Traffic Engineering
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Module: D
Week: 05
Lecture: 9
Analysis of Urban Street Segments (As per HCM, 2016) – III

Welcome to Module D, Lecture 9. In this lecture, we shall continue our discussion about analysis of Urban street segments as per Highway Capacity Manual 2016.

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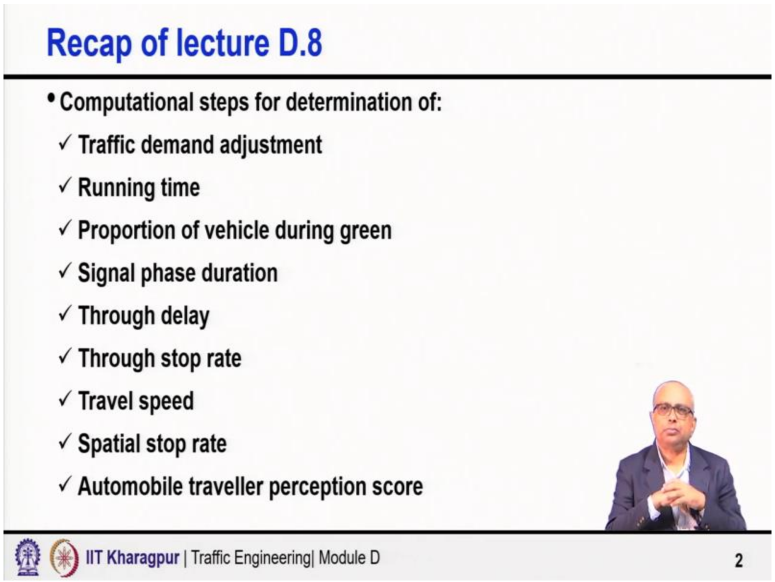

And what we discussed in lecture 8, the previous lecture is the computational steps for determination of level of service, operational level analysis and all the steps of the flowchart they were discussed for example, Traffic demand adjustments, Calculation of running time, Proportion of vehicles during green, Signal phase duration, Through delay, Through stop rate, Travel speed, Spatial stock rate and the overall LOS as well as the travelers perception score.

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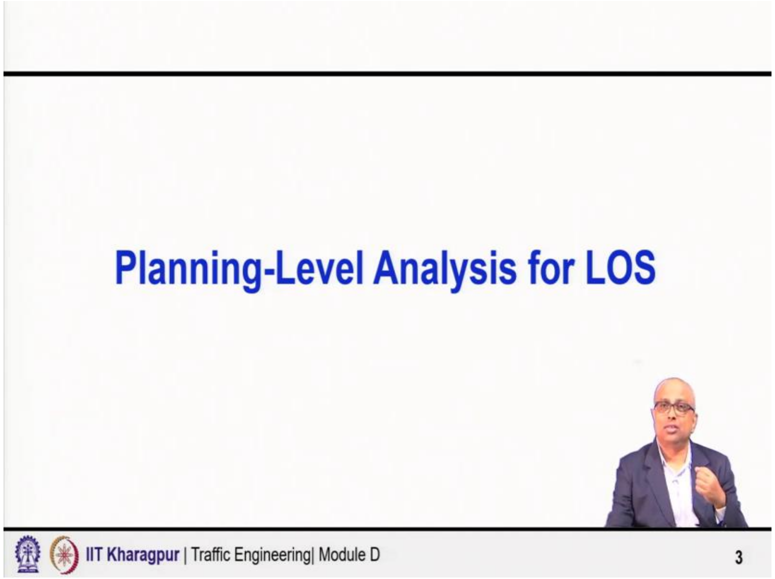

With this background today, our focus is on planning level analysis of LOS. So, the previous lecture and even the last two lectures I think it was more on the operational framework. The flowchart what we have shown, we have discussed in details in the last lecture was operational framework and in lecture 7 also towards the end, what we presented to you is operational level analysis framework.

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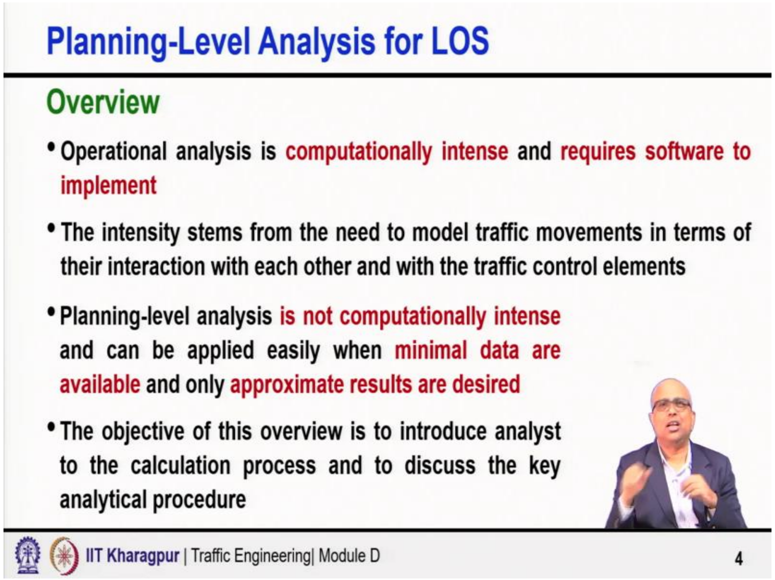

Now, what we have seen the operational analysis is exhaustive, but computationally intense and also requires software to implement. Why it is computationally intense the intensity stems from the need to model traffic movements in terms of their interaction with each other. And with the traffic control elements you have seen when we discuss all the steps even I did not discuss everything in details, because it was simply not possible within just one lecture. So, I just mentioned to you many cases, the concepts the ideas what we are doing, why we are doing and how we are doing many cases we omitted, I omitted because of the complexity.

Now, planning level analysis what we are going to discuss today is not computationally intense. So, that is one advantage. And this can be applied easily with minimal data and particularly suitable for an approximate, results are desired. That is, what is the planning level application, because in planning level, we really do not have all the data and also it is not necessary to have very accurate results because the purpose is the planning, alternative evaluation?

The objective of this overview in today's lecture is to introduce analyst to the calculation process, what we do, how we go ahead with the planning level analysis of level of service and to discuss the key analytical procedures.

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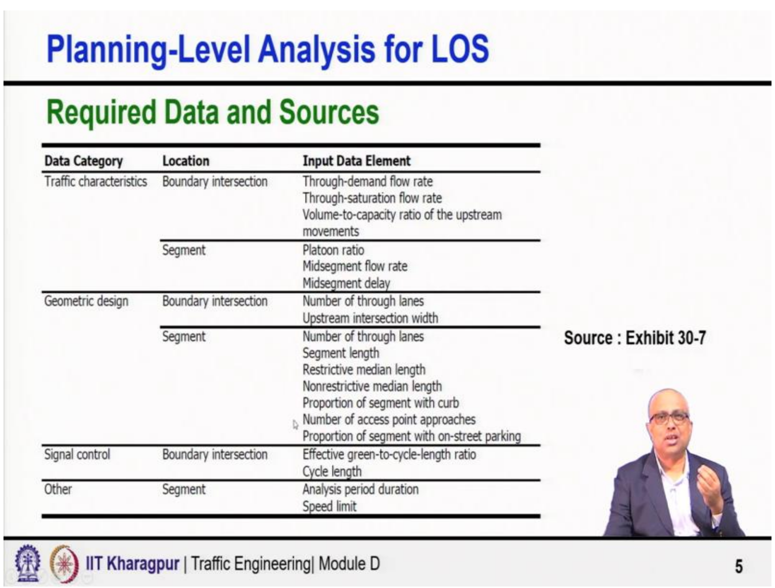

In this slide, I am showing you the input data requirements as per exhibit 37 of Highway Capacity Manual 2016, you can see the data category, primarily there are three categories of data which are required Traffic characteristics, Geometric design or Geometric characteristics I should say, traffic signal control related data and some other.

Data coming to traffic characteristics the boundary intersection and segment two types of two locations where we need the traffic data and these are the inputs I will not read everything and you can see that those all the inputs are written here. The geometric data also includes for boundary intersection as well as for the segments.

Signal control data obviously is only for boundary intersection and some other data we may require at the segment level for example, Analysis period duration, Speed limit and this exhibit gives you in details, what all inputs are required for planning level analysis, some of the inputs I am going to discuss.

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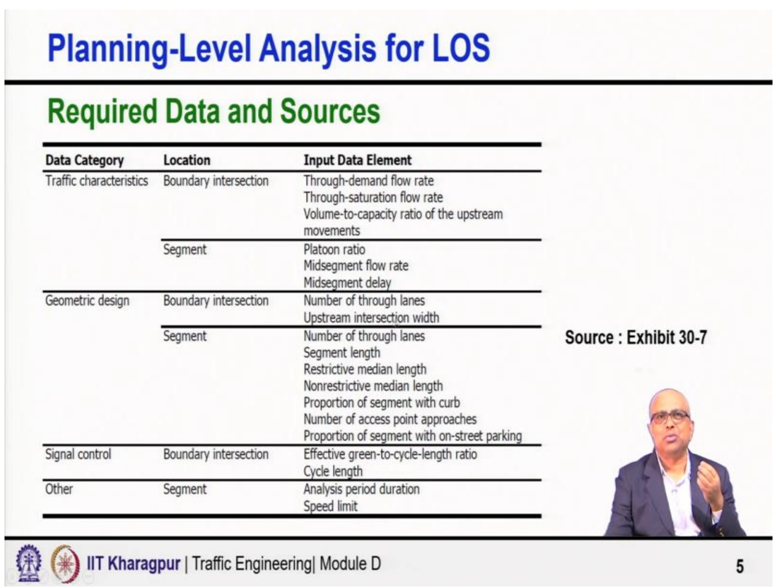

Data Category	Location	Input Data Element
Traffic characteristics	Boundary intersection	Through-demand flow rate Through-saturation flow rate Volume-to-capacity ratio of the upstream movements
	Segment	Platoon ratio Midsegment flow rate Midsegment delay
Geometric design	Boundary intersection	Number of through lanes Upstream intersection width
	Segment	Number of through lanes Segment length Restrictive median length Nonrestrictive median length Proportion of segment with curb Number of access point approaches Proportion of segment with on-street parking
Signal control	Boundary intersection	Effective green-to-cycle-length ratio Cycle length
Other	Segment	Analysis period duration Speed limit

For example, through demand flow rate, is a major input to this process and it is defined as the count of through vehicle which is arriving at the intersection downstream intersection during the analysis period and generally expressed as an hourly flow rate. Upstream intersection width is again an important factor you can see here it comes under geometric design data and for the boundary the intersection upstream intersection width this is intersection with is this intersection with the applies to the upstream boundary intersection for the upstream boundary intersection for a given travel direction.

So, direction wise it will be different and is the effective width of the crossroad upstream intersection you have the stop line then the crossroad and then the segment is coming actually. So, it is the effective width of the Cross Street. Now, for Two-way streets when both directions are there the distance between stop lines for two opposing through traffic movements.

That is used to describe the upstream intersection width and it is measured along the centerline of the segment the one way street scenario when we are analyzing one way street, the upstream intersection width is the distance from the stop line to the far side of the most distant traffic lane on this crossroad. So, that what it is and you can understand it now. So, the in a way both cases it is the effective width of the crossroad but how we are calculating for Two and One way street that I described.

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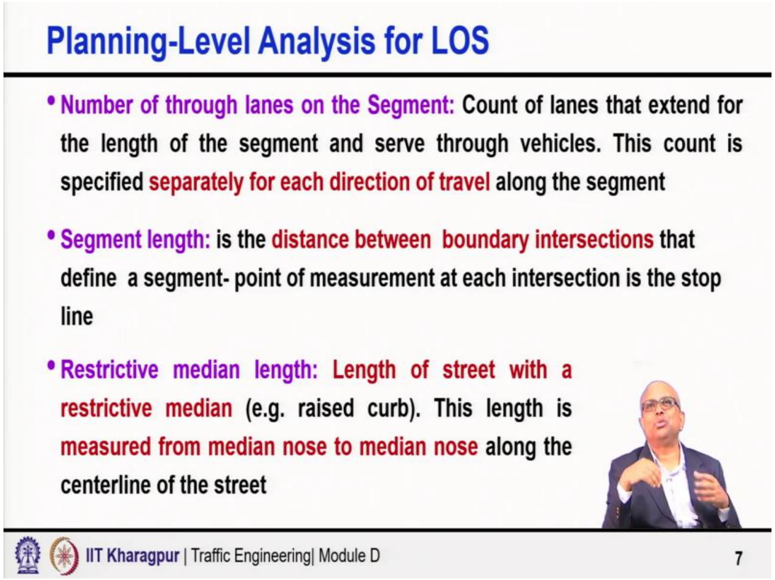

Then the next one important input is number of through lanes on the segment again for the through traffic what are the how many number of lanes are available. So, it is count of lanes that extent for the length of the statement and serve through vehicles. This count is specified separately for each direction of travel along the segment.

So, we have to identify this number separately for upstream and downstream. Then the segment length I have described the distance between boundary intersections that define the segment and point of measurement at inches at each intersection is the stop line. So, that is the way the segment length is defined. The restrictive median length is the length of the street with a restrictive median for example, raised curb.

How we calculate this length, this length is measured from median nose to median nose the entire length but along the centerline of the street. That is the way the length is measured because restrictive median length for the segment. So, it has to be measured along the centerline of the segment but from median nose to median nose. So, any median opening that we exclude.

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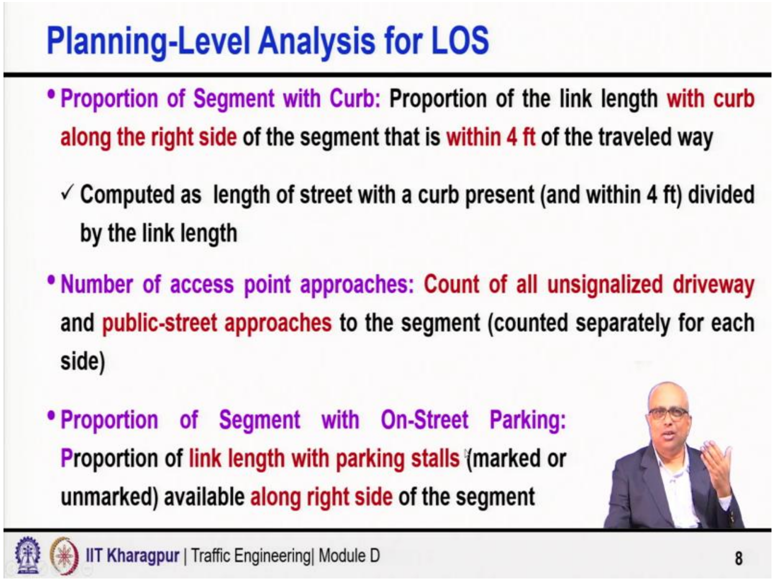

Then proportion of segment with curb these are all inputs. There are many inputs and some of the inputs I thought I could discuss It is the proportion of link length with curb along the right side following US convention because since this part or in this module I am entirely focusing so far, I am entirely focusing on Highway Capacity Manual.

So, the convention has to be different, it is just opposite to what we do in Indian context in Indian context along the left side. So, as per Highway Capacity Manual, it is on the right side, right side of the segment that is within 4 feet of the traveled way that is the way the proportion of segment with curb is defined.

And as usual, it is again computed as length of the street with the curb and within 4 feet divided by the entire link length that is what is proportion of segment with curb, number of access point approaches, when you consider the segment there could be other roads, traffic may be entering, exiting uncontrolled intersection could be there. So, count of all unsignalized driveway and public street approaches to the segment and therefore, the left side and the right side, whatever convention you follow, the number of access points may be different.

So, we have to calculate the number of access point approaches separately for each direction traveled. The next proportion of segment with on street parking here the proportion of link length with parking stalls or marked it could be marked or it may not be marked it be unmarked, which are available along the right side of the segment in Indian condition, it will be left side of the segment because in Indian condition on street parking happens always on the left side. So, that is what the proportion of segment on with on street parking that may be calculated.

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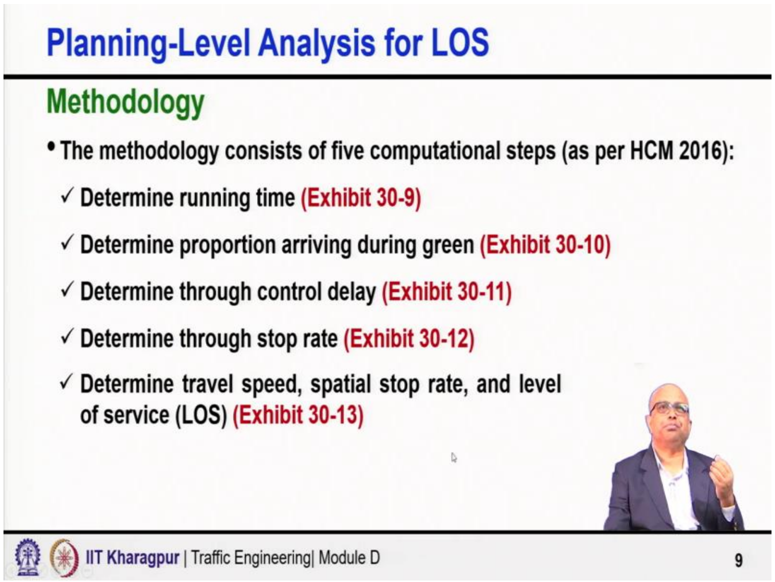

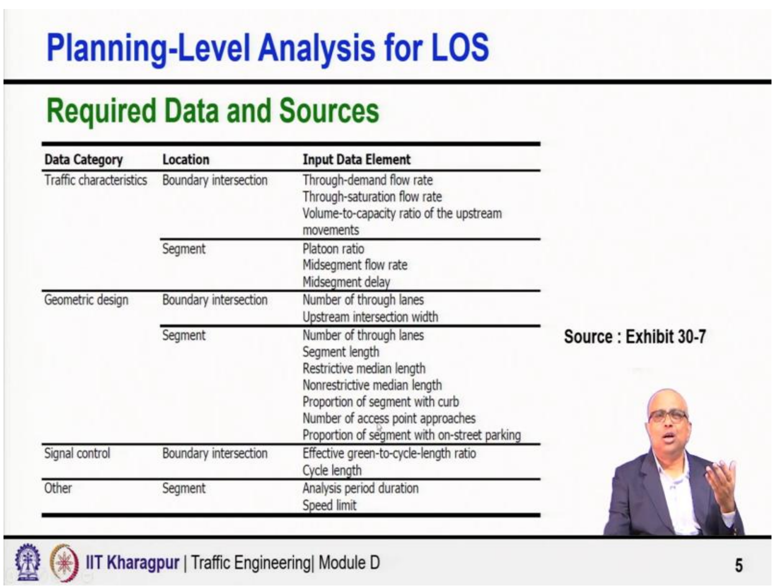

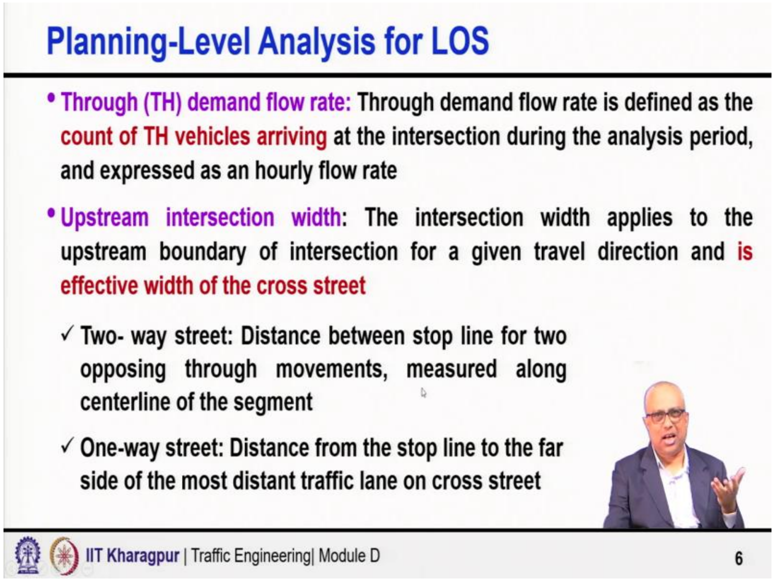

Now, as I said, I have listed all the inputs here I have not discussed all the inputs here. But some of the inputs I discussed and I tried to describe. Now, with this background, let us go to the methodology part. If you see highway capacity manual, the planning level methodology consists of five computational steps, five computational steps, namely.

You Determine first the running time, then determine proportion of arriving vehicles arriving during green then determine through control delay, control delay, for through movement, determine through stop rate, then with all this input, determine travel speed, special stop rate and level of service. So, these are the five computational steps.

For each step, they suggest a worksheet which is very useful, you can actually link those worksheets and, create very useful Excel spreadsheet to do the calculation in a systematic manner and they are really very helpful. So, I have indicated here what exhibits you may refer if you are interested to really know in details each and every steps, obviously, for the class purpose, I need not describe each of this exhibit. Rather, I am just indicating what exhibit you can refer for what computational steps.

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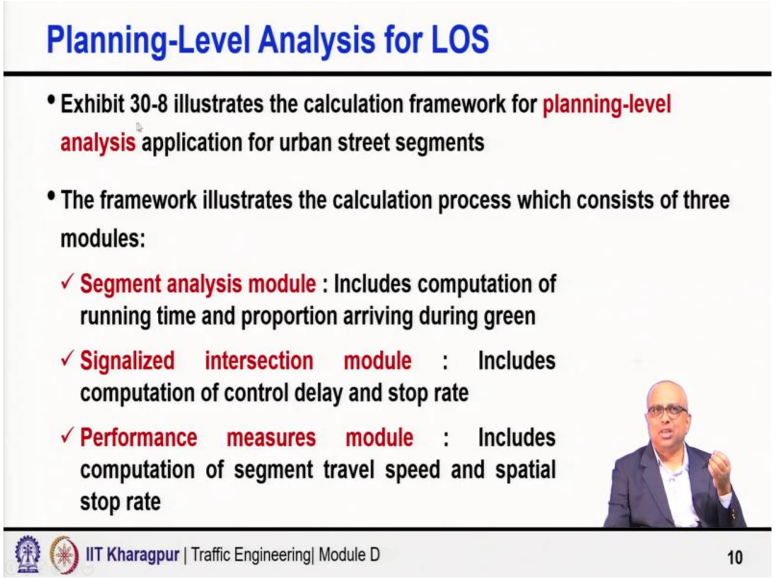

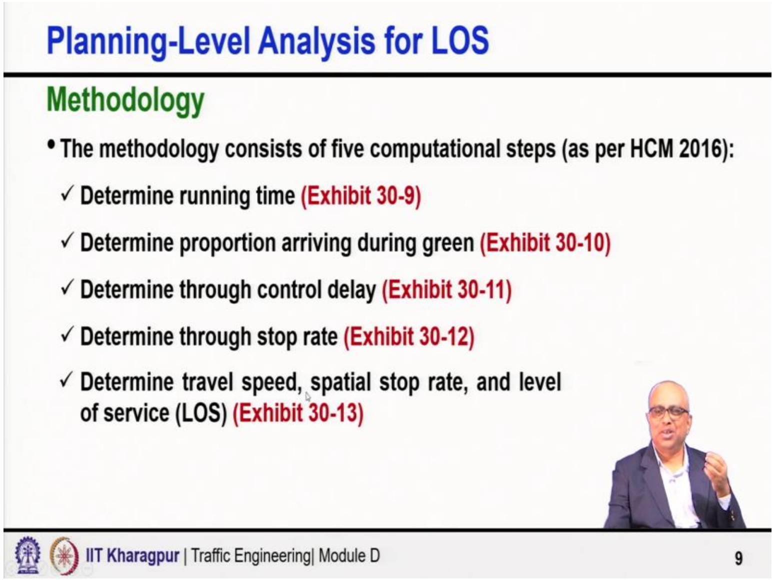

Now, if you think exhibit 30.8 now exhibit 30-8. It is another exhibit which illustrates the calculation framework for planning level analysis application for urban road segments. Now this framework illustrates the calculation process which consists of three modules. So, five computational steps, three modules we are referring here one is, Segment analysis module, then Signalized intersection module and then Performance measures module.

So, the whole flowchart methodological flowchart it consists of three components, first segment analysis module, then signalized intersection module and then performance method module. In segment analysis module we compute the running time and proportion arrive and during green this two things are getting computed.

Now, there is corresponding you can see, running time determination is again a step here which is shown in exhibit 30-9 and proportion of vehicle arriving during green these are also two computational steps identified here and which are actually included if you see that is the computational steps or the worksheet and here it is in this part of the module, which is actually taking care of that.

Then signalized intersection module it includes computation of control delay and stop rate. So, again if you go back you can see this is determination of through delay and determination of through stop rate exhibit 30-11 and 30-12. So, the broad methodology is here the corresponding computational steps are in the worksheet how to calculate actually following this worksheet.

But this worksheets are actually developed linking it to this overall framework or the methodological framework. Then, the third module includes performance measures computation of segment travel time and spatial stop rate. So, similarly, you can see this is this exhibit with determine travel time spatial droplet stop rate and finally, the level of service.

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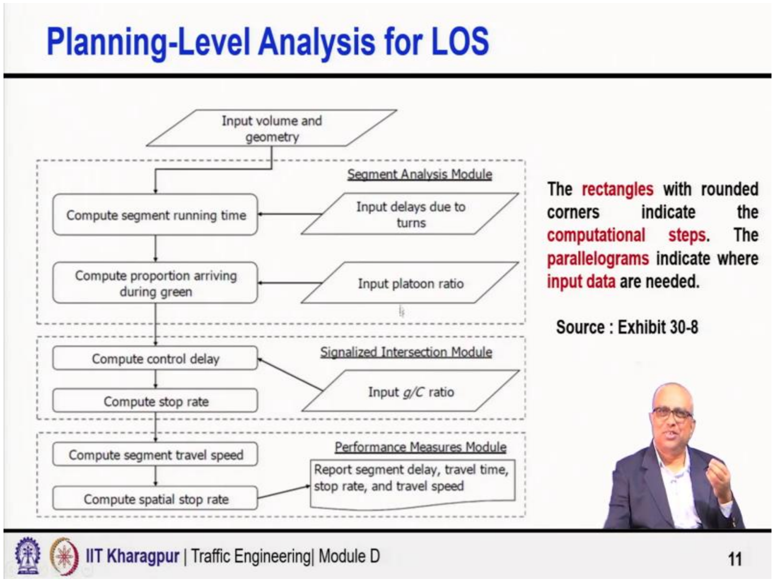

Now, this framework with this as I said three modules is shown here, you can see here this box the first one as it is shown here. This box this part is actually showing you the segment analysis module two measure things we are calculating as we said running time we are calculating and proportion arriving during green.

So, for calculation of running time, we are including the input such as delays due to turns and to compute the proportion of a vehicle arriving green the additional input given is the platoon ratio. We have not yet discussed what is platoon ratio again as I said this module and the next module, the next module deals with intersection and intersection control specially signalized intersection in details.

So, many of the terminologies are actually discussed there. Again the signalized intersection module compute control delay stop rate and for that one we are giving input such as intersection effective green time to cycle ratio g by c ratio. So, that is going for computing the control delay and the stop rate also is calculated once you know all the previous inputs then the last module.

Which, is performance measures module in this, one we are calculating the segment travel speed and also the spatial stop rate. Now, many of these steps are very similar stepwise to what I have explained to you already in the operational level framework. So, they some of them are really very similar same equation is also used, but, the overall calculation is made much more simplified at this planning level analysis as compared to what was shown in the operational level analysis.

But, some of the steps like many of the say compute segment travel speed compute spatial stop rate or stop rate control delay many of the things were actually there in the operational level analysis also these were the steps, but here it is much more simplified, some of the steps are very similar, some of the equations are very similar basic equations.

But things are the way we are calculating many of the intermediate input or processed values, which are again further going into calculation of the final equation simplified equation, the way the inputs are getting calculated, there lot of simplification segment. Now, here all these rectangles, which are shown with rounded corner, indicate the computational steps and the parallelograms which are shown here indicate the input data.

So, these are all the input data and rectangles with rounded corners like all these, these are the computational steps. So, these are the computational steps and these are the parallelograms indicate the input data.

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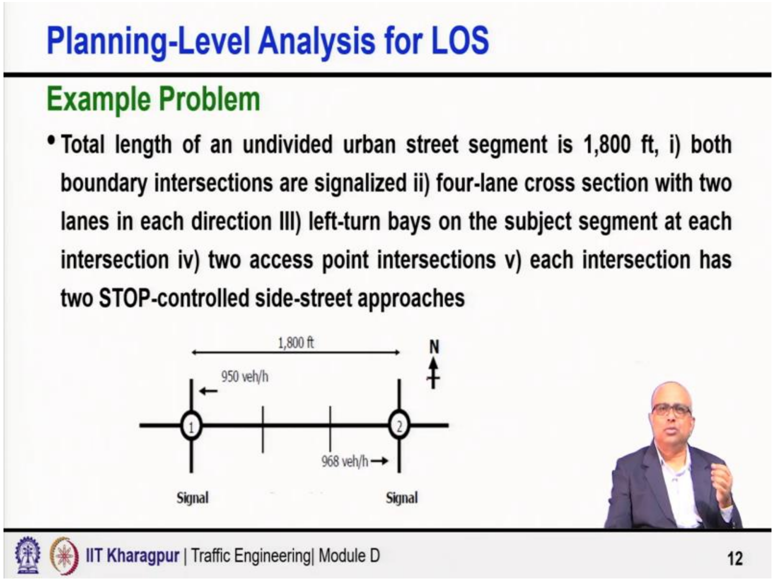

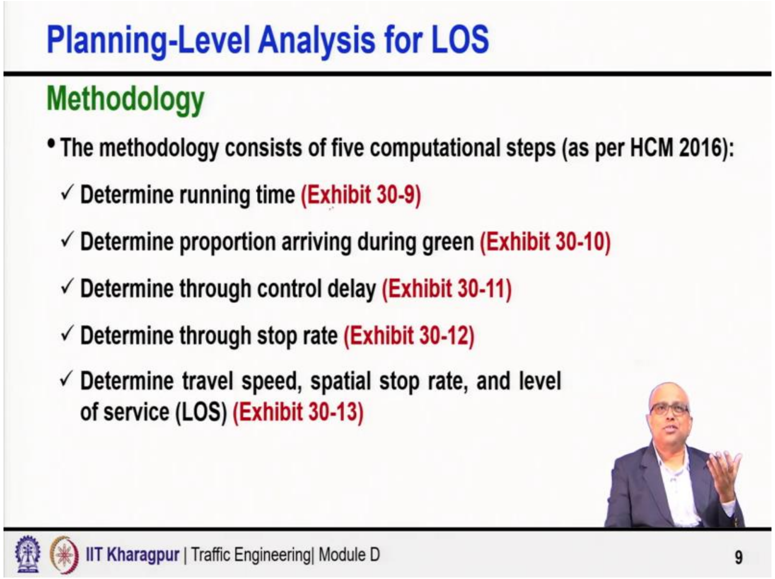

Now, as I said that here also, if I want to take up an example, which will include all these computational steps in details, I need to tell you many things which are related to intersection operation some of the terminologies are not yet known to you. Of course, you will learn those in the next module as a part of our discussion on intersection control and signalization.

And some of the cases like the basic free flow speed, if I want to estimate it with all the inputs, the equations is same as what has been mentioned to you, when I discuss the operational level analysis, but, it will be unnecessarily lengthy. So, I have now picked up a problem, which is quite simplified version of the overall problem that could be formulated and where I will not go or demonstrate calculation with each computational steps as shown here.

But, I will take is much more simplified problem, where I will omit some of the computational step for example, determine through control delay this I will omit, because a lot of discussion related to intersection control signalization you need to know, lot of things you need to know. So, I will simply assume the value of control delay.

How to calculate you will eventually learn in the next module when I go to module and also some of the inputs which may not require to directly calculate LOS because LOS what we need. Finally, to say whether LOS, A B C D E or F, we need speed segment whatever under consideration, what is the speed, what is the free flow speed, the threshold values are already known, I have shown you earlier when I talked about how to define LOS for urban state segments.

So, one is volume to capacity ratio, the other is the segment speed what is the real representative speed for the segment with respect to the free flow speed. So, I will only calculate through the calculation of those components which are required to finally conclude what is the LOS the, to calculate the traveler perceptions score additional data will be required and some of those calculations I am going to omit.

So, I have actually taken now an example which is a simplified example with this background, the total length of an undivided urban segment is 1800 feet, both boundary intersections are signalized there are four and cross section with two lanes in each direction left and bays on the subject segment at each intersection is present two access point intersections are there and each intersection has two STOP-controlled side-street performance. So, as shown here, the through volume is 950 and 968 and the distance is 1800 feet of the segment.

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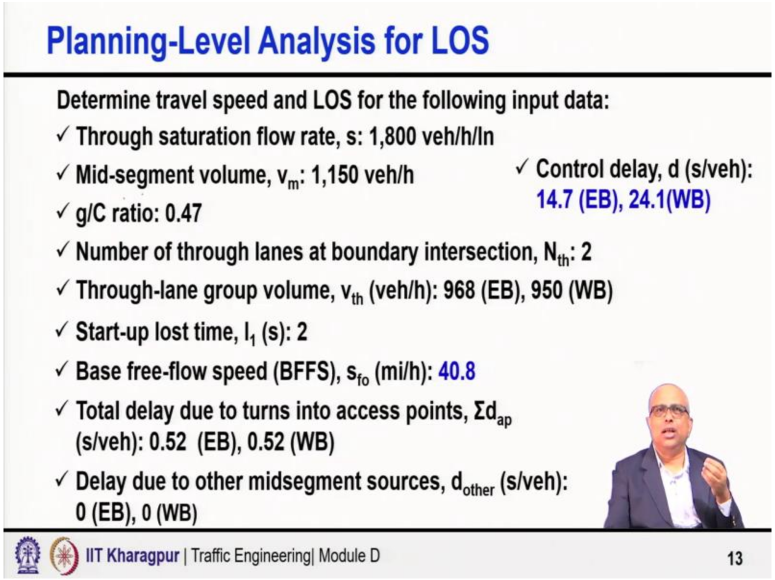

So, determine travel speed and LOS for the following input data as I have said, whatever inputs are required for the calculation of LOS with the simplified framework that I have used, so, the segment through saturation flow rate is given Mid-segment volume is given g by C ratio, effective green time to cycle time that ratio is given number of through lanes at boundary intersection is given through lane group volume that is given eastbound and westbound startup loss times is given based free flow speed we could estimate even whatever you know, how the base free flow speed and the free flow speed can be estimated.

But we could estimate using several other inputs, but the components I have explained you, while I discussed about the operational level analysis, so, I have directly assumed the BFFS value and omitted all other inputs required which are required to calculate or estimate BFFS. That is, so, base free flow speed is directly given total delay due to turns into access point that is also given here, the eastbound and westbound then delay due to other mid segment sources I have said that there could be delay also due to other reasons, I have explained it in the last lecture previous lecture.

And the control delay we could calculate actually there is a spreadsheet worksheet for you can calculate with all given inputs. I have made it simplified; I have assumed the control delays known how to calculate the control delay you will anyhow learn in the next module. So, I have omitted that part here. With this background let us go.

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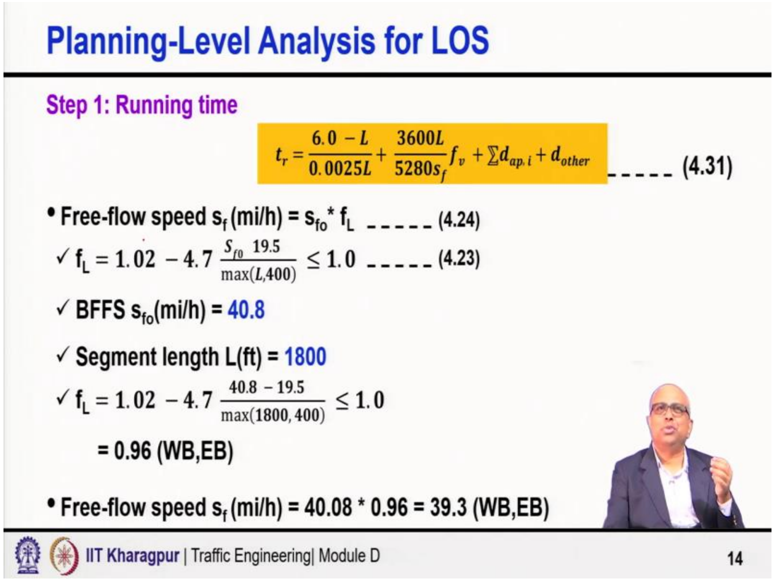

Let us proceed further to see first step here is the calculation of running time, I have shown the equation which will be used in operational level analysis I mentioned to you about various components, but I did not show you this final equation I mentioned to you how what are the different components you have to calculate.

So, but those who are discussed, but did not show you this equation here I have shown it. So, if we look at this equation, you need to calculate the free flow speed S_f, S_f is S_{fo} into f_L. Now, f_L, how you can calculate again this equation was mentioned earlier, I have reproduced it here 4 23 that was the 4.23 is the equation number.

This was mentioned to you earlier we have used that equation in that case we know the BFFS value. So, S_{fo} that is the BFFS value is given 40.8 and the segment length is also given 1800 feet. So, you can actually then calculate the fL value. So, (1.02 -4.7) $\times S_{fo}$ is this BFFS 40.8 minus 19.5 divided by maximum of segment length and 400 that maximum value we take. $\left(= 1.02 - 4.7 \times \frac{40.8-19.5}{\max(1800,400)}\right)$

So, this is to consider the effect of length of the segment on the free flow speed. So, that calculation we do segment length how it is going to affect so actual free flow speed FFS will be BFFS which is 40.8 multiplied by this correction due to the segment length. So, now you get this Sf as 39.3 for eastbound and for westbound same calculation. $(40.8 \times 0.96) = 39.3$

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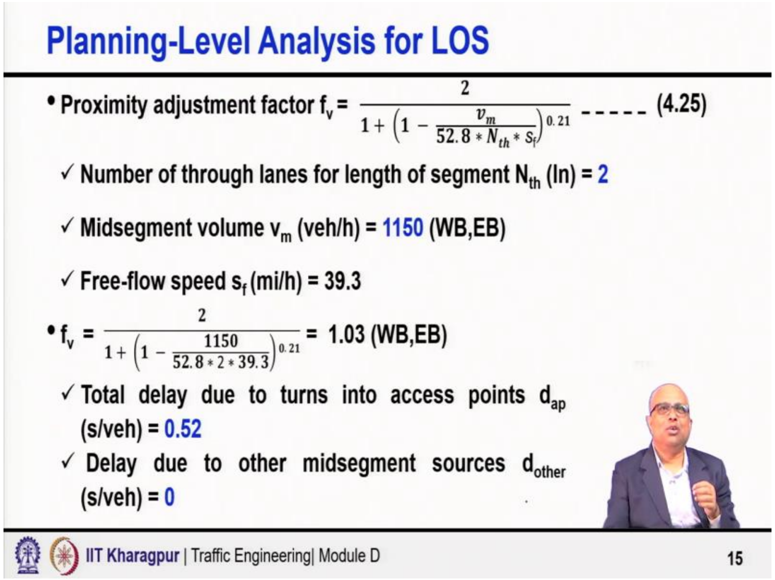

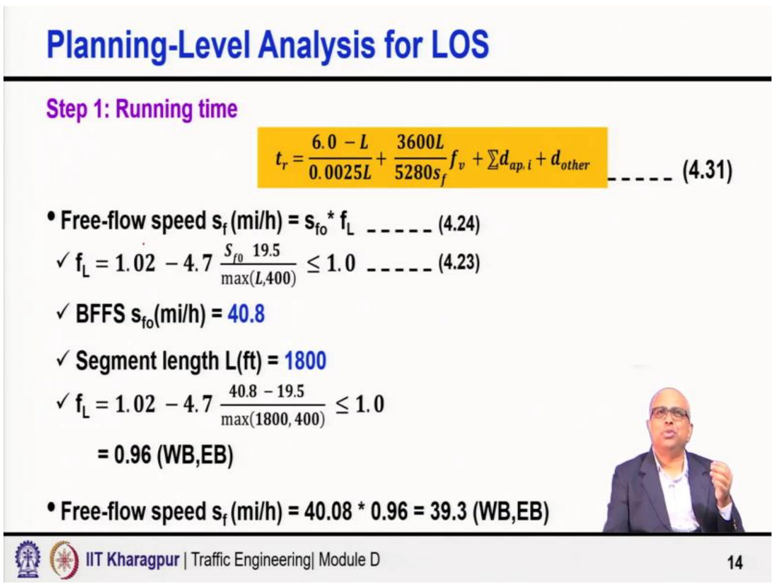

Now, going to the next step proximity adjustment factor we are calculating. What is proximity adjustment factor I have described it earlier in the last lecture. So, it takes care of the mid segment volume and what is the effect of volume now, on the speed whatever we have estimated as the free flow speed.

So, the number of lanes through lane is given here to mid segment volume we calculate how we calculate this volume, we have to do all adjustments actually balancing the OD part all considerations I have discussed the similar procedures may be applied. So, mid segment volume is already given here, free flow speed you have just calculated in the previous step. So, that is again an input to the next calculation. So, now, with this you calculate the proximity adjustment factor. So, that is 1.03.

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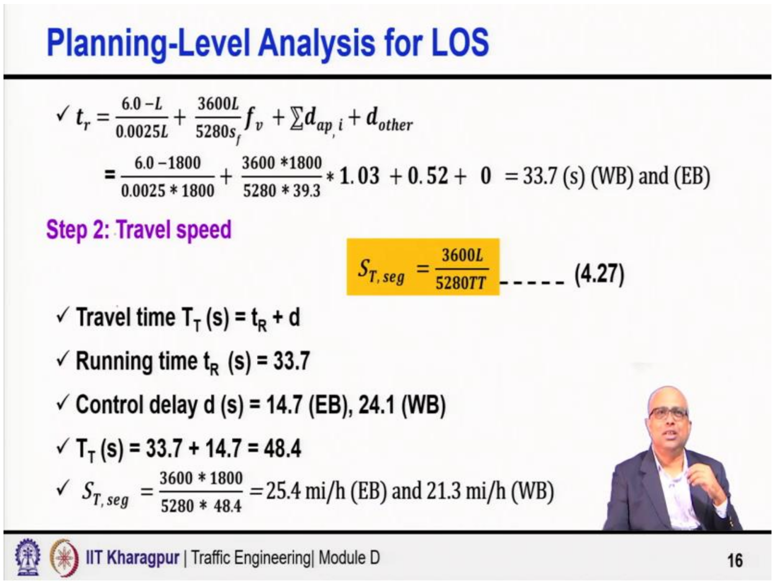

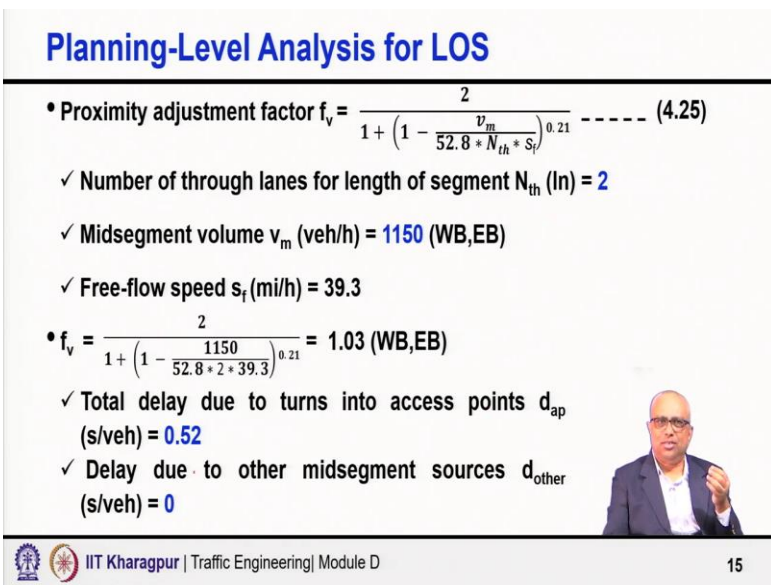

Now, next is our calculation that is t_R running time. So, how we calculate the running time to calculate the running time we need total delay due to turns in the to the access point. So, that is given 0.52 seconds per vehicle and delay due to other mid segment sources is assumed as 0, here that is given. So, with this we calculate the t_R value running time, this is the equation that is used.

And you calculate the value as 33.7 seconds for both westbound and eastbound. So, that is our step 1.

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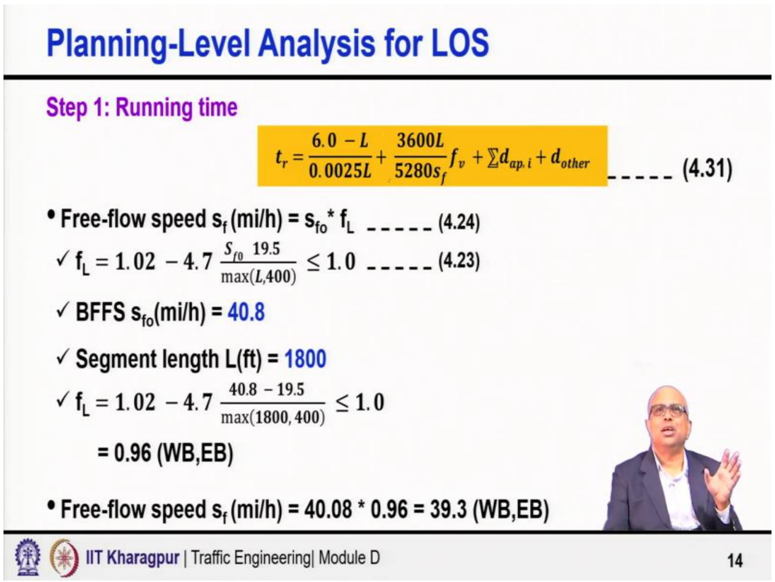
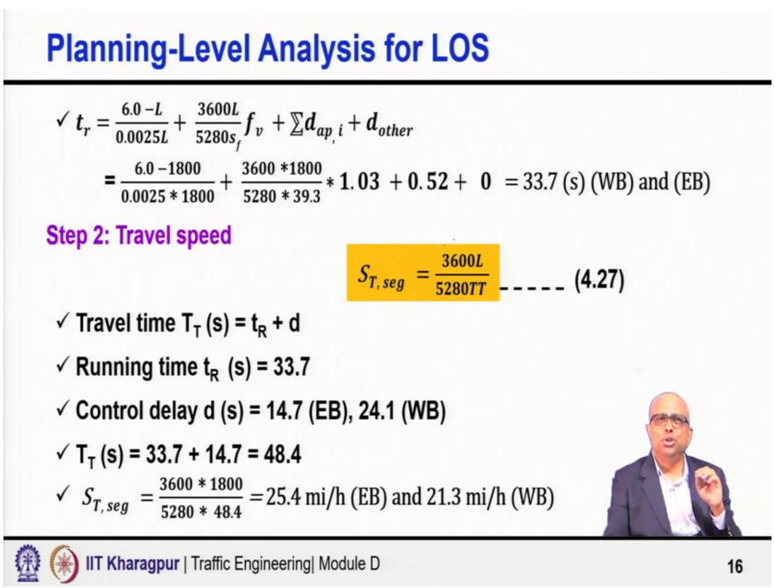




Planning-Level Analysis for LOS

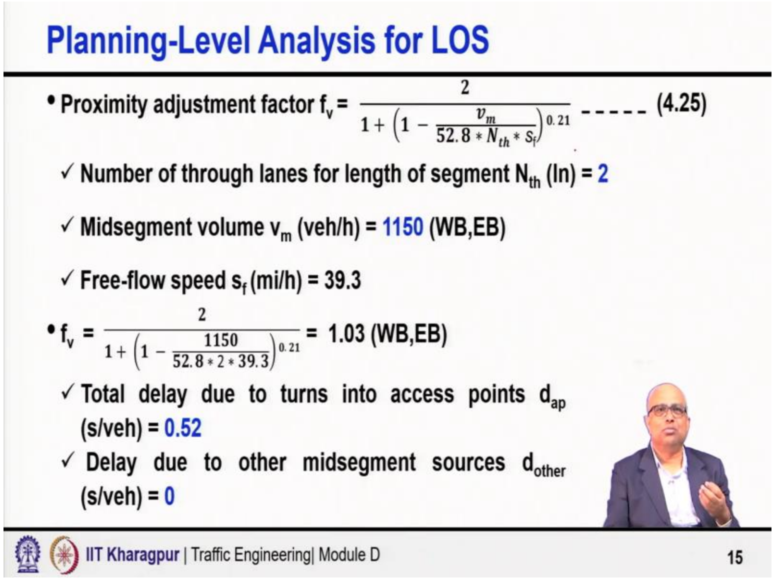
Determine travel speed and LOS for the following input data:

- ✓ Through saturation flow rate, s: 1,800 veh/h/ln
- ✓ Mid-segment volume, v_m: 1,150 veh/h
- ✓ g/C ratio: 0.47
- ✓ Number of through lanes at boundary intersection, N_{th}: 2
- ✓ Through-lane group volume, v_{th} (veh/h): 968 (EB), 950 (WB)
- ✓ Start-up lost time, l_1 (s): 2
- ✓ Base free-flow speed (BFFS), s_{fo} (mi/h): 40.8
- ✓ Total delay due to turns into access points, Σd_{ap} (s/veh): 0.52 (EB), 0.52 (WB)
- ✓ Delay due to other midsegment sources, d_{other} (s/veh): 0 (EB), 0 (WB)
- ✓ Control delay, d (s/veh): 14.7 (EB), 24.1(WB)

Planning-Level Analysis for LOS

Methodology

- The methodology consists of five computational steps (as per HCM 2016):
  - ✓ Determine running time (Exhibit 30-9)
  - ✓ Determine proportion arriving during green (Exhibit 30-10)
  - ✓ Determine through control delay (Exhibit 30-11)
  - ✓ Determine through stop rate (Exhibit 30-12)
  - ✓ Determine travel speed, spatial stop rate, and level of service (LOS) (Exhibit 30-13)



Where, we have actually calculated the running time. So, the running time calculation is done. So, once we know the running time, then we are going to step 2 that is travel speed, how you do it with this equation (3600 into length)/(5280 into TT) it is not written correctly here, it is typographical error. So, travel time could be TT.

Now, what is the TT it is the running time plus the control delay. Now, the control delay is again an input for us 14.7 and 24.1 I have said that we could calculate it with all the inputs, several inputs will be required, several steps will be required. Even there is also this exhibit 30-11, for determining through control delay, I have completely omitted that I have just assumed that you know it. You will learn in Module E, how to calculate control delay.

So, the control delay is known now in this case. So, with that we know the running time as calculated 33.7 and the control delay is known control delay is different for eastbound, westbound. So, the TT value also has to be calculated separately because TT is tR plus D. So, in one case, I have shown the calculation for this bound 33.7 plus 14.7. So, 48.4 and then you can calculate this ST using this formula travel speed. So you get it for the eastbound as 25.4 mile and for westbound using this different control delay value 21.3 miles per hour.

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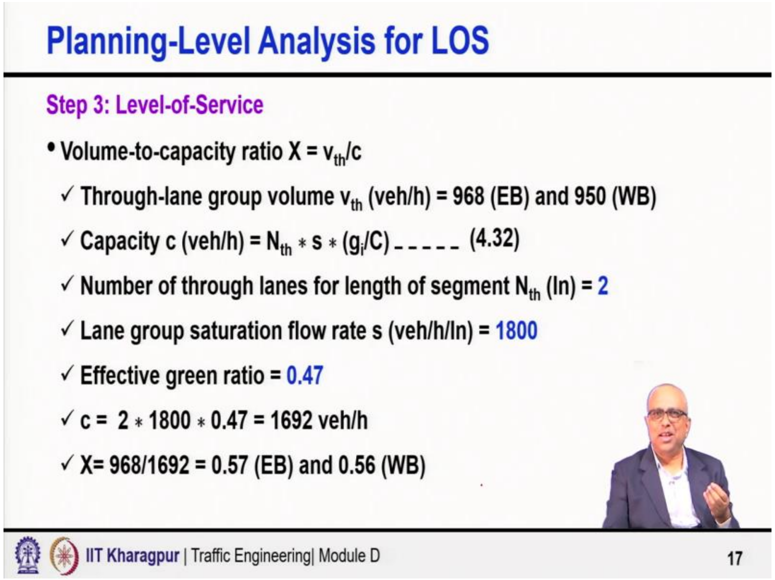

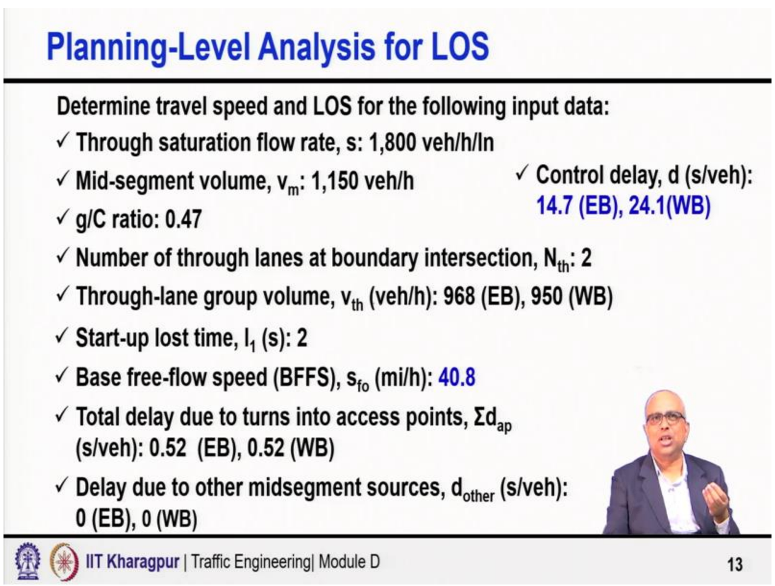

Once this is done, then our job is done. We go now to the level of service calculation. So, for level of service calculation, first we need to calculate volume to capacity ratio. So, what is the through volume and what is the capacity? Through lane group volume we know that it is 968 and 954 for eastbound and westbound respectively, these are given 968 and 960.

These are given through lane group volume. So, we are directly taking those values then the capacity how we can calculate this is again known to you saturation flow rate into g by C multiplied by number of lane g is the effective green time. So, green time to cycle time ratio effective green time to cycle time ratio this g by C into s because that is the fraction where you actually getting the discharge at saturation flow rate.

So, the capacity can be calculated in this case the number of lanes is 2 and lane group saturation flow rate s 1800 again it is given vehicle per hour per lane and effective green ratio that is nothing but gi by C. Green to effective green to cycle time ratio is 0.47. So, you can calculate the capacity here and the capacity using this 4.32 this equation number and using all these inputs, you get 1692 vehicle per hour.

So, what is then volume to capacity ratio, for eastbound it is 968 lane through lane group volume 960 divided by 1692 and in this case, similar way you calculate it for the westbound 950 divided by 1692. So, the values that 0.57 and 0.56 respectively.

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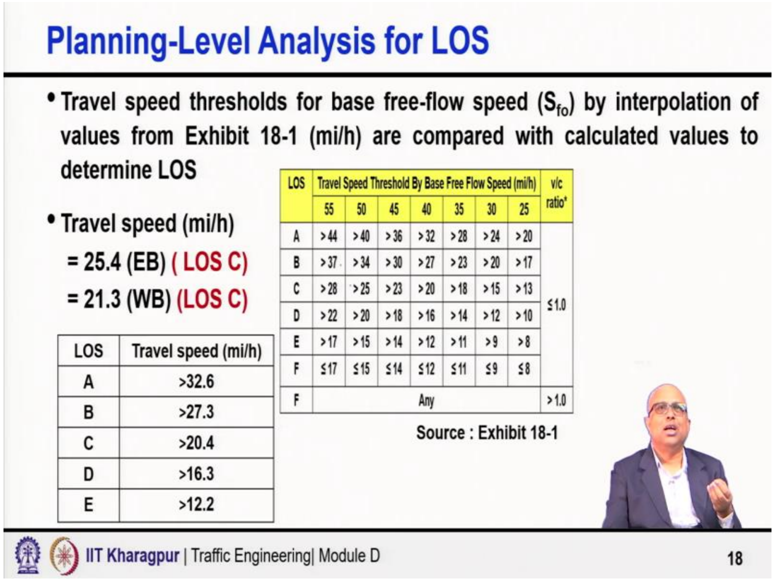

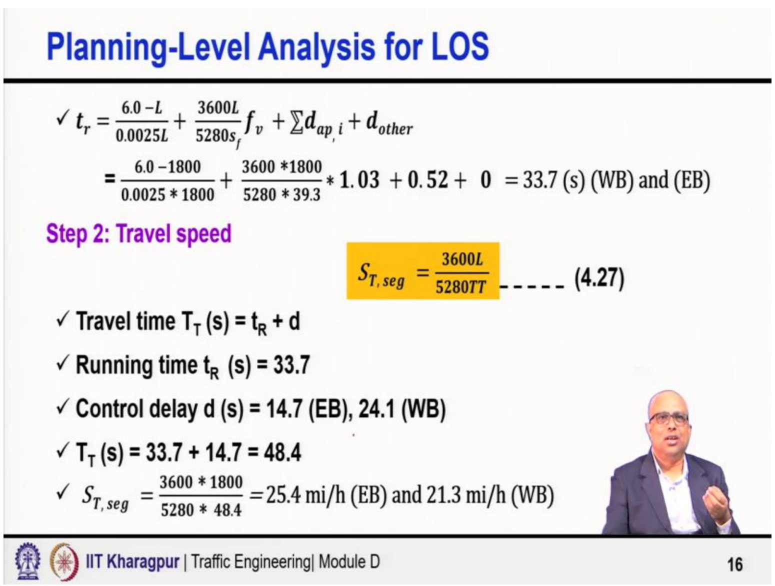

Now, with this travel speed threshold for the base free flow speed, you if you remember this exhibit I mentioned earlier also in my earlier lecture, it was wrongly mentioned as Exhibit 18-3 or 18-4 something it was it is supposed to be 18.1. So, this exhibit actually show for different free flow speed based free flow speed in miles per hour then what are the threshold speed values for different levels of service?

So, in our case, the free flow speed we know what is the S_{fo}, S_{fo} we have calculated earlier where is the value we have calculated earlier in a S_{fo} and based on that, we know like 55-50-45-40-35-30 these values are given. So, if it is in between we can interpolate and accordingly the threshold value also for the given base free flow speed can be obtained.

So, those are calculated already and shown here. Now the travel speed we have calculated from this step that what is the speed, speed we have calculated 25.4 and 21.3. So, we put it here 25.4 for eastbound and 21.34 westbound. So, our volume to capacity ratio is less than 1. So, it does not go to LOS F and then we take this travel speed and according to this travel speed both directions, the level of service C.

So, you calculate the level of service C. So, this way you can calculate obviously, additional inputs, what I have assumed here for this example, can also be calculated, you only need to do additional calculation and some of the terminologies once when we discussed Module E, then you can make those calculations very easily.

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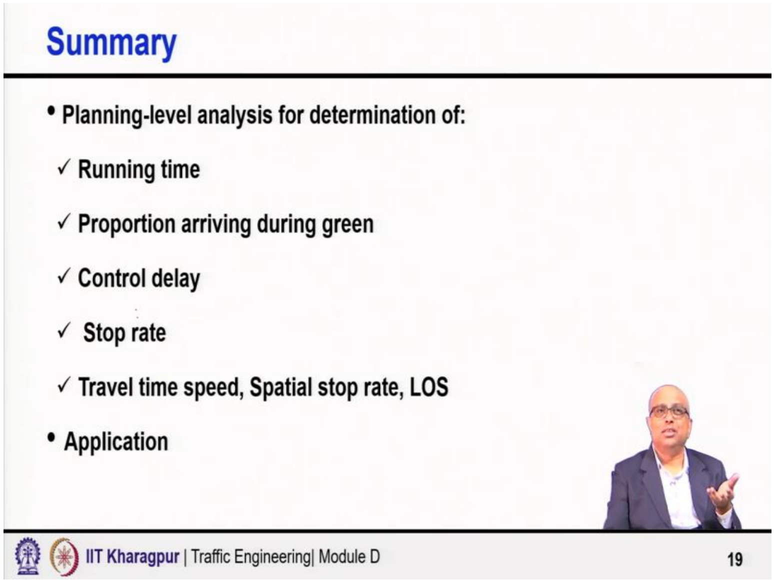

So, what we discussed is planning level analysis. Finally, with an aim to define or calculate level of service, we discuss in between how the overall framework the calculation of Running time, Proportion of arriving during green, Control delay, Stop delay, these are the five work spreadsheets which you can use effectively. Then we took a simplified example and showed you how you can calculate the level of service. So, with this I close this lecture. Thank you so much.