shared left, left and through and one through. So, corresponding volumes are left one is Vl, total shared left and straight total is Vsl, out of Vsl the specific left turning volume is Vsl lt.

Similarly, Vr is the right turning volume through exclusive land Vsr is the total vehicle that is using that lane through plus right turn. So, shared right out of that Vsr rt is that number of vehicles which are actually turning right from the shared lane and Vt is the straight going traffic volume. Now, the corresponding Sl is St, Sst, Sr these are indicating the saturation flow.

So, first is the volume V indicates volume, S indicates saturation flow and N indicates the corresponding case how many number of lanes are there. So, all these terminologies must be clear to you. This slide also it is explained the volume part or the flow rate is explained and in the previous slide number of lanes what number means what and the table below is the saturation flow rate.

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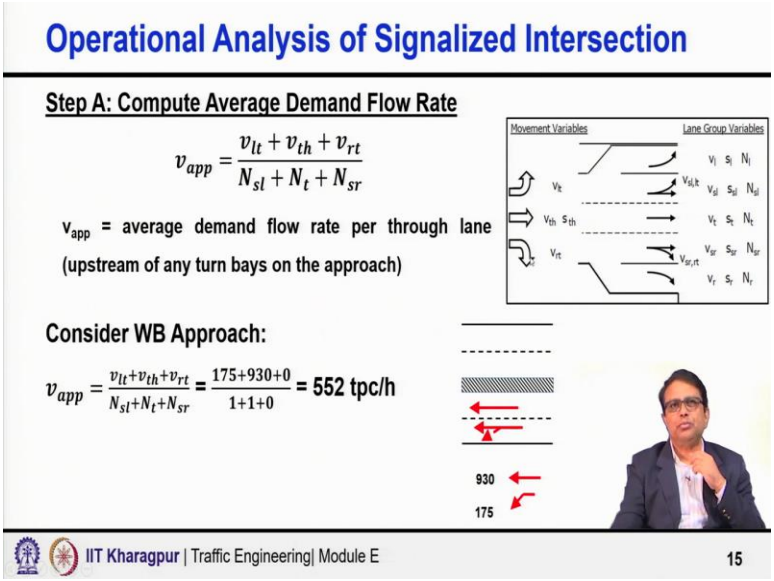

Now, here within this lane group and flow rate or shared lane approaches how to get the lane group flow rate. We have to follow certain steps and it will be iterative in nature. The first step is compute average demand flow rate. What is how we are calculating that? We are calculating this Vlt left turn volume through Vth and Vrt.

$$v_{app} = \frac{v_{lt} + v_{th} + v_{rt}}{N_{sl} + N_t + N_{sr}}$$

So, Vlt plus Vth plus Vrt this is the total approach volume to the intersection approach divided by carefully observing in Nsl plus Nt plus Nsr. So, Nsl is this one shared left lane through and shared right. We are not considering here exclusive right and exclusive left these two are not considered exclusive left and exclusive right are not considered.

So, this volume divided by the number of lanes as it is shown, that is what the average demand flow rate per through lane. Then, if we now consider our example and just take the westbound approach one of the two approaches where the shared moments are happening or shared lane is there.

So, in that case you know that straight is 930, left turning is 175, and right turning in this case is 0. So, 175 plus 930 divided by how many lanes are there, we have only 1 lens for left shared and one through. So, 1 plus 1. So, vapp is approximately 552. We have neglected the decimal just taken it in round figure. So, that many vehicle or that many tpc through passenger car equivalent per hour.

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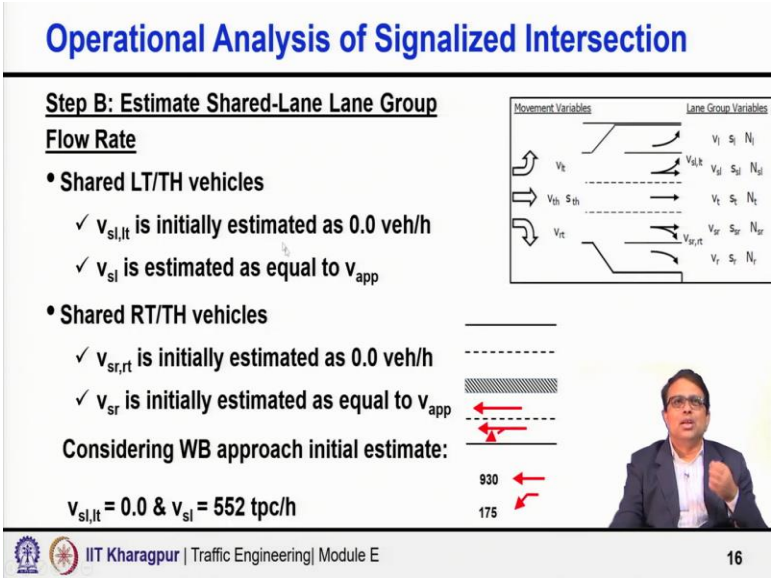

Then step B estimate shared lane lane group flow rate. How we can get that? First we will assume that Vsl lt what is Vsl lt, Vsl is the whatever is coming in the shared lane for left and straight, out of that whatever number of vehicles are actually taking left that Vsl lt, that means out of total Vsl what is actually what are actually taking left turn.

Now, this left turning vehicles from the shared lane initially is assumed as 0 same thing for the right turning shared lane also the right turning vehicle volume is considered 0, then what is the Vsl? Vsl, if Vsl lt 0, then Vsl equal to Vapp the average volume what you have calculated here, because there is no left turn left turn is 0. So, the entire volume is then the through traffic and in this example then, what is Vsl lt is taken 0, so Vsl is how much? 552, Vsl is 552 total. Now, then what will be the Vsl is estimated equal to Vapp.

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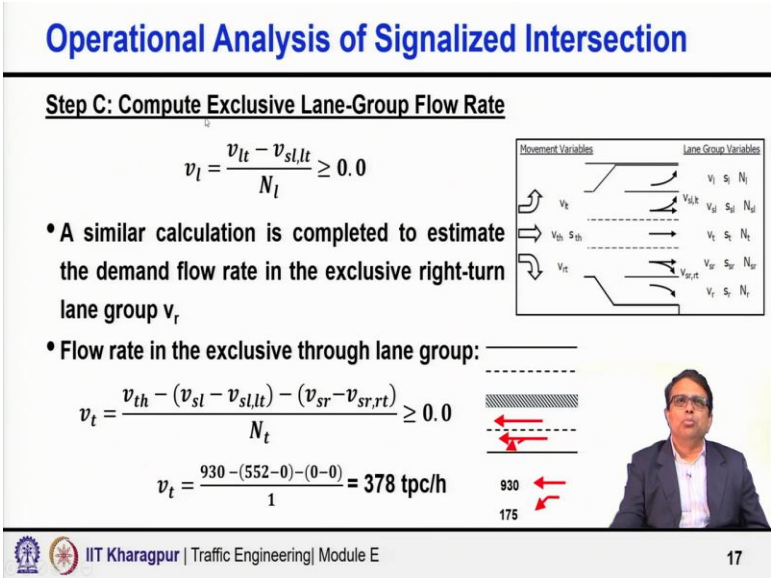

Now, Step three, compute exclusive lane-group flow rate. How we do that? We know what is the value of Vl left turning volume. Now, this is Vlt minus Vsl lt, of course, in this iteration we considered Vsl lt 0, but subsequently it will get changed. So, it is a generalized formula Vlt minus Vsl lt divided by per-lane number of lane Nl, Nl is the number of lane exclusive left turn.

$$v_l = \frac{v_{lt} - v_{sl,lt}}{N_l} \geq 0.0$$

Say similar calculation we do for the Vl also you have done for Vl and similar we do it for Vr. So, in this example problem, then what will be the through volume? Before we tell specifically for this approach. Let us, look at the generalized formula, then what will be the Vt? Vt is the through lane only.

Through lane will be whatever is the total through minus whatever is going through this going straight through this shared left lane minus whatever is going through this shared right lane. Now, how much is going straight through the shared left lane? It is Vsl minus Vsl lt. Similarly, how much is going straight through this shared right lane? Vsr minus Vsr rt.

$$v_t = \frac{v_{th} - (v_{sl} - v_{sl,lt}) - (v_{sr} - v_{sr,rt})}{N_t} \geq 0.0$$

So, V minus this component minus this component, then that is the total divided by how many number of through lanes Nt that is the through lane volume per lane and obviously, it has to be greater than 0 some cases computationally if it is otherwise you have to take the minimum thing

as 0. Now, for this example problem again for the westbound approach, our total flow V through is 930 minus Vsl how much we have calculated Vsl minus Vsl lt, Vsl is 552, Vsl lt is 0 in this iteration. So, what will be then Vt through lane 378 tpc per hour.

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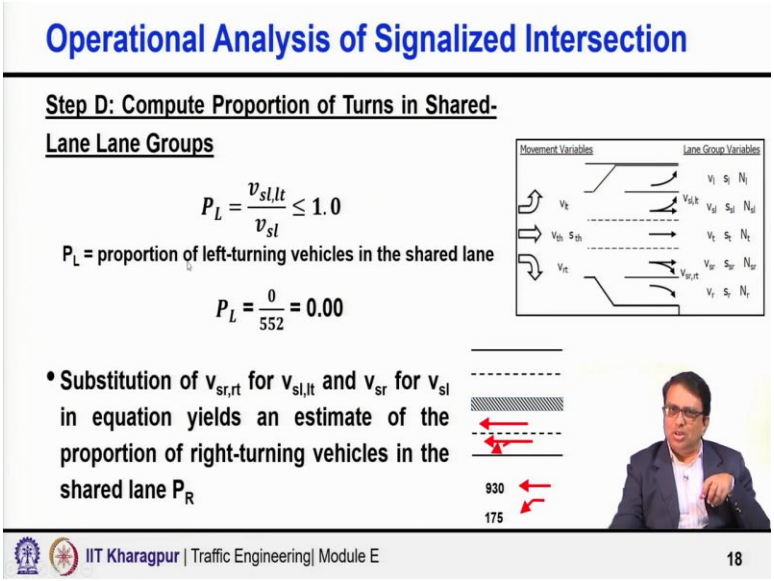

Now, go to next step, step D step the what we will do, we will compute proportion of turns in shared length groups, proportion of turns in shared lean groups easy. What is then the PL? PL is Vsl lt in the shared lane how much volume is taking left turn divided by Vsl total how much is going in the shared lane. So, how much is taking left turn from the shared lane divided by how much total is going in the shared lane.

$$P_L = \frac{v_{sl,lt}}{v_{sl}} \leq 1.0$$

So, it is Vsl lt divided by Vsl and obviously, it has to be less than or equal to 1, 1 it will be when it is exclusive turn lane left turn. Same way we can also calculate the proportion of PL, PR proportion of right turning vehicles in the shared lane and in our example problem, so, far whatever steps we have done so, far it will change later.

But so, far our Vsl lt is taken as what 0 we started with that, you remember we said that Vsl lt is initially estimated as 0 Vsr rt is also initially estimated as 0. From the shared lane, we considered the left hand and right turns correspondingly are 0 that we there we started we have not yet updated.

So, that is still 0 and if it is 0, then PL in the shared lane at this stage in this step is 0. Now substitute same way you can get it for the right lane.

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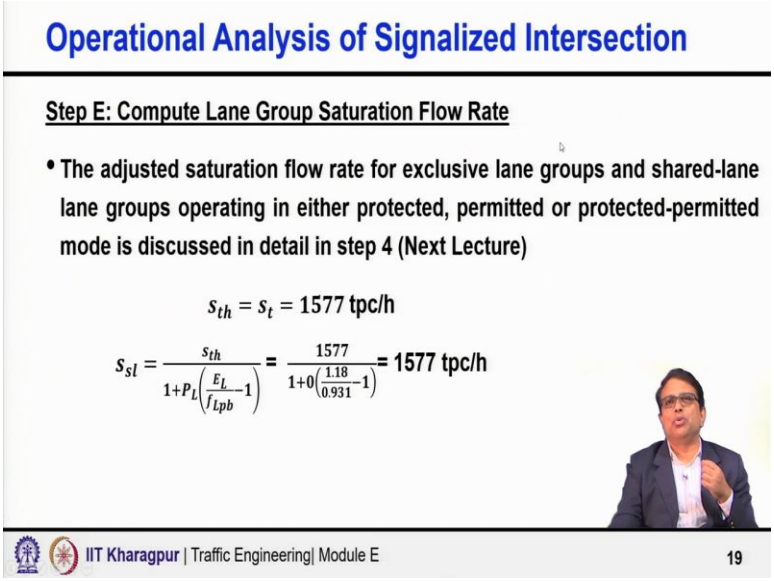

Step E, next step is compute lane group saturation flow rate. Now, this lane group saturation flow rate, how the saturation flow rate also will change depending on whether it is through, whether it is shared left, whether it is shared right obviously the saturation flow is not going to be same because we have discussed here that whenever this I will go back.

As I said here the turning vehicle tend to have longer service time and again when turning vehicles are operated in permitted mode, they have to yield to the pedestrian movement. So, they have to look for a suitable gap. So, the gap search process also will take time. So, naturally the service time will not be same. So, the saturation addition flow also cannot be same.

So, further details and discussion I will make in the next lecture, but for the moment you simply accept that this is the model or this is the formula that can be used to get the saturation flow for the shared lane and this is for his Ssl shared left. Because in our specific example, there is no shared right for this particular approach.

Now, interestingly, this is also a function of PL apart from other thing that means, this saturation flow is a function of proportion of left turning vehicle. Now, because it is 0 in so far whatever steps we have computed, so, far it is 0. So, naturally if it is 0 means all through although we are

calling it is a shared lane, but, in this iteration we are considering that the left turning volume is 0 from the shared lane.

So, PL is 0. So, obviously, the through and shared left the saturation flow values are same, it will change subsequently, it will change subsequently, when our PL is other than 0 as PL will be higher the saturation flow also will change it will go lower.

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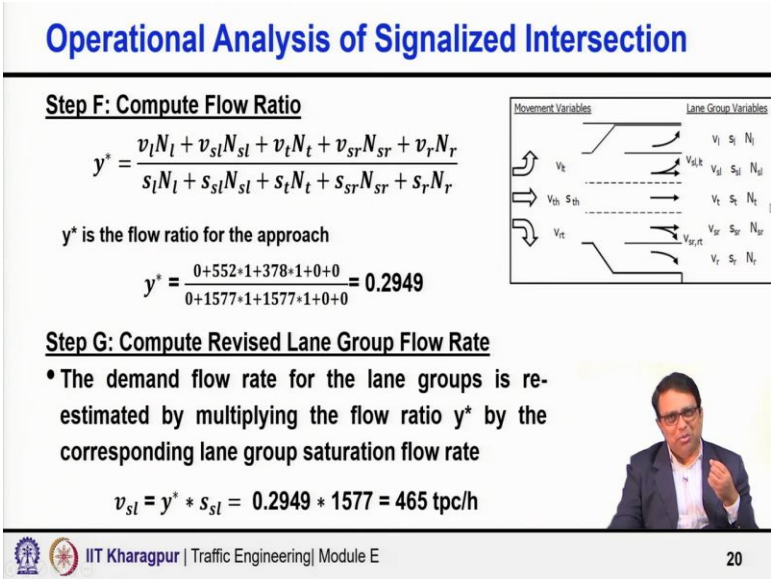

Now, next step is compute the flow ratio. What is the flow ratio? For the overall approach. It is almost like a volume to capacity ratio. The flow ratio is something like that, what we are doing we are considering Vl in any iteration Vl multiplied by Nl plus Vsl multiplied by Nsl through multiplied by number of lanes because these are all per lane per lane and number of lane. So, the total volume we are taking.

$$y^* = \frac{v_l N_l + v_{sl} N_{sl} + v_t N_t + v_{sr} N_{sr} + v_r N_r}{s_l N_l + s_{sl} N_{sl} + s_t N_t + s_{sr} N_{sr} + s_r N_r}$$

Similarly, divided by a Sl saturation flow for the left lane left turning moment multiplied by number of lanes. So, basically if you say the numerator is all volume and denominator is all saturation flow, we are only considering for left shared left through shared right and exclusive right.

And these are weighted by number of lanes because these volumes are per lane. So, we are actually taking the number of lane to get the total volume. So, it is something like volume to saturation

flow or volume to capacity ratio in a way. So, for our approach calculation, with this example westbound approach westbound approach, what is then the value of y?

Now, the left exclusive left is 0, shared right is 0, exclusive right is 0 only I have one straight there 552 one lane and one shared left 378. That is what we got okay through sorry through is 378 and shared left is 552, I just told opposite. So, shared left is 552 and through is 378. So, we have only these two and each case a single lane divided by saturation flow because we have 0 proportion of left turning traffic up to this iteration or at the stage of calculation. So, it is 1577 in both case, so you get value y star flow ratio.

Now, update will happen, what we are saying? Now compute revise lane group flow rate, how will you compute the demand flow rate for the lane group is re-estimated demand flow rates whatever we have calculated so, far will be re-estimated by multiplying the flow ratio y star with the corresponding lane group saturation flow rate. So, if we are considering one lane group whatever was the demand, we did fine, but we have now calculated the flow ratio. So, what will be there the new value? What will be there? It will be flow ratio multiplied by the corresponding lane group saturation flow.

So, if you are considering Vsl we will take Ssl like that if there would have been a Vsr then it would have been y star multiplied by Ssr. Now, obviously, since that shared right does not exist in this case, so, we will not do that calculation even though some cases some value you may get, but you will not do that calculation. So, apply that, what then we are getting? Now, we are getting Vsl as 465.

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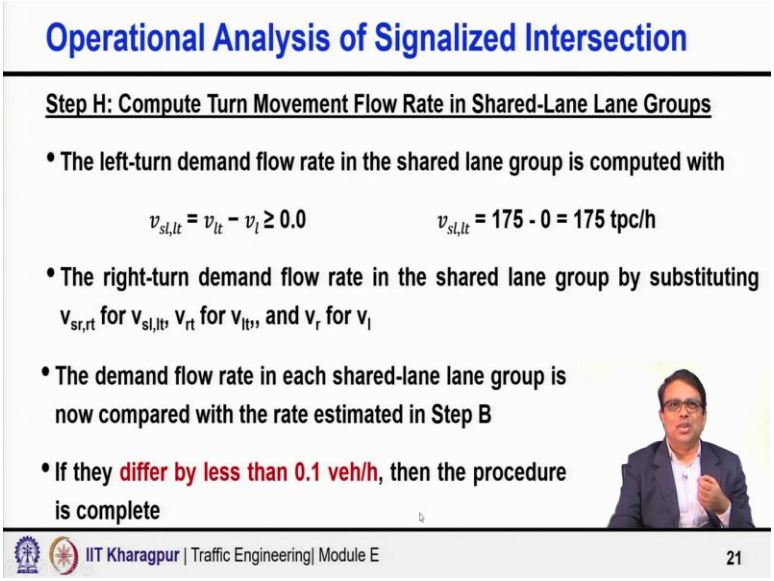

So, left turn demand flow rate in the shared group now is computed with Vsl lt equal to Vlt minus Vl. So, in this case what will happen? It will be simply 175 minus since Vl is 0. So, 175. So, what do you got? Similarly, the right demand flow rate in the shared lane group can also be calculated and the demand flow rate in each shared lane group is now compared with the rate estimated in step B.

So, finally, what we got after iteration one now, my iteration is completed. Now, my iteration is completed. So, what I got we got Vsl lt as 175, Vsl is 465 So, total 465 Vsl out of that, how much is taking left turn is 175. The remaining is through and also the other lane flow we know. Now, what we are saying this demand flow rate in each shared lane group is now compared with the rate estimated instantly step B. Step B go back we calculated and then what we are saying that if the difference is less than 0.1 vehicle per hour, then the procedure is complete. But obviously, after one iteration it is not going to be same it is it will be different.

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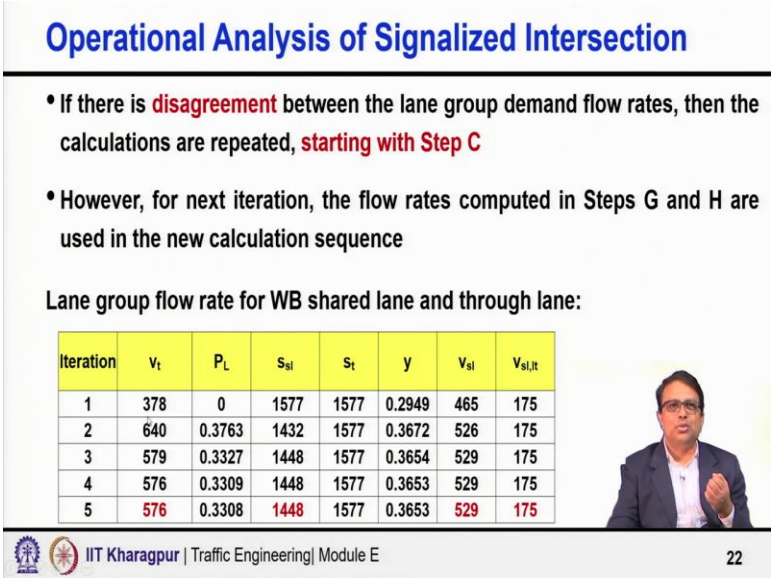

So, where we will go back, so, there will be disagreement, it will not be matching. So, if there is a disagreement between the lane group demand flow rate and then the calculations are repeated starting from step C, what is step C? I again go back. So, we start here now compute exclusive length group flow rate.

So, what is the Vl again we will calculate Vl will be Vlt minus Vsl lt, Vsl lt we know now, divided by Nl. So, we will calculate Vl will calculate then again Vt the steps C, D, E, F, G, H, the whole thing will get repeated and with a few iterations, you will find finally this condition is getting satisfied. The demand flow rate each shared lane group when you compare with the rate estimated in the latest iteration in step B, then the difference will be nominal.

So, once it is done, then you close it. So, I have shown here for the westbound shared lane and through lane you can do the calculation on your own I have shown it this is the fast iteration value what we got. We got Vt as 378, Vsl 465 and out of Vsl, Vsl lt is 175. So, the remaining is actually through in that shared lane in that first iteration.

And if 47 65 minus 175 whatever is the value plus you take 378 you will get it. It will match with the overall total through traffic that is 930. Now, you see how iteration, why is it is changing. So, PL started with 0 that is why the straight and shared left value saturation flow values are also same.

But now as the PL started changing the saturation flow for shared left and through are not same anymore, they are changing higher the value lower will be the saturation flow for the left turn. And

then finally, you can see iteration 4 and 5 exactly the change is very very nominal within the, whatever error we said in the previous slide. It is matching with that.

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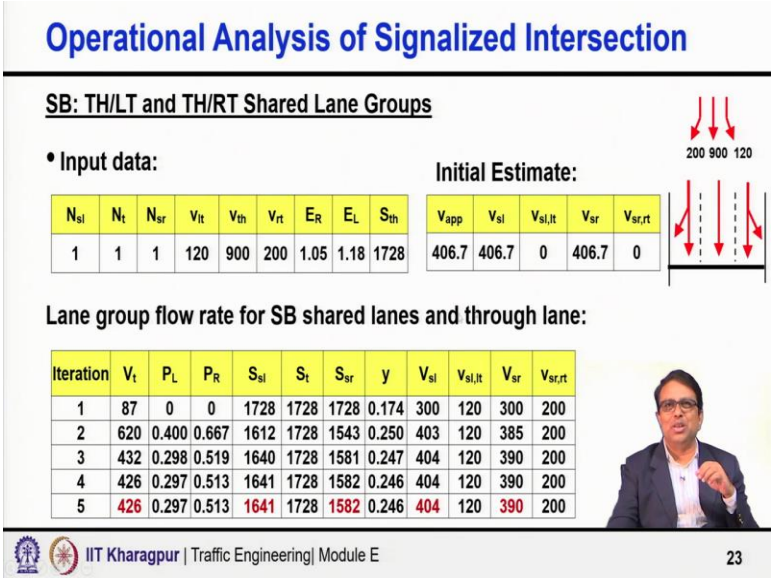

N_{sl}	N_t	N_{sr}	v_{lt}	v_{th}	v_{rt}	E_R	E_L	S_{th}
1	1	1	120	900	200	1.05	1.18	1728

v_{app}	v_{sl}	$v_{sl,lt}$	v_{sr}	$v_{sr,rt}$
406.7	406.7	0	406.7	0

Iteration	V_t	P_L	P_R	S_{sl}	S_t	S_{sr}	y	V_{sl}	$v_{sl,lt}$	V_{sr}	$v_{sr,rt}$
1	87	0	0	1728	1728	1728	0.174	300	120	300	200
2	620	0.400	0.667	1612	1728	1543	0.250	403	120	385	200
3	432	0.298	0.519	1640	1728	1581	0.247	404	120	390	200
4	426	0.297	0.513	1641	1728	1582	0.246	404	120	390	200
5	426	0.297	0.513	1641	1728	1582	0.246	404	120	390	200

So, same calculation I have now shown all the relevant calculation for the southbound approach. So, far I took the calculation for eastbound approach, similar way I have now shown the calculation for the southbound approach and again, you see here also 4th and 5th iteration the values are same.

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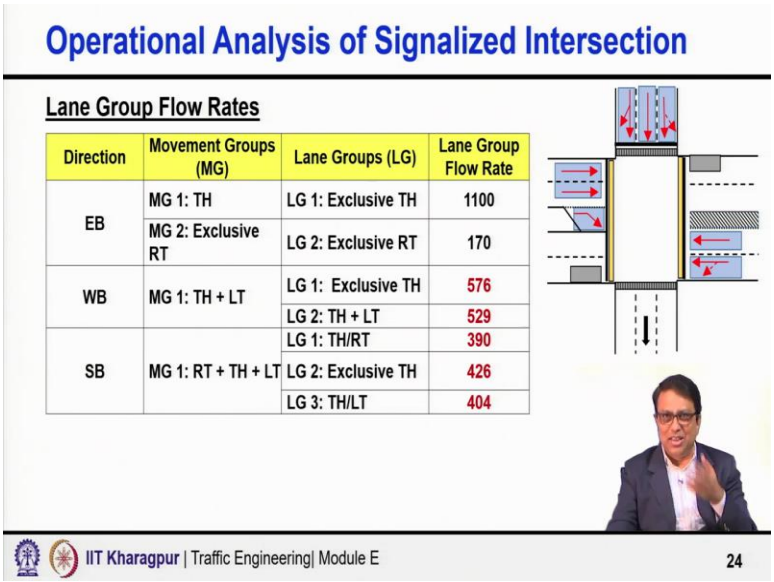

Direction	Movement Groups (MG)	Lane Groups (LG)	Lane Group Flow Rate
EB	MG 1: TH	LG 1: Exclusive TH	1100
	MG 2: Exclusive RT	LG 2: Exclusive RT	170
WB	MG 1: TH + LT	LG 1: Exclusive TH	576
		LG 2: TH + LT	529
SB	MG 1: RT + TH + LT	LG 1: TH/RT	390
		LG 2: Exclusive TH	426
		LG 3: TH/LT	404

So, therefore, now finally, finally, I have this flow lane group flow rates are available. So, finally, now, I have the lane group flow rates for westbound and southbound approaches, where there are

shared lanes and where the movement groups and lane groups are different because of the shared lane.

And this whole procedure, how to go about it, how to start with sudden assumption considering the left and right volume in the shared lane is 0, we are starting from that and then doing the calculations getting the flow ratio, iterating and reiterating finally we get the convergence and with that we can actually now get the lane group flow rates.

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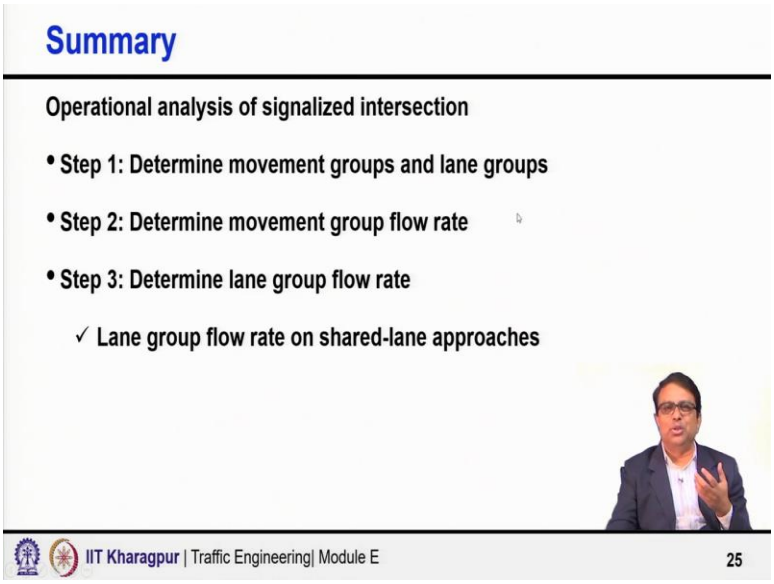

So, with this I will close what I will say to summarize my today's lecture that we mainly discussed about step 1, step 2 and step 3, step 1 is straightforward determination of movement groups and lane groups the concept you were having earlier and we just applied it then determined movement group flow rate that was also easy.

So, the main discussion today's lecture was on how to determine that lane group flow rate specially for shared lane and where the movement group and lane group there is no one to one correspondence because of the shared lane. So, what philosophy we apply, how step by step procedure is followed, how the whole iterative procedure works to get the lane group flow rate for shared lane approach. So, we shall continue in our next lecture with the subsequent steps and with the same example problem. Thank you so much.