Introduction to Multimodal Urban Transportation System
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Lecture-18
Public Transportation: Bus and Rail Transit Capacity - II

Welcome back friends. In the previous lecture we had introduced you to the various concepts in capacity and speed calculations of bus and rail transit. In this lecture we will show you some solved examples of capacity calculations of rail and speed rail and bus transport. This will help you understand those theoretical concepts that you have already learned in the previous lecture.

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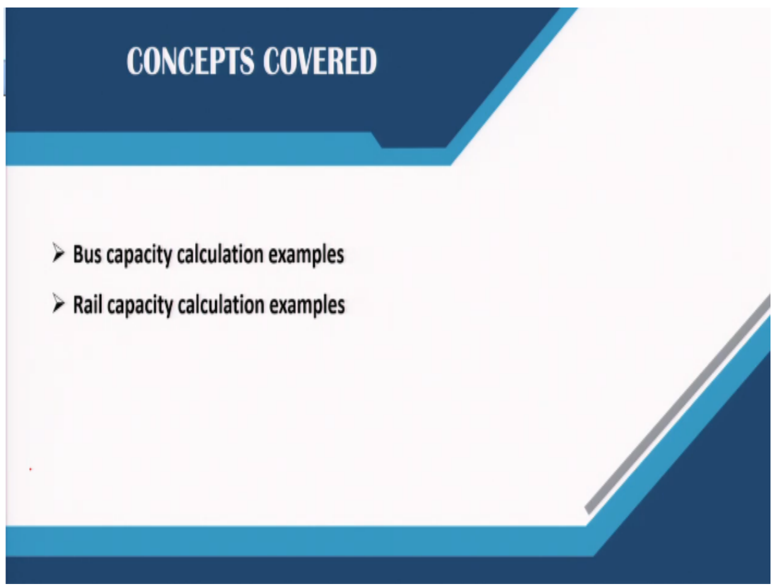

So, we are going to give you one example each of bus capacity and rail capacity and mostly what you will see they are empirical formulas that are used in calculating these problems. So, you do not have to worry about memorizing these formulas, but understand the concept of what are the different inputs that are needed in these calculations. And if you understand those, the rest is pretty simple.

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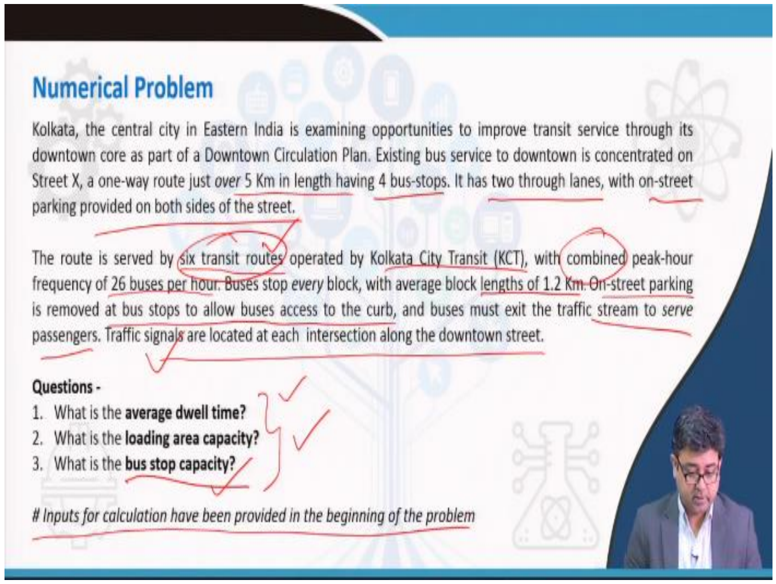

So, we start with the first problem where we are trying to determine the bus stop capacity. So, as you see finally what we need to determine is the bus stop capacity. Say Kolkata, which is a major city in eastern India, is examining opportunities to improve transit service through its downtown core as part of a downtown circulation plan. Existing bus service to the downtown is concentrated on say a street X which is a one-way route just over about 5 kilometers in length and has 4 bus stops.

It has through lanes with on-street parking provided on both sides of the street. The route is served by 6 different transit routes. So, along this 5-kilometer stretch, there are 6 different transit routes operated by say a fictitious agency called Kolkata city transit with combined peak hour frequency of 26 buses per hour. That is a combined frequency of all the 6 routes. Buses stop every block with an average block length of 1.2 kilometers.

On-street parking is removed at bus stops to allow buses to access the curb and buses must exit the traffic stream to serve the passengers. Traffic signals are located at each intersection along the downtown street. So, this gives you the understanding of the existing situation. So, this is a common scenario in any of the cities or towns where you may have a bus route or a bus network or a bus system.

You will have certain bus routes, certain overlapping bus routes, they will have certain designated bus stops, they may or may not have on-street parking and traffic signals may or may not be there. So, in this case everything is given to you and what you are asked to calculate is to first calculate the average dwell time, second calculate the loading area capacity and finally, using all these to calculate the bus stop capacity. We have learned about all these theoretical concepts in the previous lectures.

So, just go back and look at the definitions of all of this and then you will follow through the example problems. So, now, let us first look at the inputs that will be needed to calculate each of these 3 parameters.

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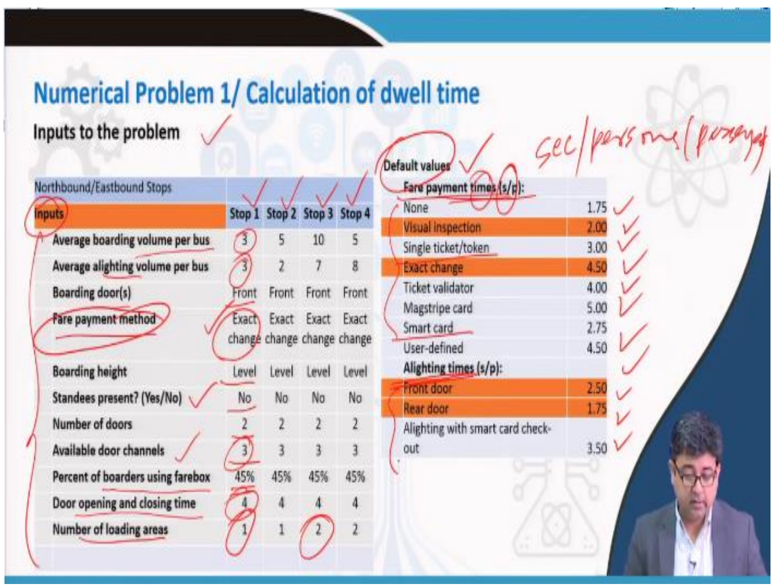

So, we know that there are 4 stops along that line. So, for each of the stops what you will need is average boarding volume per bus, average alighting volume per bus, how many boarding doors are there? Or where they are there? Are they in the front? or is boarding allowed only through the front door or back doors, or both doors. So, wherever are the boarding doors, what is the fare payment method? Is it exact change only, or is it say for example- Smartcard, is it a single ticket token?

So, what is it? What type of fare collection is operating in your bus system, that you have to know. Boarding height, whether your platform is at level with the bus, bus landing, or is there a difference? standees are present or absent? So, do you allow standees on the bus or only sitting is allowed? Number of doors, available door channels, i.e. Door channels meaning if it is a double door that opens into the bus, then the 2 doors will have 2 channels, although to be considered as one boarding gate or boarding door, but it will have 2 channels. So, if 2 channels open that means 2 rows are formed.

So, it is one door, but now there are 2 channels. So that is what is known as channels. Next is percentage of borders using fare box. There may be some persons, or a lot of persons, who have daily passes or they do not need tickets. So, there will be only a portion of them who will need tickets. What is the percentage of people who actually use the fare box that is in the bus? Now you will be thinking that realistically in most of our buses, there is no fare box kind of a system. But think about it as these modern POS machines.

So, there may be POS machines through which you can buy ticket then maybe if you have a pass then either show a pass if you are a student, for example, or if you are an elderly citizen. Say for example maybe the bus ride is free for you, if you are a woman in Delhi, maybe the bus ride is free for you. So, all those factors act in the calculation of the dwell time at a stop. You remember what a dwell time is, dwell time is the amount of time a bus is stationary at a stop to pick up and drop off passengers.

So, all of these factors that we are talking about goes into the calculation, they are all inputs, they go into the calculation of the dwell time. Door opening and closing loss time, so, there may be some few seconds that go into the door opening and closing and the number of loading areas. So, remember, a bus stop may have only one loading area or it may have sometimes 2 loading areas back to back. So, there may be 1 or 2 loading areas.

So, these are all the inputs that are need, then you will have some default values that you can use, these default values have been developed by looking at various bus systems across the world, so these are average values or best values or best practices values. They are default values which will allow you to at least get started with understanding how your bus system capacity works or what is the dwell time. So, there are some of these fare payment types.

So, these are number of people or number of seconds per person, how much time is needed to process the payment of one person or one passenger who is boarding the bus. So, seconds per person or seconds per passenger. So, you will see there are different times that are given as default values. So, based on what type of fare payment method your bus system is operating on, you may assume, or you may select any one of these 2 values.

So, alighting times, there are also some standard values for alighting times. These are fare payment times, and these are alighting times. So, these are some standard values, like I said, these are all based on empirical studies that have been done across the world. And these values or this formula is also developed based on these empirical studies that have been carried out.

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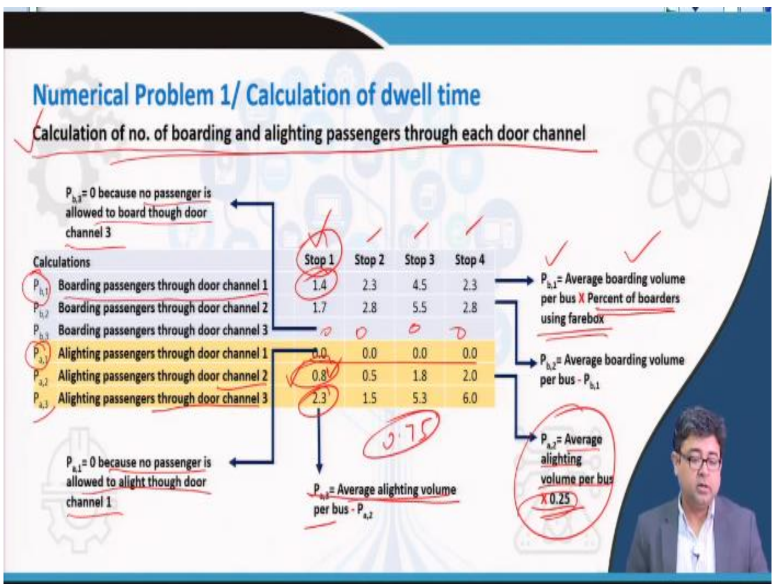

So, first what you would like to do is, you will have to calculate the number of boarding and alighting passengers through each door channel. So, remember it is not the door but door channels. Like we discussed one door has 2 panels that may create 2 channels. So, in order to do so, I will just go through the calculation for one stop, and you may do the similar calculations for all the other stops. But anyhow, the answers are showed here, just follow through these answers.

So, if you want to calculate for example, what is called P_{b1}, which is the boarding passengers through door channel 1. So, what you have to do is average boarding volume per bus multiplied by the percentage of borders using fare box. So, now these 2 values are already given to you as input parameters, for example, average boarding volume per bus, in stop 1 is 3.

So, 3 people on average board this bus from stop number 1. You multiply that by the percentage of borders using fare box. So, the percentage of borders using fare box has already been given here, which is 45%. So, if you multiply 3 times 0.45, what you will get is 1.4. So, you do all those for every other stop or you will see some of the stops have 0 values or no values that is because no passenger is allowed to board through door channel 3 or no passenger is allowed to alight through door channel 1.

So, there may be some restrictions. So, if there is nobody allowed to board or alight through one of those door channels, then the number of people boarding and alighting then value will be 0. Similarly, while calculating the number of passengers alighting through door channels 1 values are 0. So, if you do it for door channel 2, for bus stop 1.

All you need to do is an average. Alighting volume per bus time is 0.25, again 0.25 is a standard number that is assumed for alighting and those alighting times are given here. These are alighting times are average alighting volume, you know the average alighting volume. So, multiply the average alighting volume by 0.25 you will get these numbers. And if you just want to do the next number, so P_{a3}. So average alighting through door channel 3 because you know the total average alighting volume is, you know 3. So, 3 - 0.8 essentially is 2.3.

So, I think it is rounded off to the one decimal, that is why 0.8 instead of 0.75, or something like that. So, they are rounded off, do not worry about the rounding off. So, these are simple calculations for the first step which we have to calculate to determine the number of boarding and alighting passengers through each door channel.

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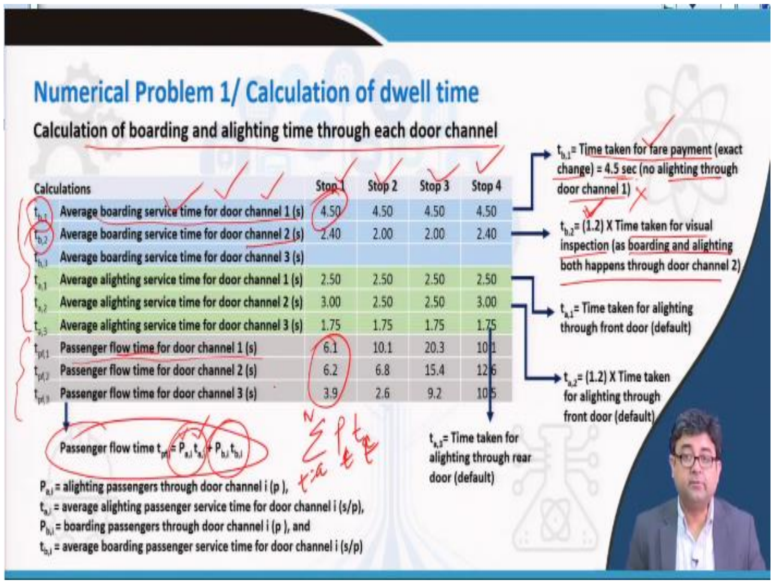

Next, we have to calculate the boarding and alighting times through each channel. Now you know how many people are boarding and alighting through one channel. Now, you need to know the time that people are using to board or alight. So, again similarly all the calculations for all the 4 stops are shown, let me just take you through one stop. So, if you have to calculate t_{b1} that is the average boarding service time for door channel number 1. All you need to do is to calculate time taken for fare payment with exact change, which is equal to 4.5 seconds and there is no alighting through that door.

So, this is the time taken to board through channel 1 as there is no alighting allowed to channel 1. So, it will be only the time that is needed by people to board and we already know that time is equal to the time taken for fare payment in case of exact change. Since we have already shown that these are using exact change. As in case of exact change here, we know that the time taken for exact change is 4.5 seconds.

So, average boarding service time taken through channel number 1 for stop 1 is 4.5 seconds. So, it is as simple as that. If in case for channel number 2, for example, where both boarding and alighting are allowed, these are door channel number 2 where both boarding and alighting time allowed, you have to multiply this time taken for visual inspection into 1.2, because now you are visually inspecting who is boarding, who is alighting.

So, that adds a little bit of time to it. So, you know, what is the time taken for visual inspection that is 2 seconds, 2 seconds per passenger. You multiply that by 1.2 and you will know the time taken. After you have calculated the time taken for boarding and alighting, next what you have to do is you have to calculate the passenger flow time through each of the door channels. Now, you know the number of passengers, you have calculated the boarding number of passengers and you have calculated the average boarding service time.

Now, you have to know the passenger flow time. So, all you have to do for passenger flow time is you have to multiply the number of passengers boarding through each channel times the time taken for them to board. And you have to sum all of those for all the different channels that are available. So, it is just a summation of the product of t_a times.t is equal to N so, how many channels are there, you develop the product of it and sum it, that will give you each of these values. So, that gives you the passenger flow for each of the door channels.

$$Passenger\ flow\ time\ t_{pf,i} = P_{a,i}t_{a,i} + P_{b,i}t_{b,i}$$

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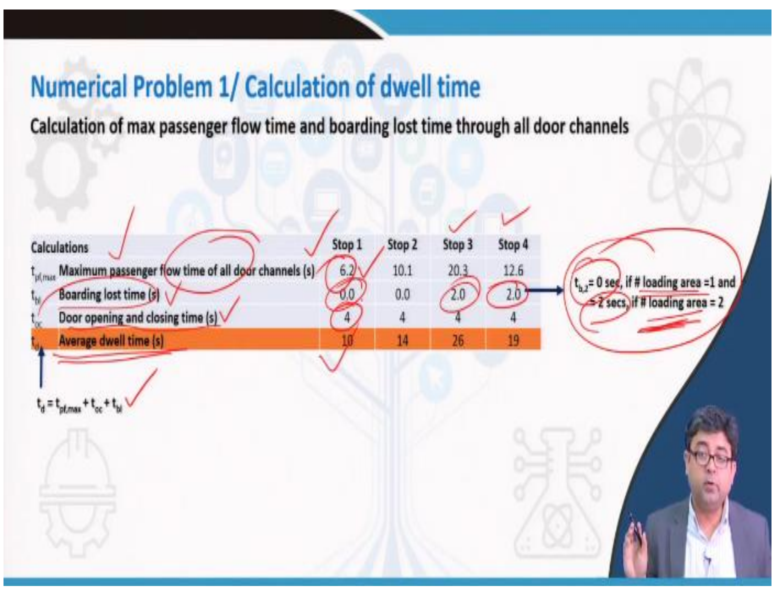

Now, you know the passenger flow through each of the door channels, in order to determine your first answer which is average dwell time. Now, you have to all you have to calculate. You already know the passenger flow which you have calculated. One boarding lost time is something that again is a standard value that are given if there are only one loading area, there is no loss. If there are 2 loading areas there is a 2 second loss because, you know there 2 loading areas back to back.

So, the bus that is coming behind sometimes faces a little bit of delay if the bus in front is not parked properly, so, there will be a slight delay there are 2 loading areas. So, stop 3 and stop 4 has 2 loading areas. So that is kind of boarding lost time and already the door opening and closing times are given to you as standards here both door opening and closing times here. So, you take these 2-time factors and you take the maximum passenger flow time.

Then you add up all the 3 times. This tells you that this much time is needed to process the passengers boarding and alighting because there will be people paying tickets, ticket fares and so on, so forth. So that gives you the total time needed for that, gives you the boarding lost time in case there are multiple loading areas. And this gives you the door opening and closing time. So that will give you the average dwell time for each of that stops. So that solves the first problem.

$Average\ dwell\ time\ (s) t_d = t_{pf,max} + t_{oc} + t_{bl}$

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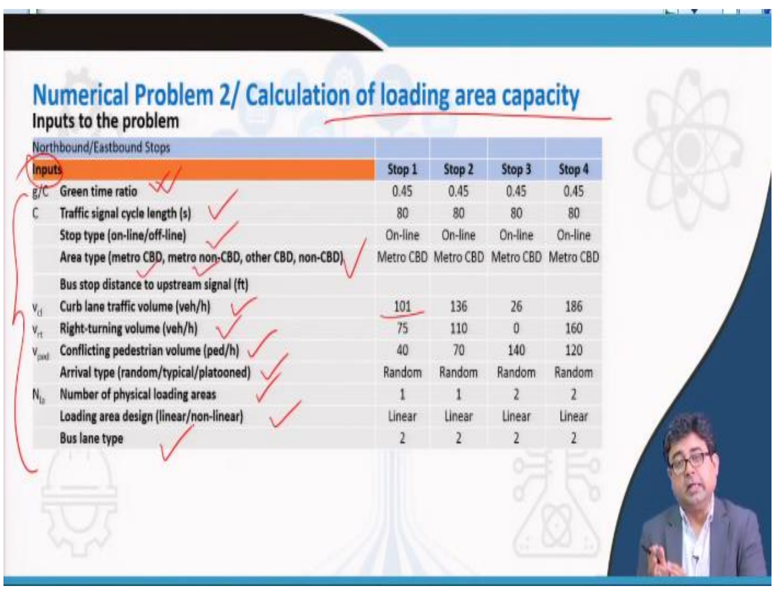

For the next problem which you have to calculate the loading area capacity again there are a bunch of inputs that are needed, and these inputs are shown here again. Inputs include green time ratio. Now, loading area capacity is influenced by if the bus stop is near the intersection, then the green time at the intersection affects the loading area capacity. So, you have to know the green time ratio, i.e.the traffic signal cycle lengths; what type of stop it is, or does it have a bus bay, and so on and so forth. Which area it is, is it in a CBD or non-CBD or some other type of area, residential area, so and so on and so forth. You know which area the bus stop are in. Then you have to know the curb lane traffic volume, curb lane only. Like if there are multiple lanes, all you have to know is that traffic volume on the curbside lane, the turning volume.

In our case the left turning volume that is because we have free left. So, those vehicles turning left may affect the loading area capacity of the buses. So, since this example is taken from the United States, they have right turning volume conflicts, we have left turning volume conflicts. So, in our case, this will be left turning volume. Next is conflicting pedestrian volume. So, at the intersection there may be pedestrians who are trying to cross, and the bus is also trying to go through.

So, there may be some conflicts there. Next is arrival types of the buses -- do they arrive in a platoon or together or bunched, or do they arrive in a random fashion. Number of physical loading areas, loading area design and bus lane type. All these are input parameters and have to be known. Some of these input parameters will have standard values which will come along with these known parameters.

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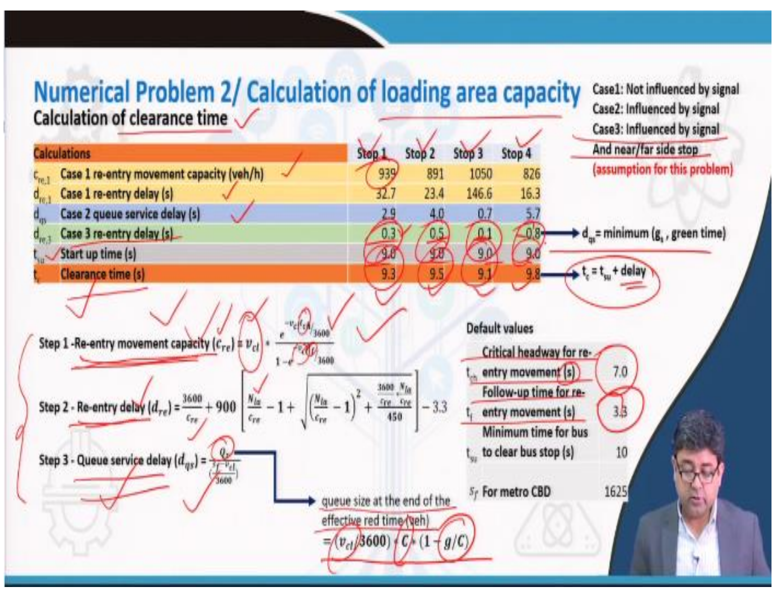

And once you know that, you can start calculating this. The first step in calculation of loading area capacity is the calculation of the clearance time. So, in calculation of clearance time you need to calculate 3 different parameters, one is the re-entry movement capacity, re-entry delay, and the other is queue service delay. Now, do not get caught up in the complexity of the formulas, the formulas are very empirical, each of the values for each of them are given.

$$Re-entry\ movement\ capacity\ (C_{re)} = V_{cl} * \frac{e^{\frac{-v_{cl}t_{ch}}{3600}}}{1-e^{\frac{-v_{cl}t_{f}}{3600}}}$$

$$re-entry\ delay\ (d_{re}) = \frac{3600}{c_{re}} + 900\left[\frac{N_{la}}{c_{re}} - 1 + \sqrt{\left(\frac{N_{la}}{c_{re}} - 1\right)^2 + \frac{\frac{3600}{c_{re}} * \frac{N_{la}}{c_{re}}}{450}}\right] - 3.3$$

$$Queue\ service\ delay\ (d_{re}) = \frac{Q_r}{\left(\frac{s_f - v_{cl}}{3600}\right)}$$

All you have to understand is what is happening in this case, since you are trying to calculate the loading area capacity, the loading areas may be 1 or 2. So, what the loading area capacity depends upon is the re-entry movement capacity. So, since these buses are stopped at the loading area, they cannot re-enter the traffic lane, then the next bus cannot come into the loading area. So, the re-entry movement capacity affects the capacity of the loading area re-entry delay. So, from capacity you can calculate the delay and then queue service delay.

So, now if there are queues formed for buses that want to come into the loading area, the queue service delay due to the queuing system for these buses is also calculated in order to determine the clearance time. That is the first thing in understanding or in calculation of loading area capacity. Again, these are all shown for 4 different stops, let us go through one of the stops and say that re-entry movement capacity.

So, the first calculation of re-entry movement capacity only depends upon your volume of vehicle, on what you call the curb lane volume, or traffic volume of the curb lane V_{cl}. V_{cl} times e to the power - V_{cl} and t_{ch}, t_{ch} is the critical headway for re-entry movements, again standard values are given there. This is the re-entry in seconds. So, you have to convert it I guess, and then divided by 1 - V_{cl} times t_f, t_f is the follow up time for re-entry movement, again that is given.

So, you just enter those values you get the re-entry movement capacity. From the capacity you can calculate the delay at all the terminals. N_{la} is the number of lanes, c_{re} is something that you already calculated here. You insert those values you get the re-entry delay and from the-re entry delay what you need to calculate is queue service delay. Again, queue service delay depends upon Q_r which is the queue size at the end of the effective red time.

So, may be the signal has red time, even after the red time, there are n number of vehicles that are queued up, that means the green time was not able to service all these vehicles. So, there was a queue formed. So that queue service delay here is calculated. Again you see the g /c ratio, you already know the green time ratio here. You know the capacity; you know the volume for the curb side lane.

So, all of these are already known, you calculate this. So, you know now your re-entry capacity, you have calculated re-entry delay. Now, you have calculated your queue service delay, there is something called re-entry delay for case 3 where case 3 is influenced by the signal nearer the far side. So, it is again an assumption whether it is influenced or not? And standard values are again given here.

You assume those start up time, time needed to if you are stuck in the queue and you want to start back up. Those are standard values that have to be inserted in. Clearance time is nothing but your t_{su} + delay times. So, you add up these 2, you get your clearance time s.

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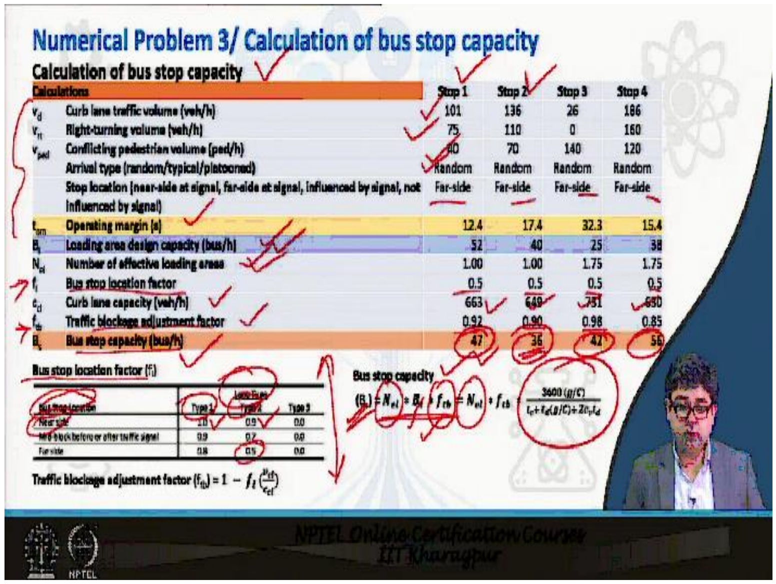

So, now that you have your clearance time, your bus stop capacity calculations can begin. Before you do your bus stop capacity, what we are calculating loading area capacity. So, loading area capacity, you bring in all these input values that are already been calculated - green time ratio, coefficient of variation of dwelling times, the dwell times from numerical one. So, you bring them in here, you calculate the coefficient of variation in each of those dwelling times and you put it in there.

You know how to calculate the coefficient of variants of any given data set, then along with that, you know what the failure rate is. A standard failure rate can be assumed here. Failure rate meaning every time the bus is unable to get re-entry back into the stream. So, there may be certain percentage of time because of the queuing delay because of the queues formed on the travel lane it is not able to re enter.

So, you can calculate the failure rate and from the failure rate you can say that the failure rates are normally distributed, then you can calculate the corresponding standard normal variables for the failure rate. So, 15% times it fails that means 84-85% of the times it can get in. So, for a standard normal, if you go and look at the Z curve what is called Z curve, then you can find these normal values of 1.04, before in case 25% re-entry will be 75% times. So that values will be different.

So, you know all those operating margins, they are something that are standard. Let me see if I can give it here. These are operating margins and operating margin calculations is given here. So, operating margin calculation is nothing but the coefficient of variance in dwell times multiplied by the standard normal multiplied by t_d where t_d is the average dwelling time which you have already calculated in problem 1. So, if you just multiply those you will get the operating margin and then you know from the operating margin you can calculate the loading area capacity with this formula.

Again, this is g/c ratio you already know, t_c you already have been given; t_d, you have already calculated; g/c you know; t_{om} is the operating margin that you have calculated. Using these you develop the loading area capacity. So, now you have calculated dwell time you have calculated loading area capacity, based on this loading area capacity, you can determine what are the number of effective loading areas.

So, if you have one loading area the efficiency is 100%, so, effective loading areas are 1. If you have 2 loading areas, the efficiency 75%, and the cumulative effect is 1.75. So, these are again standard tables that are available for you. For online loading areas versus offline loading areas, you can input those values. Again, why are we putting those values because finally, we want to calculate the bus stop capacity.

All these calculations in bus stop capacity have already been developed. Because we are going sequentially from one problem to the other problem. So, you know already what is the curb lane traffic volume, the turn lane volume in our case the left hand lane volume, pedestrian volume you already know, arrival time you already know, stop location has been determined, t_{om} we just calculated.

Loading area design, we just calculated, effective loading it is also you know. Now to calculate the bus stop location factor f_l, bus stop location factor again is given in a standard table. These standard tables tell you that if it is a lane use lane type versus bus stop location for the near side type 1, then you can use this one, if it is near side type 2 then you can use these values.

So, we all put in whatever value it is, that means, this is a far side lane type 2 bus stop, which is located on the far side of the intersection. So, 0.5 has been used. Curb lane capacity, curb lane volume we know, we can develop curb lane capacity. For traffic blockage adjustment factor, Aagain, these are standard values that is usually given to you. What is a traffic blockage adjustment factor, again it depends upon whether the queuing buses are blocking the traffic behind them.

So, if they are not able to get into the loading areas, they are queued up and they are queued up into the traffic lane. So, then the traffic is not able to move so, that is the traffic blockage and adjustment factor. So, if you know the standard values, you can calculate the bus stop capacity. Bus stop capacity is given by a multiplication of these 3 factors.

N_{el} is the number of effective loading areas. You already know f_{tb}, f_{tb} is a traffic blockage factor, you have already calculated that; and B_l. which is given by this factor which you have already calculated in the previous step; that is the loading area design capacity, loading area design capacity we already just calculate here. So, that is the same one here. So, you will develop the bus stop capacity. So, now, you know that this stop number 1 can process 47 buses per hour whereas, bus stop number 2 can only process 36 buses per hour.

$$Traffic\ blockage\ factor\ (f_{tb}) = 1 - f_l(\frac{v_{cl}}{c_{cl}})$$

$$Bus\ stop\ capacity\ (B_s) = N_{el} * B_t * f_{tb} = N_{el} * f_{tb} * \frac{3600\ (\frac{g}{c})}{t_c + t_d\left(\frac{g}{c}\right) + zc_v t_d}$$

So, that gives you the understanding of how your bus stops can handle your bus frequency that you have scheduled for the entire route. So, that is an example of bus stop capacity.

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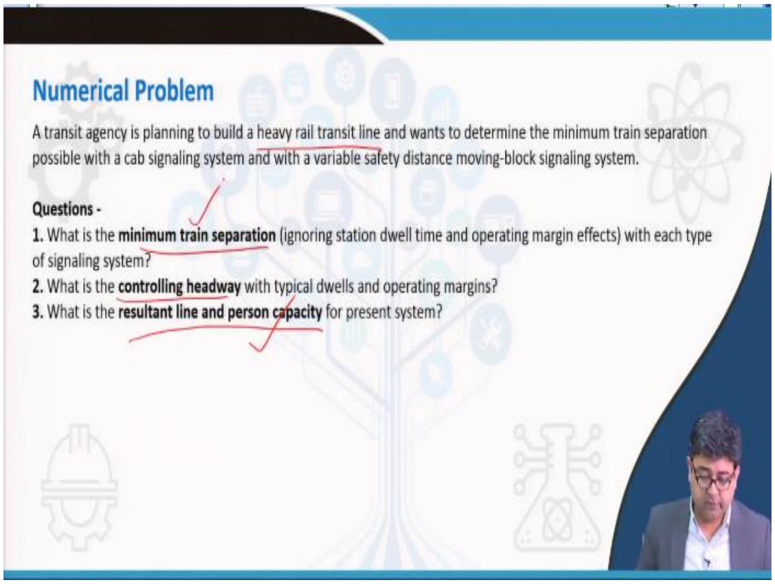

Similarly, we will quickly go through an example of how to calculate the capacity of a rail transit line. What you need to know is the minimum train separation, the controlling headway, because headway remember, headway is what determines the capacity your trains are running at and the resultant line and person capacity. So, line capacity is different than person capacity because line capacity meaning how many train coaches you have in one line.

How many trains run every hour that gives you the entire line capacity whereas, person capacities how many people actually are running on the line whether there are fewer than line capacity with more than line capacity or coach capacity. So, all that gives you the capacity of your transit of your transit rail line. So, it gets metro line or suburban train line, if you want to calculate mostly for heavy rail transit. Similarly, we will go through different input parameters.

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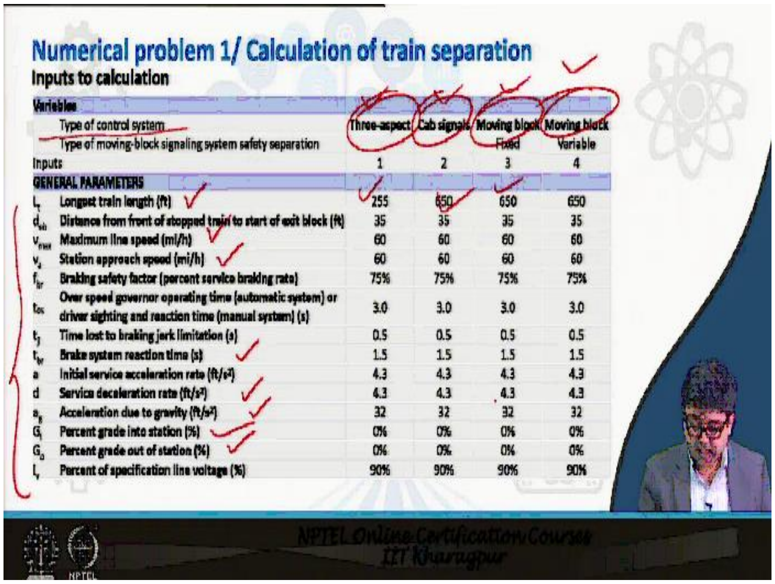

Minimum train separation -- if you want to calculate there are a lot of parameters that you need to get into. You can look at each of these, we have already given you the reference link at the end of the presentation, all these problems are solved there as well. So, go through that. Similarly, you already know the concept by which we are telling you how to calculate. These given sets of parameters will be there.

Their default values will be there, all you need to do is take the empirical formula you need to know which empirical formula to pick, which of the variables which of the constant values to pick and you have to pick them insert them into the right formula in order to get the answer. So, understand all these quickly. Longest train length you must know, maximum line speed you have to know, and approach speed.

Similarly, all the others -- acceleration deceleration speed, braking time, whether the station is at grade or is there any incline or decline into the station. So, all these values are given here for different types of signaling systems. This is something that you have to determine. What type of control system you have for your rail line and for different types of systems, there will be different parameter values that you would need to insert.

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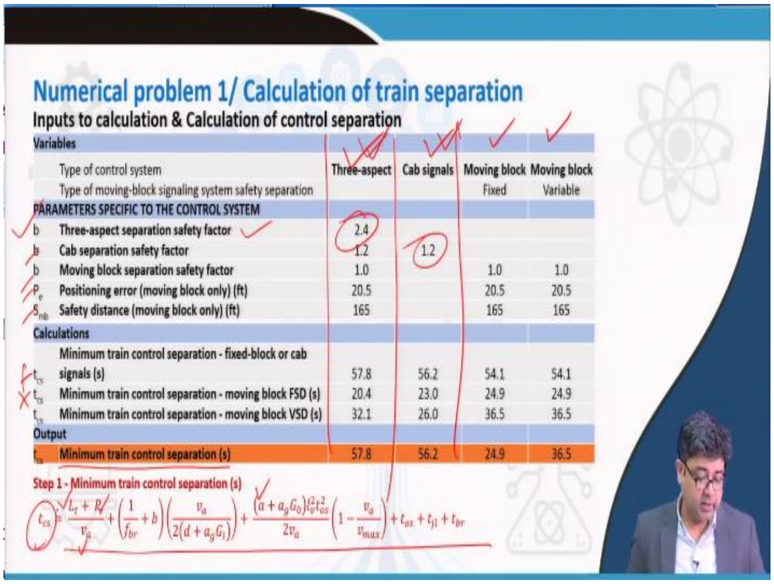

So, again these parameter specific control systems are given here. Safety factors for this type of control system, the value is this much whereas, for a cab signal type, the value is this much. You need to know which one to pick based on what you have or what type of system you are developing. And finally, the minimum train control separation is what you are trying to find out and it is given by this empirical formula like I said again in the case of bus do not get intimidated by the length of the formula, they are not very complex.

Each of those values are already the values that have already been given as input parameters just go through each of these tables, each of these input parameters here and also the input parameters. These input parameters here, insert them for each type of control system. So, this is one type, this is the other type. So, insert the parameters as per the control systems and you will calculate what is called a minimum train control separation.

$$Minimum\,train\,control\,seperation\,(s)t_{cs} = \frac{L_t + P_e}{v_a} + \left(\frac{1}{f_{br}} + b\right)\left(\frac{v_a}{2(d + a_v G_i)}\right) + \frac{(a + a_g G_o)l_v^2 t_{os}^2}{2v_a}\left(1 - \frac{v_a}{v_{max}}\right) + t_{os} + t_{jl} + t_{br}$$

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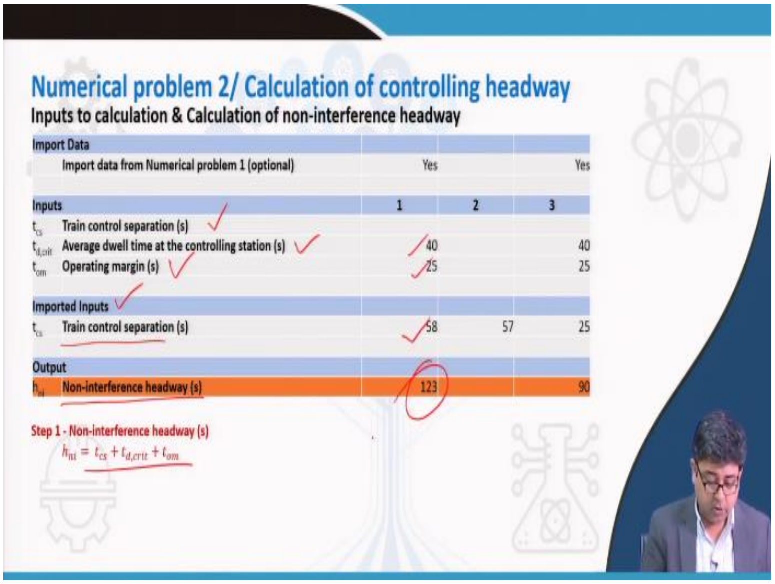

Once you know the minimum train control separation, the next step or the second problem is, if you remember, controlling headway. Now in order to calculate controlling headway, first you need to calculate what is called a noninterference headway, noninterference headways very simple it is just the addition of 3 different times.

$$Non-interference\ headway\ (s) h_{ni} = t_{cs} + t_{d,crit} + t_{om}$$

The train control separation time which is just calculated, average dwelling time at control station, again standard values that will be given, an operating margin, again will be given. So, this is something that you just calculated. So, you see these are imported inputs that means, imported from the calculation that have already done and you just add these 3 to get this value so, that is noninterference headway.

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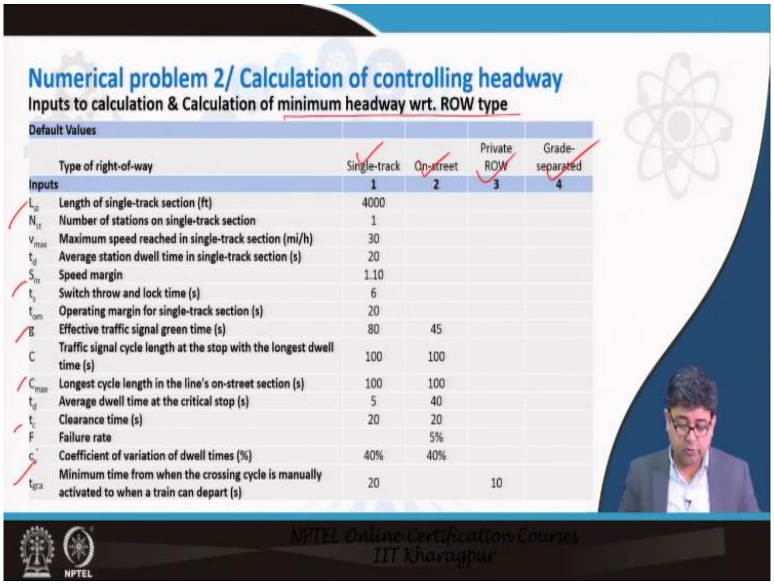

The second headway that you need to calculate is the minimum headway with respect to right-of-way type. If it is an exclusive right of way, single track, on street, private right of way, or grade separated, for different types of right of ways you will have different capacities. Remember if it is a grade separated or private right of way, it has the highest capacity, whereas if it is on street and is mingling with other types of vehicles, it has a lower capacity. So, all of that will be depending upon. Again, there are a bunch of inputs that you could go through.

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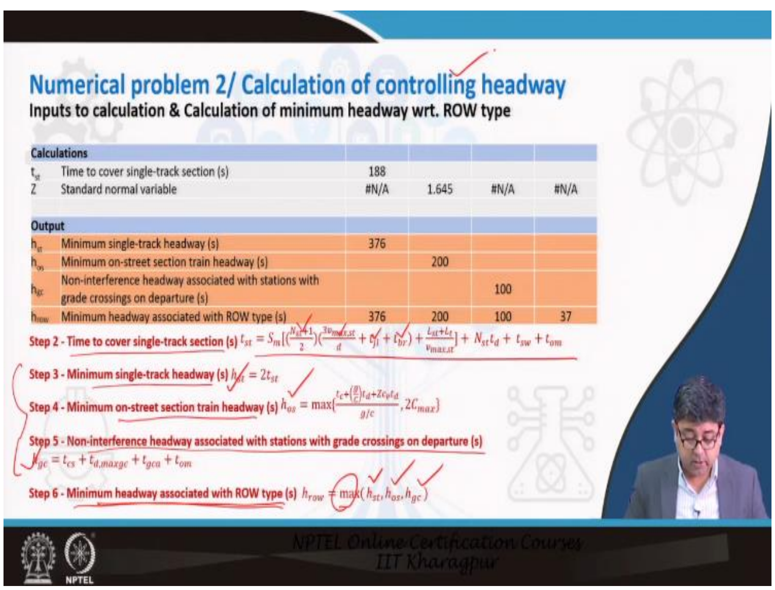

And finally, what calculations you have to do is, first you have to determine the time to cover single track section, minimum single track headway, minimum on street section, that will give you the noninterference headway associated with stations. And finally, minimum headway associated with right of way type, which is the nothing but the maximum of h_{st} that you have already calculated as h_{os} here, and h_{gc} here.

So out of these 3, whichever is the maximum that will be the minimum headway associated with the right of way type. Again, do not get carried away by the length and complexity of the formulas. All input parameters have already been given to you. Just input these parameters into the formula. What you need to understand is what each of the elements in the formulas talk about. You have to know what is t_{ij} you know what is t_{br} and why they are affecting the calculation of controlling headway; why they are affecting that. If you understand that and that should be easy to understand.

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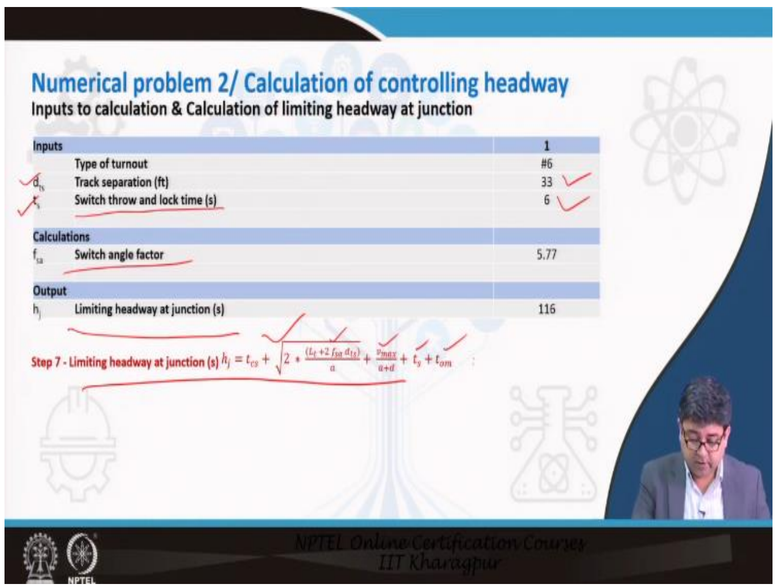

Finally, you must calculate the limiting headway. The next, the third type of headway we have to calculate is the limiting headway, the limiting headway at the junction is calculated by this formula here,

$$Limiting\ heqadway\ at\ junction\ (s) h_j = t_{cs} + \sqrt{2 * \frac{(L_t + 2f_{sa}d_{ts})}{a}} + \frac{v_{max}}{a+d} + t_s + t_{om}$$

You already have most of the input parameters that you have calculated in the previous ones. The only inputs that you will need here is the track separation in feet, how much your tracks are separated from the grade, i.e. it is at grade or not at grade.

And then the switch through and lock time. These are again standard values that will be given to you in a table, or in a tabular fashion, all you need to do is look for the right value. So that is what you have to do calculations switch angle factor again, with something that you have to be looking for. These are just standard values. You input all these values in this formula and you will get the limiting headway.

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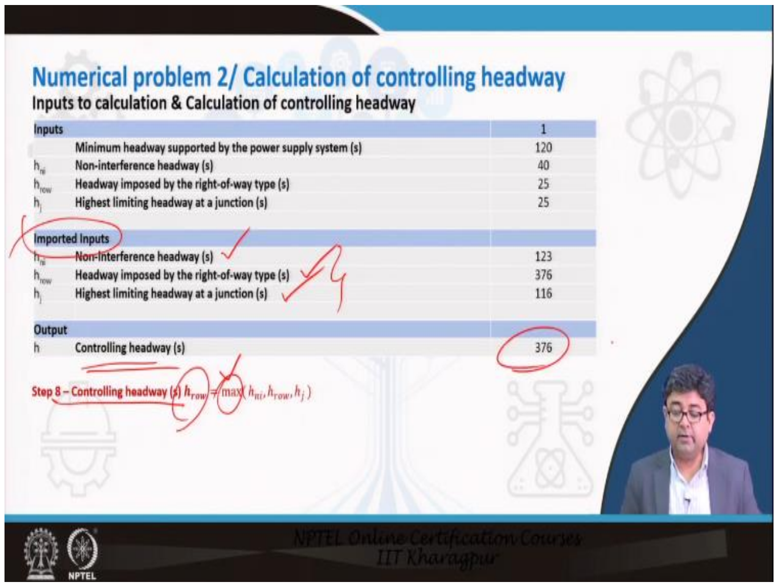

So now the controlling headway is the maximum of these 3 headways that you have just calculated. See important inputs you have calculated the noninterference headway. You have calculated the headway imposed by right of way types and you have calculated the highest limiting headway at junction. The maximum value among these 3 will be your controlling headway. So, once you know the controlling headway, or the headway value is 376.

$$controlling\ headway\ (s) h_{row} = \max\left(h_{ni}, h_{row}, h_j\right)$$

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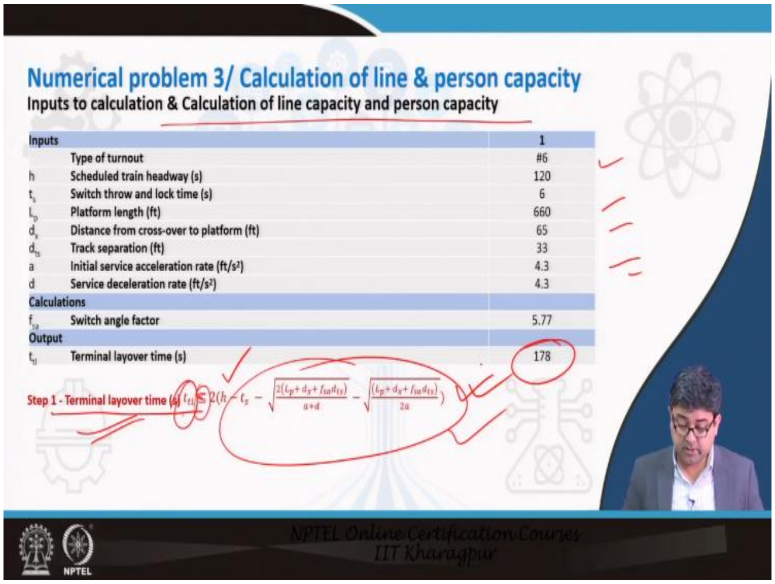

You have calculated the controlling headway now; you can go ahead and calculate the line capacity and the person capacity. To do so first you have to determine whether there is any layover time at the terminal. Layover time at the terminal should be less than or equal to this entire formula. Again, all of these are input values that are either given here or already has been given earlier in solving these problems input this.

$$Terminal\ layover\ time\ (s) t_{tl} \leq 2\ (h - \ t_s - \sqrt{\frac{2(L_p + d_x + f_{sa} d_{ts})}{a + d}} - \sqrt{\frac{(L_p + d_x + f_{sa} d_{ts})}{2a}})$$

If it is not less than or equal to that, then use the value that you get here, it has to be at least less than or equal to the right hand side value. So, that is what terminal layover time is telling you, calculations show that the terminal layover time is 178 here.

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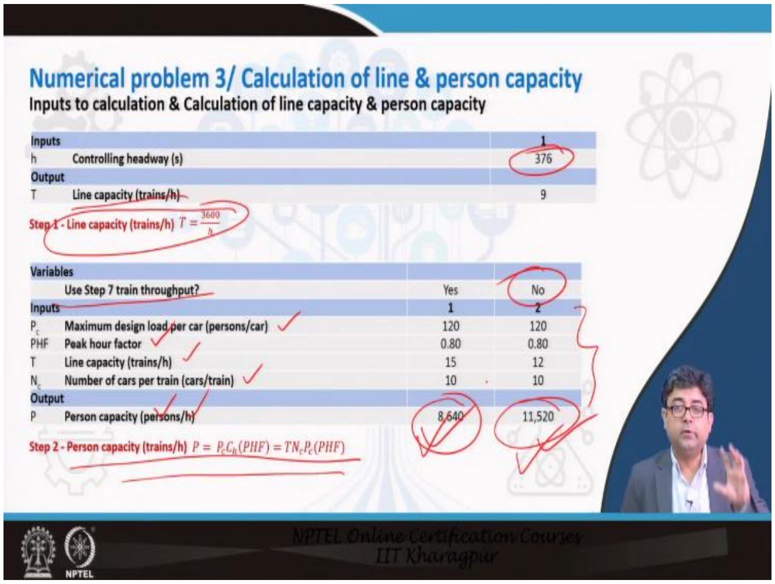

With that terminal layover time and controlling headway that you have already calculated, the line capacity is given by this formula.

$$Line\ capacity\left(\frac{trains}{h}\right)T = \frac{3600}{h}$$

And the person capacity is given by this formula.

$$Person\ capacity\left(\frac{trains}{h}\right)P = P_cC_h(PHF) = TN_cP_c(PHF)$$

You already know the line capacity, number of trains per car, maximum design load number of persons per car, the peak hour factor in all that personal capacity. So, your transit line can carry 8640 persons per hour. If you have used different way if you have used for a different control system.

So, the different control systems that we were talking about if there is a different type of control system then all these calculations for the capacity would be different. So, basically it depends upon which type of control system you are using for the train, which will tell you what capacity your train is running at and what the headway between the trains are? What is the controlling headway? Which is the maximum of the 3 headways that headway will also control? What is the capacity of your transit line?

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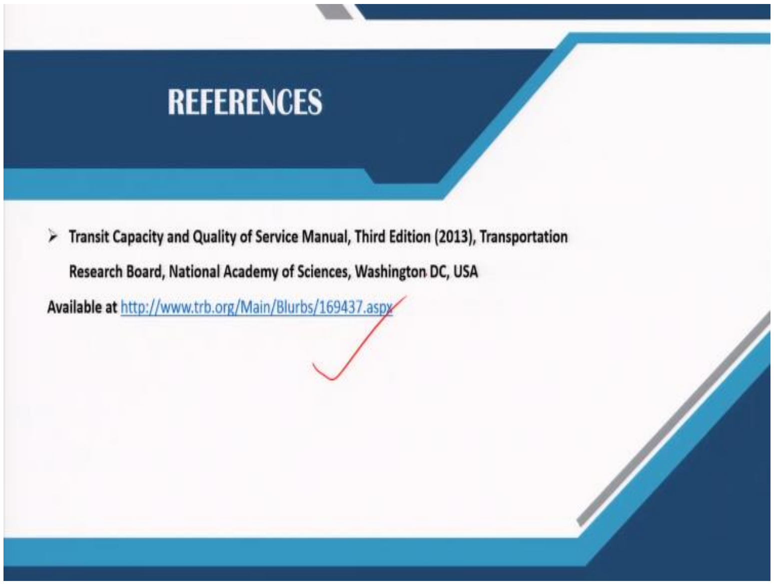

So, this is the reference that we were talking about and all of these examples are solved in that reference, so please look at it carefully. The calculations may seem complex but they are not at all; there the input values that are given to you; standardized values are available in standard tables or you need to do is pick the right value from the tables and pick the correct formula for calculating these values.

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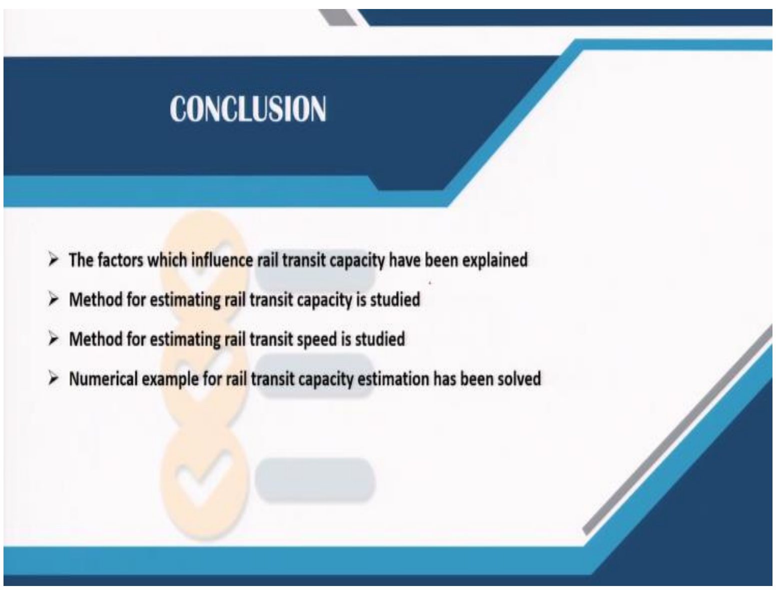

And in conclusion we explained to you in detail how to calculate the capacity of a bus transit line and calculate the capacity of rail transit line. What those capacities depend upon, for e.g., bus capacity depends upon loading areas. Not only number of loading area but also loading area capacity which may in-turn depend upon the dwell time. Similarly, in case of transit or rail transit, the controlling headway will affect your line capacity as well as person capacity. So, understanding these terminologies and these factors is very important in determining the capacity of a bus and rail transit. Thank you very much for your attention.