Traffic Engineering
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Lecture 40
Signal Coordination – I

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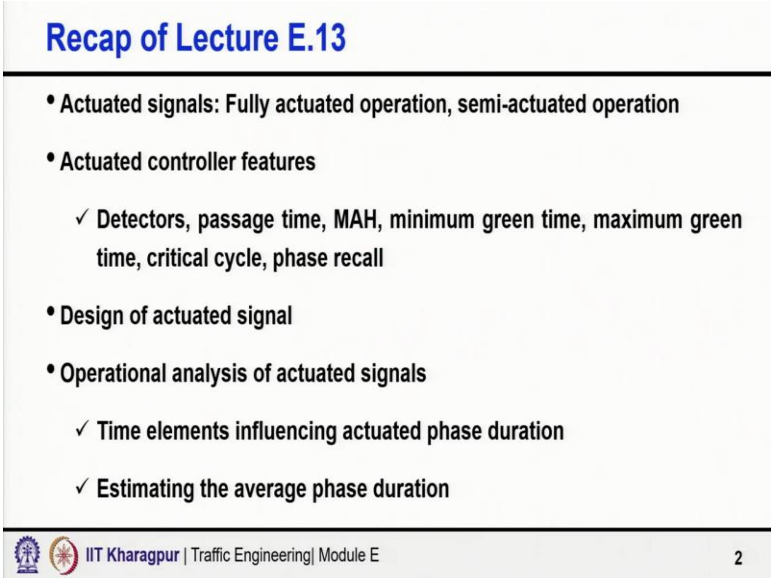

Welcome to module E, lecture 14. In this lecture, we shall discuss about Signal Coordination. In lecture 13, I mentioned to you about various types of actuated signal operations. Then the controller features, detectors, passage time, MAH, minimum green time, maximum green time, critical phase, concept of phase recall, different types of recall etcetera. Then how to design actuated signal and briefly indicated to you the procedure for operational analysis of actuated signals.

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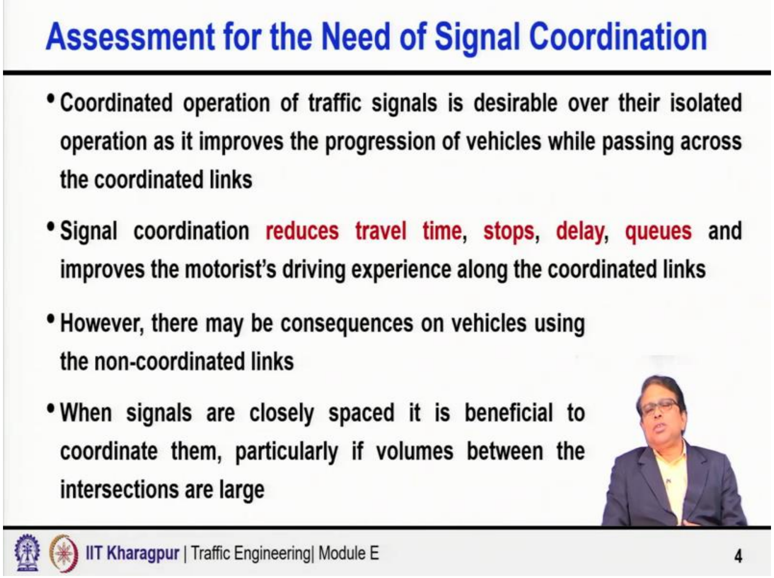

With this background, today we shall start our discussion about signal coordination. In the first part how to do the assessment for the need of signal coordination. Where and why we try to do coordination of traffic signals. When you are travelling in an urban network, where most of the intersections are signalized, you often find that you get clearance during the green and you move or vehicle get discharged from the upstream signal during the green phase and you can see that the downstream signal is green showing green indication but by the time you reach near the signal it becomes red.

And like that on multiple occasions you stop and you often feel like why we do not coordinate the green time in such a manner that the green for a particular phase is given when most of the vehicles are actually reaching or arriving at that intersection only at that time. So, coordinated operation of traffic signals is desirable over their isolated operation that means each individual signal is designed and operated separately and independently.

Instead of that, we want to do the coordination as it improves the progression of vehicle while passing across the coordinated links or intersections. That means ideally, once the vehicles are getting discharged during a green then all subsequent intersections as the vehicles are reaching they should get green without getting any red indication or red phase.

So, if so and if at all that can be done then obviously the progression will be excellent. So, the progression of the vehicles will improve very significantly and because of that signal coordination also will reduce travel time, stops delay, the queue length and improves the motorist overall driving experience along the coordinated link specially where or in the direction where majority of vehicles are moving along a corridor and basically the through vehicle share is very high.

However, when we are trying to do that there of course many challenges which we will discuss in due course of time but overall, there could be some benefit from signal coordination for the mainstream traffic or the primarily the through traffic which is passing through a set of signals and may be in the morning moving towards the CBD area and in the evening going back from the CBD area.

Sometimes, because of that there may be some consequences of vehicles on vehicles which are not operating on this coordinated link. That means an intersection has got so many approaches, one approach we are receiving vehicle from the upstream signal and we are trying to coordinate that movement so that most of the vehicles can pass through but there are other approaches where from also vehicles are approaching.

So, while we are trying to give some benefit to the through traffic, there could be some negative impact on the vehicles which are approaching from the non-coordinated arm or link. Obviously, when signals are closely spaced it is beneficial to coordinate them particularly volumes between the intersection are large. Obviously, if majority of the traffic is actually through moving traffic then if I can coordinate that direction all the signals if I can coordinate along the direction then the majority of the traffic gets benefits. So, there is overall still it will make sense and overall still probably it will be beneficial.

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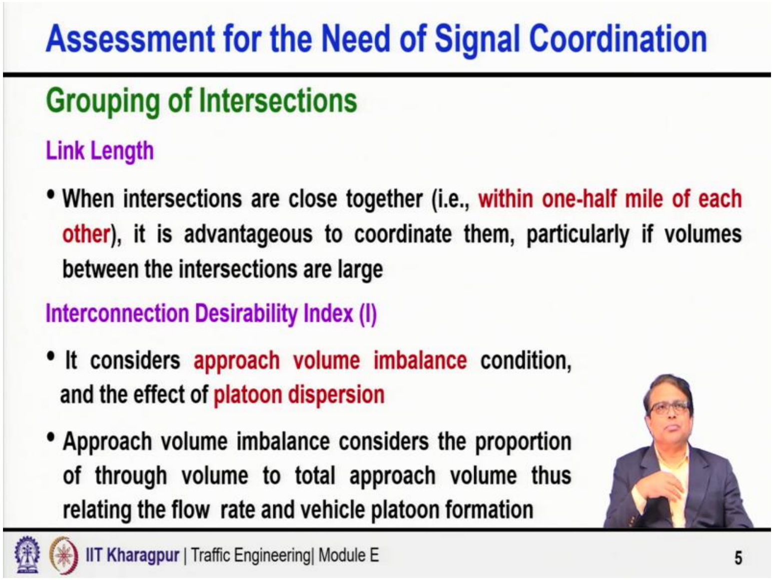

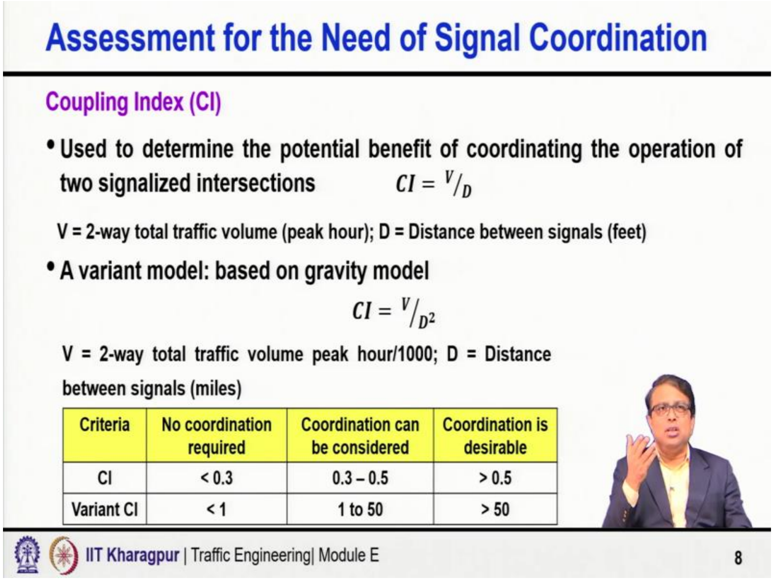

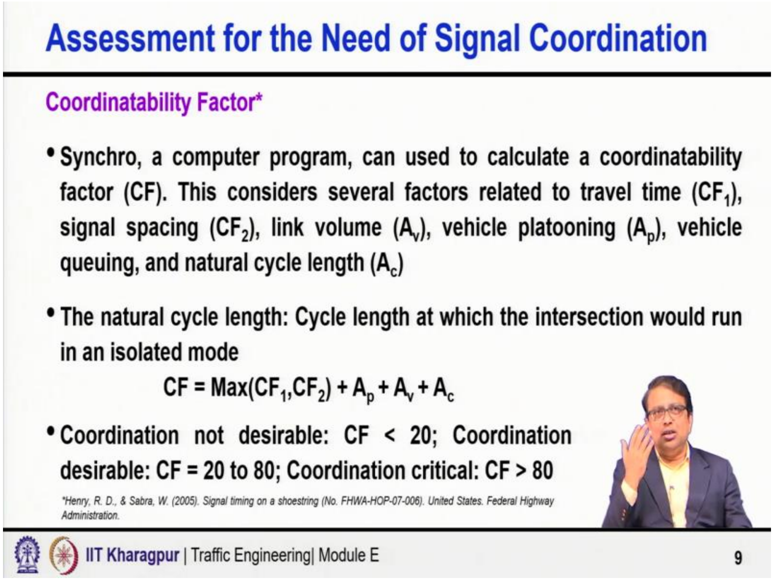

Now, regarding the grouping of intersections that means when two intersections I should try to coordinate. There are many ways, people have suggested many things, people have suggested there are many things people have suggested based on the link length, based on interconnection desirability index, also based on the platoon dispersion, using the coupling index, using the coordinatability factor. So, there are so many ways you can check whether it is worth coordinating the signal. This gives you in a gross way whether the coordination is meaningful.

Actually, how much to what extent the coordination is going to be beneficial for a given context, you can actually carry out a micro simulation. You can also based on the micro simulation you can finalize your design. You can check also whether the benefit is significant and with all necessary calibration, validation you can actually go and implement it also in the field that is a different part of it.

Let us see how we can decide about the grouping of intersections whether two intersections, we need to coordinate or not. Based on the link length, first part. When intersections are close together it is advantageous to coordinate them particularly volumes between the intersections are large. Why closely? Because you know the vehicles get discharged in platoon, platoon means its a bunch of vehicles getting released.

Now as the vehicle start moving or as the platoon starts moving, the platoon will disperse, disperse because of the differential vehicle, differential speed criteria. Different types of vehicle will be there, their acceleration characteristics will be there, their speed capabilities would be there driver behaviour would be there.

So, many things are there so the platoon will disperse. Obviously, the roadside, road condition, you know averting land use many other things also will influence probably the way the platoon will disperse but if they are close enough then the platoon remains more or less reasonably intact.

That is very important because otherwise if the platoon dispersed too much then the coordination not, majority of the vehicles may not even get the benefit of the coordination, even though they are moving in the same direction because the platoon has dispersed. So, the intersections are close together that is very important and as I said in when I was discussing in the previous slide, as I said already, earlier that the volume has to be large enough because then only, if you can do coordination when the volume is really large in that direction then majority of the vehicles you are able to give benefit.

So, even though the non-coordinated approach, approaches the vehicles are little bit getting delayed further still then overall sense the benefit could be very significant. How close? One thumb rule you can say, within one half mile of each other. That is one way of looking at it, so that means, if the links are placed within one half mile of each other then I can think, I can take it up for further investigation to see whether the coordination is beneficial. That is one aspect.

Second interconnection desirability index, denoted here as I. Now, this index actually it considers two aspects, one is approach volume imbalance condition and the second aspect is effect of platoon dispersion. Now, what is then approach volume imbalance? The approach volume imbalance considers the proportion of through volume to total approach volume thus relating the flow rate and vehicle platoon formation.

If you take an upstream signal or upstream intersection, the vehicles are entering as through movement as right turn, as left turn. Now, suppose we are trying to do the coordination mostly for the through movement then what is the share of through movement in overall vehicle volume that is entering from the upstream intersection to this particular link. In some way or other we are trying to measure that.

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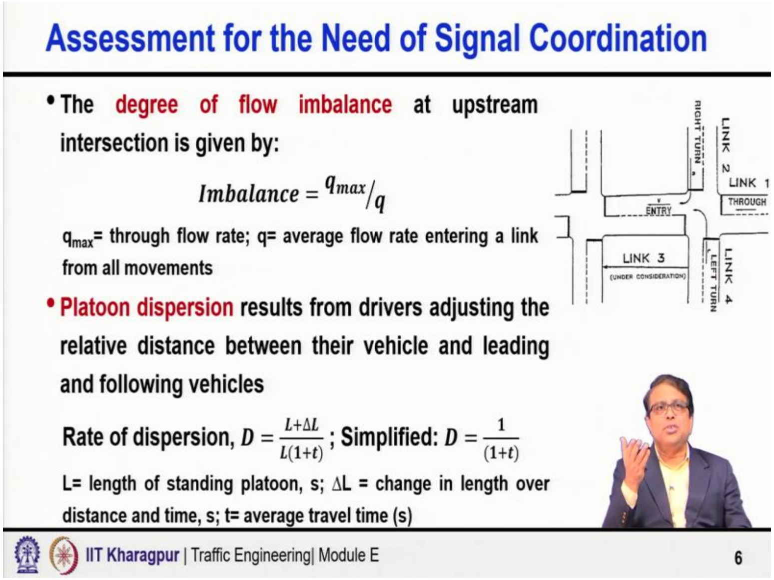

So, let us go to the next slide to see that, the degree of flow imbalance at upstream intersection is given by q max by q. What is q max? You consider here, this is an upstream signal and this is the downstream signal. So, in this link 3, vehicle may enter as through movement in all possibility that is going to be the coordinated one, but vehicles also will enter as left turning traffic, vehicle also will enter as right turning traffic.

$$Imbalance = {q_{max}}/{q}$$

So, what we are saying q max by q, q max is the through flow rate that movement through movement which we are trying to coordinate, divided by q is the average flow rate entering a link from all movements. That means left, straight, though, if you consider all movements what is the average flow that is entering and q max is the what is the through flow rate.

Now, obviously it tells you, if suppose this is 1 that means the flow rate which is entering through straight through movement, straight then left, right, so 3, one is the through one, another is the left turning, the right turning. Suppose, more or less all are equal, then obviously the through is not really a significant proportion of the overall vehicle volume that is entering the link in this case particularly link 3.

But if the q max really higher than the average value of q, higher the value that means the through movement is more and more dominating. So, it might be worth if you coordinate it the benefit is likely to be higher. So, this is the way the degree of flow imbalance at upstream intersection may be captured.

The second thing what is considered is the platoon dispersion. Now, platoon dispersion results from drivers adjusting the relative distance between their vehicles and the leading vehicles and following vehicles. That means as I said, a bunch of vehicle getting discharged but as they move, the platoon leader the first vehicle and the last vehicle in the platoon, the distance will increase.

As they travel more and more the distance will increase. So, the rate of dispersion can be expressed as L plus delta L divided by L plus 1 plus t. What is that? L is the length of the standing platoon. When the platoon is just getting discharged. So, that time what is the length? Delta L is the change in length over distance and time. As it is progressing, the length is changing. So, delta L is the change in the length over distance and time and what is small t? Is the average travel time.

Rate of dispersion, $\boldsymbol{D = \frac{L+\Delta L}{L(1+t)}}$ **; Simplified:** $\boldsymbol{D = \frac{1}{(1+t)}}$

So, this is the way we can express the rate of dispersion. This can be simplified and written as simply D equal to 1 by 1 plus t, in a simple form. So, that is one aspect, how the platoon is getting dispersed and what is the degree of flow imbalance, capturing through this equation. Considering both these aspects, the value of I is decided. What is I? Inter connection desirability index. On the basis of what? I said, approach volume imbalance and platoon dispersion. This is how we calculate the imbalance. We capture the imbalance, this is how we calculate the platoon dispersion.

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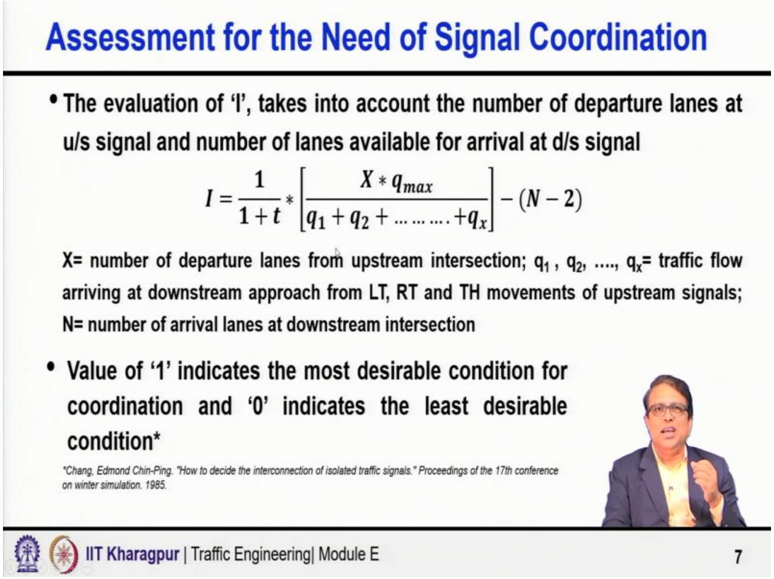

And here, this is how we combine them, put them together consider both the aspects. So, the evaluation of I takes into account the number of departure lanes at upstream signal and also the number of lanes available for arrival at the downstream signal. Sometimes, this number of signals, number of number of lanes at the departure in the upstream signal and number of lanes available for arrival at the downstream signals may not be even same.

So, if they are different and also depending on the number this I value will change. So, this is the expression, you can clearly see this 1 by 1 plus t, it is something like the platoon dispersion path and q max by q in a slightly different form, x is the number of departure lane. So, x into q max divided by all this sum, here it is q1 plus q2 and plus all approaches.

$$I = \frac{1}{1+t} * \left[\frac{X * q_{max}}{q_1 + q_2 + \dots\dots\dots + q_x}\right] - (N-2)$$

So, if there are only 3 approaches left, right, through then it should be q1, q2 and q3. In some form or other, minus n minus 2. Now, obviously value of 1 indicates the most desirable condition for coordination and the I value 0 indicates the least desirable condition. So, accordingly, once we calculate the value of I, we can tell whether it is worth investigating further regarding the coordination of these two signals.

So, as we said, if the value one indicates most desirable condition, this is the value closer to 1, if we are getting then we will pick up that possibility, that ok let us pick up these two intersections and investigate further. If we need to, if we should go ahead with the signal coordination but if the value is on the lower side 0 or nearby 0 it will not be 0 but nearby 0 then we know that it is not worth probably doing further investigation. So, these are all for like initial screening not a final design but the initial screening, should I take? Should I investigate further these are the indicator based on the link length based on the interconnection desirability index you can decide whether to go ahead further or drop it.

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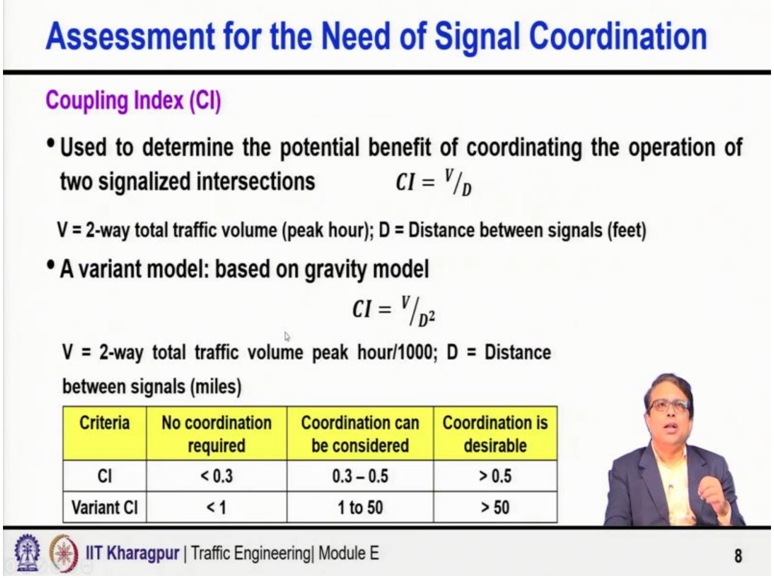

Now, the next one is basically coupling index, this is again another way of measuring something, check the suitability. Now, this is used to determine the potential benefit of coordinating the operation of two signalized intersection. How we can calculate the coupling index? CI equal to V by D, V is the two-way traffic volume in the peak hour and D is the distance between signal in feet, that is the way it has been taken. So, I retain that unit, I still kept it as feet because it was originally taken in feet.

$$CI = {}^{V}\!/_{D}$$

A variant model of the coupling index is also available which is like a gravity model and you know the gravity is what? Gravity model is always we take square of the distance. So, here the CI is V by D square instead of V by D, it is V by D square. And the same thing V is the two-way total traffic volume peak hour divided by 1000 and D equal to distance between signals and that is in mile. So, here it is in mile and here it is divided by 1000 there it was in feet and here it is the two-way traffic volume.

$$CI = {}^{V}\!/_{D^2}$$

So, these are all you need why some adjustments are actually done. Otherwise the fundamental difference is here V by D and here it is V by D square rather than D, it is D to the power 2. So, different values of, if you consider CI or variant CI, then different values are suggested. For example, if you consider CI less than 0.3 clearly tells you no coordination is required. Greater than 0.5, it tells you that coordination is desirable. And 0.3 to 0.5 it takes coordination can be considered. It could be beneficial as well.

Similarly, if you are using variant CI, coupling index then less than 1 means no coordination is required. 1 to 50 coordination can be considered in between greater than 50 coordination in all possibilities likely to be beneficial. So, you should go ahead with further investigation and you have to design the coordination, coordinated signal.

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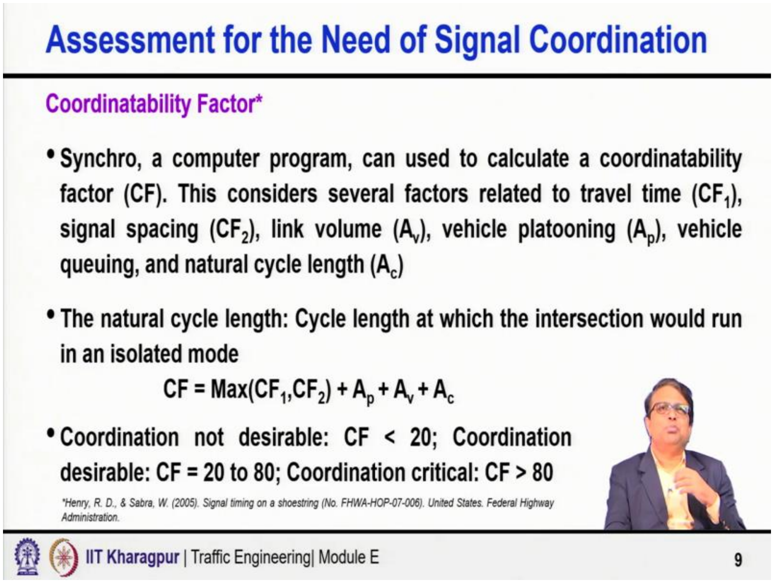

Another factor has also been used which is known as coordinatability factor. It is widely used in Synchro, a very well-known and widely used software or you can also say computer program that is running within inside the software and Synchro calculate the coordinatability factor and this considers several factors related to travel time, signal spacing, link volume, vehicle platooning, vehicle queuing and natural cycle length. All these aspects are considered, while calculating the coordinatability factor.

So, what is the natural cycle length here? Cycle length at which the intersection would run in an isolated mode. Before we think of coordinating signal, every signal is actually running in as isolated signal. So, if I have to really run the signal as an isolated signal, then what cycle time I will take, based on all parameters. Then the CF, the Coordinatability Factor is calculated using this formula, max of CF1, CF2, max of these two plus Ap factor related to vehicle platooning plus factor related to link volume, plus factor related to natural cycle length.

$$\mathbf{CF = Max(CF_1,CF_2) + A_p + A_v + A_c}$$

So, all aspects are considered to calculate this value and if the CF is less than 20 then it is said that the coordination is not desirable. If coordinate CF is 20 to 80 then coordination desirable. May be likely to give benefit and may give benefit and coordination is absolutely necessary rather if the CF value is greater than 80. I am not going into details but you can see this reference if you are interested to know more about how to calculate CF1, CF2, Av, Ap all these values how to calculate you can see it.

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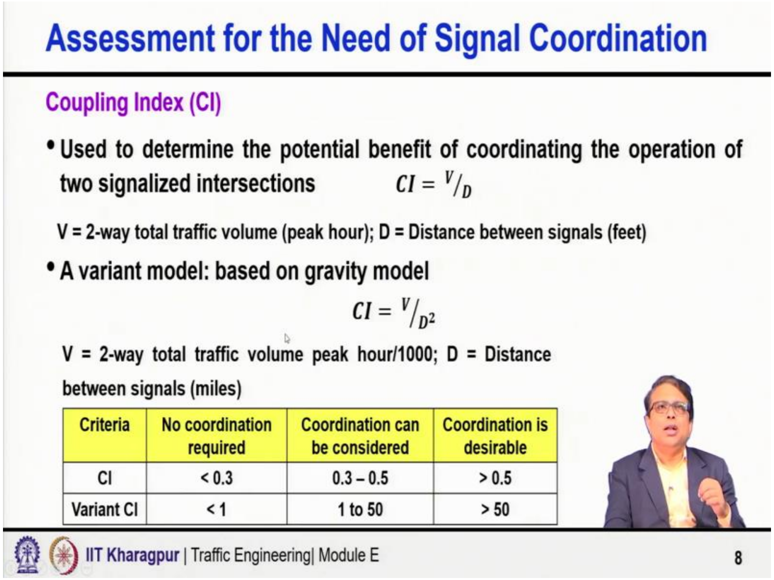

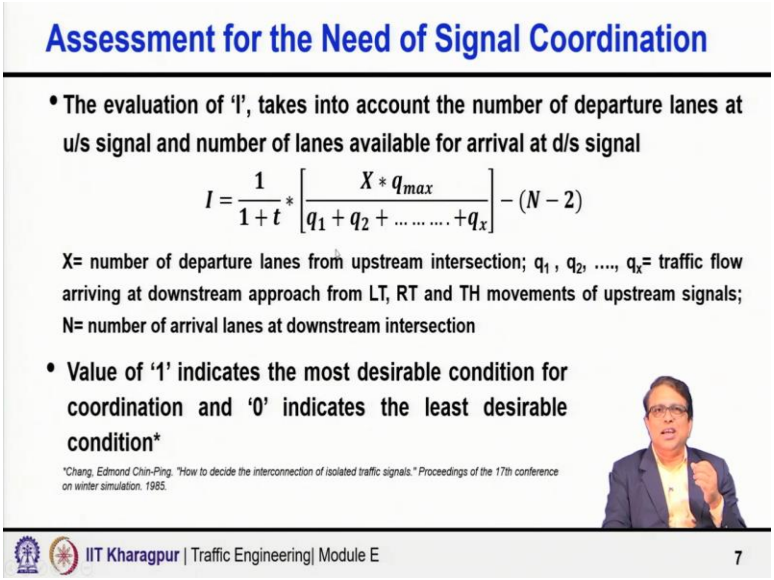

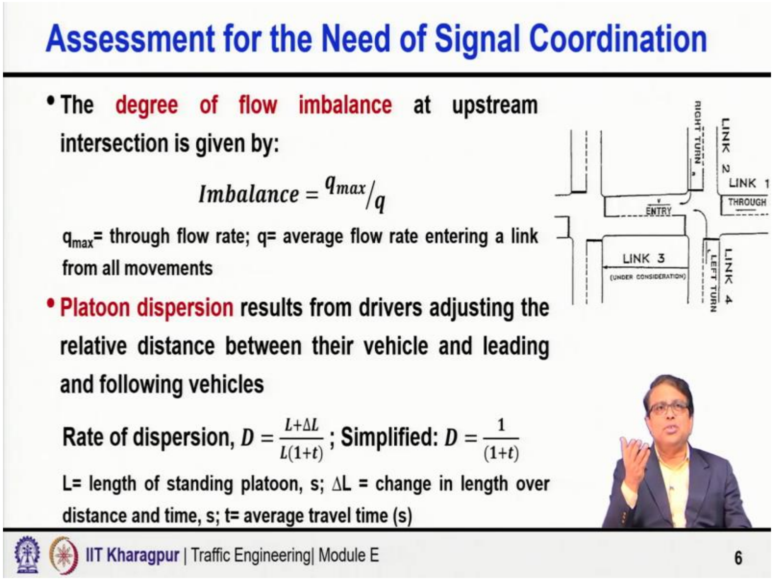

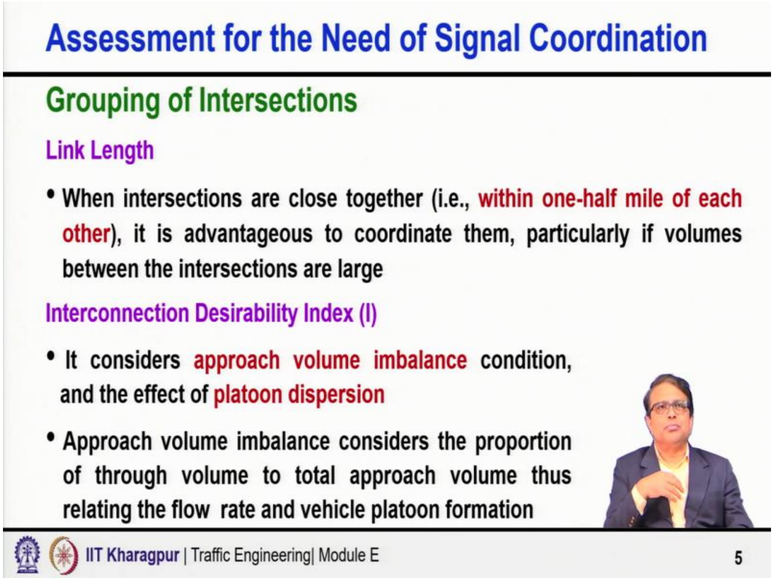

Now, as I said these are the various measures quantities index that I discussed which could be used to initially judge if the coordination is likely to give benefit and therefore whether need to be investigated further.

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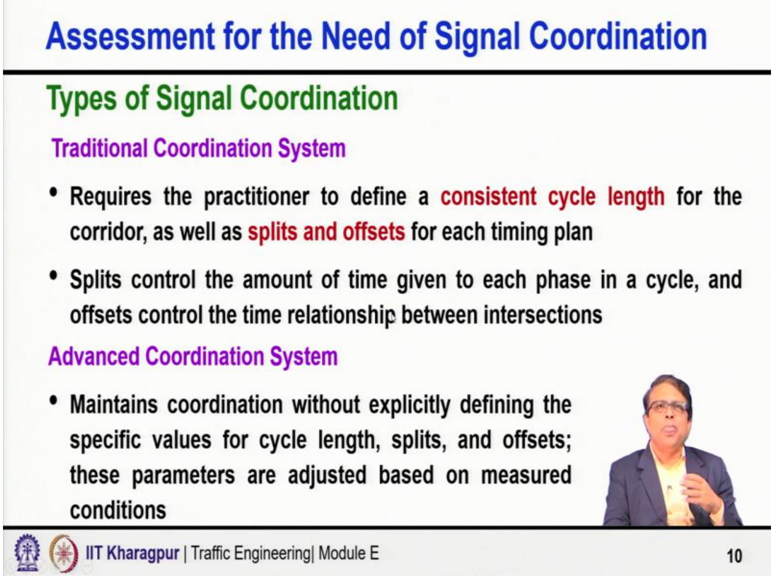

Now, the next part is what types of signal coordination we can do? There are primarily two types of coordination system exist. One is called the traditional coordination system, the other one is you can call it as advanced coordination system. What is the difference? Traditional coordination system requires the practitioner to define a consistent cycle length for the corridor, so if I am considering two or three signals or two signals then both signals should have same cycle length, the cycle length is fixed. The split and offsets are also fixed for each timing plan. So, everything is fixed.

Cycle length we have decided it, as per the traffic volume as per another condition but once you have decided then during the period when you are operating it as a coordinated signal system then my cycle length is fixed, my splits and offsets are also fixed. The split control the amount of time given to each phase in a cycle and offset control the time relationship between intersection.

What is the intersection? If I initiate green for the upstream signal then after how many seconds or minute I will initiate green for the downstream signal for the same direction. So, both through movement and let us consider the through movement only we are trying to coordinate. So, the split what is saying? The amount of time given to each phase, how much green we are giving and offset controls the time relationship between intersections that means one intersection to another intersection, what is the time gap between the initiation of green.

This time gap is very important because the vehicles platoon when it is reaching to the downstream signal then they should get green. So, initiation of green should duly consider the platoon behaviour and also any queue which is pre-existing queue in the downstream signal and other factors. We shall discuss more.

The advanced coordination system on the other hand maintains coordination without explicitly define the specific value for cycle length split and offset then how they are decided? All these parameters are adjusted based on measured condition. So, it is something like the sensor is there we know exactly what is happening and accordingly the whole coordination is being made. So, we are not saying that the cycle length split and offsets are fixed, it varies as per the requirement. The current traffic volumes and the condition accordingly all these values will be decided.

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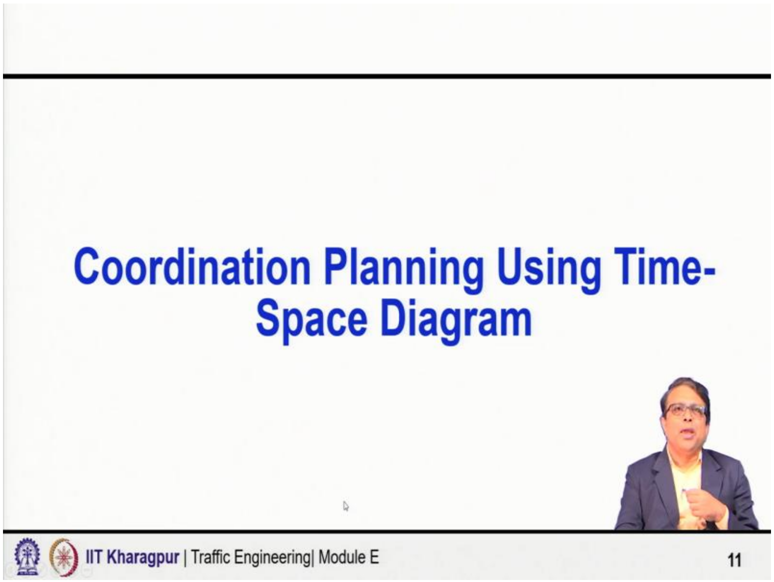

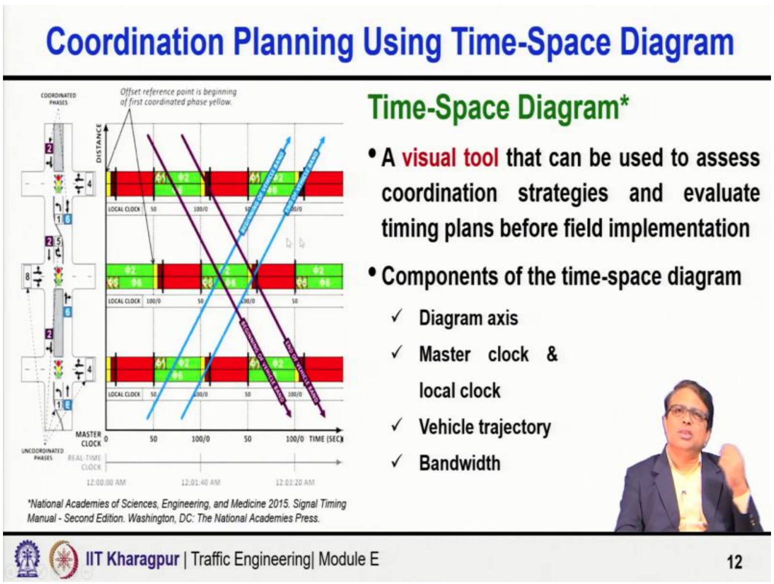

Now, going to the next part, coordination planning use in time space diagram. This is a typical time space diagram, what is the time space diagram? We often use it, it is basically visual tool that can be used to address coordination strategies and evaluate timing plan before field implementation. So, there are various components of the time space diagram you can see there is an x axis which is the time there is y axis which is showing the distance.

So, this is one signal, this is another signal, this is another signal, and each case signal is getting red time, green time. So, all these are there, there is a master clock here, the master clock is starting from 0 and going covering all the intersections which are coordinated. There the master clock is only one but there is also there are local clocks. So, every intersection has a local clock.

Now, the local clock and master clock what is the relationship? The master clock to local clock that offset is decided. So, how much time or with what time gap the green should start. Then the vehicle trajectory this you can see how vehicles are moving. You can see every possible thing, the speed because one at a time another is the distance. So, it can give you the speed.

If it is accelerating, if it is decelerating, if it is stopping then the line will be flat. All things you can get from the vehicle trajectory and there is another concept is bandwidth. Bandwidth is what? The first vehicle moving uninterruptedly among the set of coordinated signal during green and the last vehicle which is also crossing all the signals which are coordinated without stopping the time gap between these two.

So, here you can say, this is one vehicle probably the first vehicle which has crossed all the intersections without stopping and this is the last vehicle which could also cross all the intersections in green without stopping. So, the time gap between these two lines, the time difference that is called is the bandwidth.

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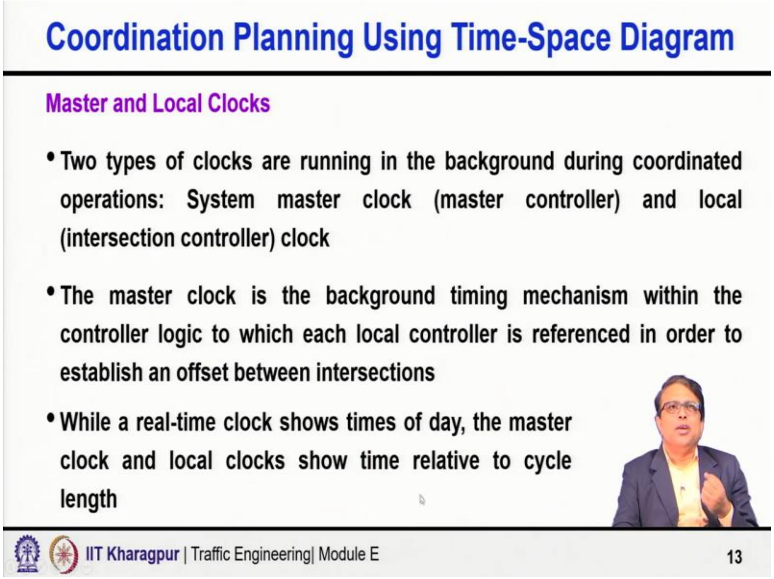

So, as I said, the master clock and local clocks. Two types of clocks are running in the background during coordinated operation. The system master clock, you can call it as master controller and local clock you can call it as intersection controller. The master clock is in the background, timing mechanisms with the controller logic to which each local controller is referenced in order to establish an offset between intersection and while a real time clock shows time of the day, the master clock and local clock shows time relative to cycle length. That is what is our objective here.

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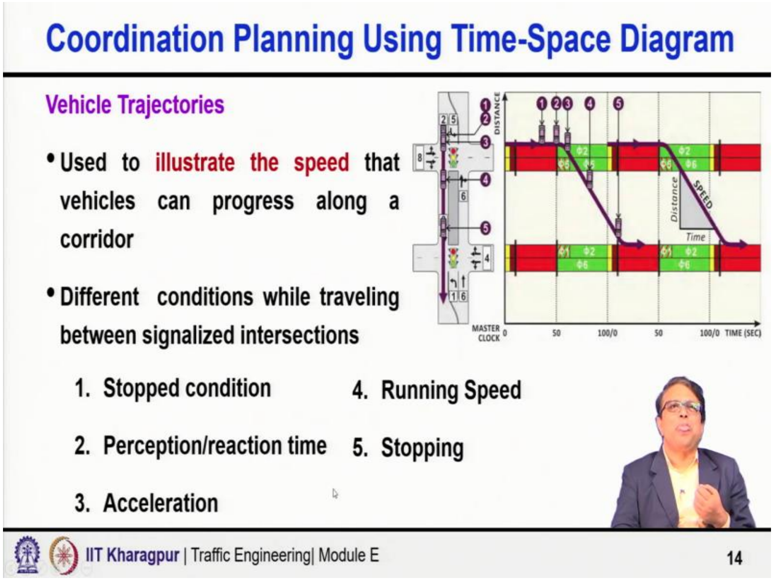

So, here I am showing the vehicle trajectories and you can clearly see the vehicle trajectory is one is the time another is the distance. So, it can illustrate the speed that the vehicle can progress along a corridor and several other conditions also can be represents if the vehicle stopped condition then it will be flat that means distance wise no movement is happening but time wise access that time is growing. So, it is a stop condition.

Similarly, running speed you can calculate. How much is the stopping time that you can calculate. If there is perception reaction time that also can be reflected, can be obtained from this one. Acceleration if the vehicle is doing that also can be captured, so everything probably can be captured from the vehicle trajectories.

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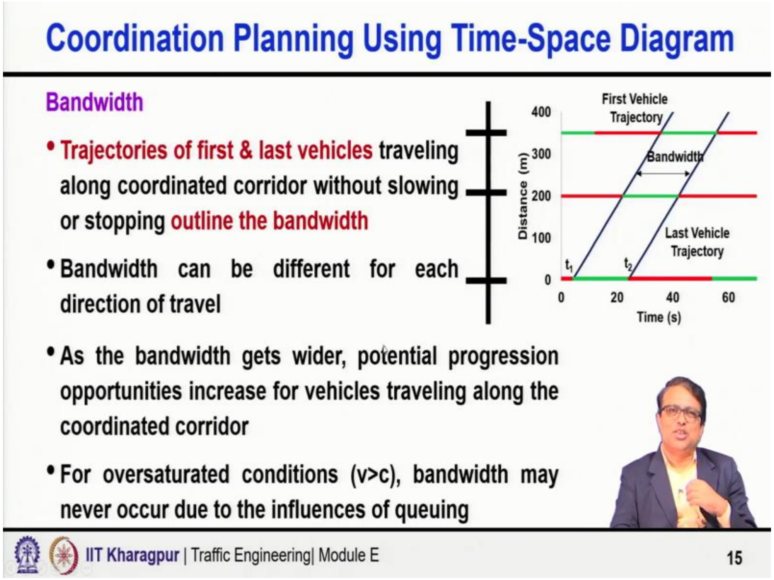

Bandwidth as I said, the trajectory is the first and last vehicle, travelling along coordinated corridor without slowing or stopping is the outline of the bandwidth. So, bandwidth can be the different for each direction of travel and here you can see that this is the line, every vehicle perfectly ideal condition. The first vehicle which is getting cleared during the green is just reaching here, when the green is getting initiated, just reaching to the next signal. Again, the green is when the green is initiated.

Similarly, the last vehicle is also able to clear through all the intersection. This is almost like an ideal situation and therefore here whatever is the green time, the bandwidth is same but it may not happen always because it may happen that the signal timings or the speed of the vehicle is such that, suppose you take any other slope of this two lines, you will find not all the vehicles which are passing through this signal A will be able to pass through signal B and signal C. It will not happen. In that case the bandwidth will be different.

So, as the bandwidth gets wider, potential progression opportunities increase, increase for vehicles travelling along the coordinated corridor and obviously for over saturated condition, bandwidth may never occur due to the influence of queuing. Now, here it is reaching but if there are already queued up vehicles here, again already lot of queued up vehicles here, that it may in worst case happen that, actually there is no bandwidth. No vehicle is able to really clear or pass through all the signals without stopping. That is the worst possible condition, coordination may not work there.

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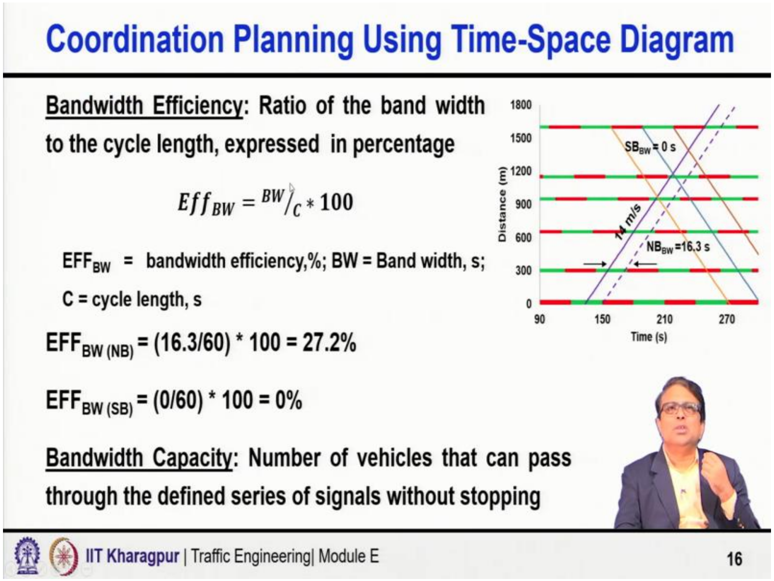

Now, bandwidth efficiencies is a term which is very important for you, it is the ratio of the bandwidth to the cycle length. So, whatever is the bandwidth you got, you are clear now about the concept of bandwidth. So, bandwidth divided by cycle into 100, 100 is to express it in percentage.

$$Eff_{BW} = {}^{BW}/_{C} * 100$$

So, we say what is the bandwidth efficiency? x percentage. So, it could be from 0 to maximum. It cannot be 100 because bandwidth you can get maximum equal to green time. So, bandwidth by cycle time. So, what is the bandwidth efficiency? It is the bandwidth in second divided by cycle time in second. So, in this case if we consider that the northbound direction, if we take the bandwidth as with a speed of 14 meter per second and with this time space diagram, northbound it is 16.3, southbound it is 0.

You can see the southbound, there is no bandwidth. There are lot of things, we will discuss. In one direction, if the northbound if you want to enhance the bandwidth, you have to do compromise on the bandwidth for the southbound direction. It is always like this. So, more discussion will happen in subsequent lecture but let us only see the calculation now.

So, what is that bandwidth efficiency? 16.3 by 60 and here it is 0 by 60. So, you know that in the north bound direction the bandwidth efficiency is 27.2 percent, southbound direction, the bandwidth efficiency is zero percent. What is the bandwidth capacity? It is the number of vehicle that can pass through the defined series of signals without stopping.

That means in a way how many vehicles are actually able to cross, number of vehicles that can pass through the defined series of signal without stopping. So, that means what is the… how many vehicles could clearly pass through the set of signals without stopping in the bandwidth.

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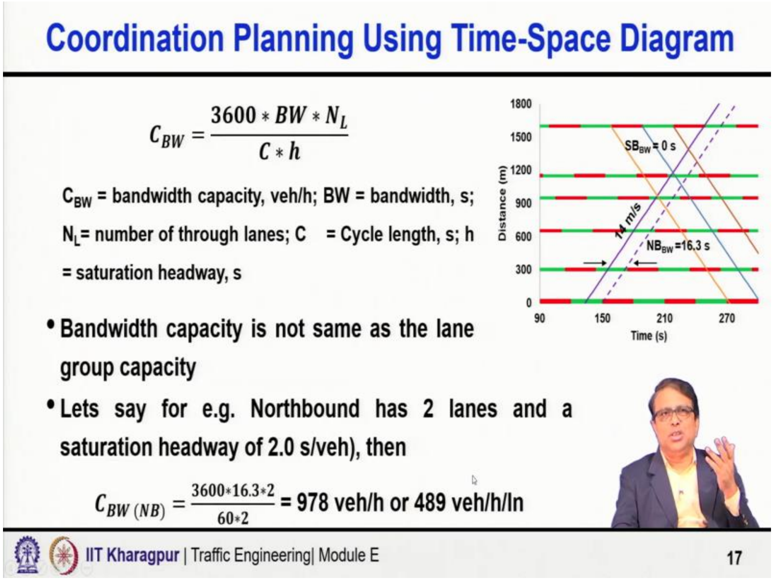

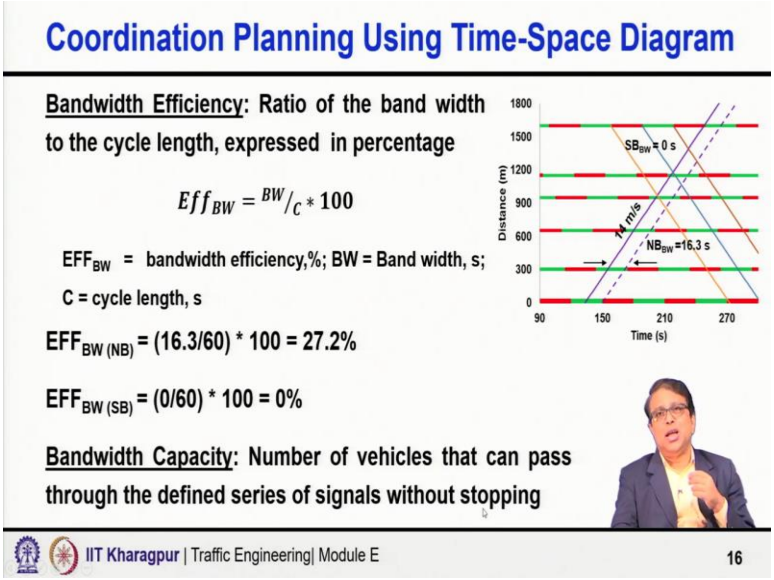

So, you can say that we can get the bandwidth capacity. So, bandwidth capacity is equal to 3600 into BW into NL by C into h. Now, obviously CBW is the bandwidth capacity. Now this is the bandwidth, how much time, this is the bandwidth and, in this bandwidth, divided by h. So, how many vehicles can pass through and C is the signal timing 3600 is the seconds, number of seconds available in an hour and NL is the number of through lanes because obviously if it is one lane, if it is two lane, three lane, the values are not going to be same.

$$C_{BW} = \frac{3600 * BW * N_L}{C * h}$$

So, it is easy to understand. Bandwidth capacity is not same as the lane group capacity. I do not want to elaborate further but you know the concept of lane group capacity. The lane group capacity is different from the bandwidth capacity because remember what is bandwidth? What is bandwidth efficiency and then how we are calculating the bandwidth capacity?

Let us say for example northbound has 2 lane and a saturation headway of two seconds. Then in this case, what will be the capacity? North bound capacity 3600 into bandwidth is 16.3 into 2 length divided by cycle length 60 second, saturation headway 2 second. So, you know that 978 vehicle per hour or you can express it since there are two lanes, you can express it divided by 2, so 489 vehicle per hour per lane.

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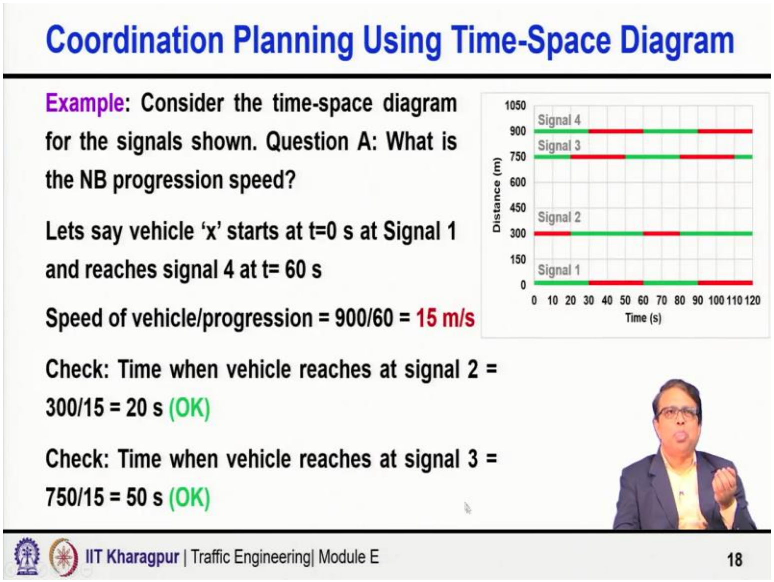

Now let us take this example, consider the time space diagram for the signals shown. I have given the time space diagram, what I am asking? First question is, what is the northbound progression speed? That is the first question we are trying to answer. So, let us say, vehicle x starts at t equal to 0. Here at signal 1, and reaches signal 4 at t equal to 60.

Exactly it reaches here at t equal to 60. So, it is traveling like this. Let us assume that. So, if it is so, then what is the speed of vehicle or the progression? This distance is how much, 900 meter and how much is this second, this is 60 seconds. So, 900 by 60 so 15 meter per second.

So, if a vehicle starting at zero time, just at the initiation of green and travelling at 15 meter per second speed. Then that vehicle will reach signal 4 just at 60 seconds when the signal 4 also will just become green. Now, we need to check what will happen to that vehicle in signal 2 and signal 3. So, we are checking the time when the vehicle reaches as signal 2, signal to it will reach at 300 meter divided by 15 meter per second to 20 second.

Exactly you can see the signal 2 is starting just after 20 seconds of signal 1. That is the ideal offset, so this is ok. Also, for signal 3, this overall distance is 750 meter. So, 750 by 50 seconds, so you can see once the first signal becoming green, the signal three becoming green exactly after 50 seconds. You can see here. This is the point.

So, actually the progression speed not bound progression speed is 15 meter per seconds and then the vehicle we started with signal 1 and signal 4, but in between we checked that will also pass through without any interruption at signal two and signal three. So, that speed is ok.

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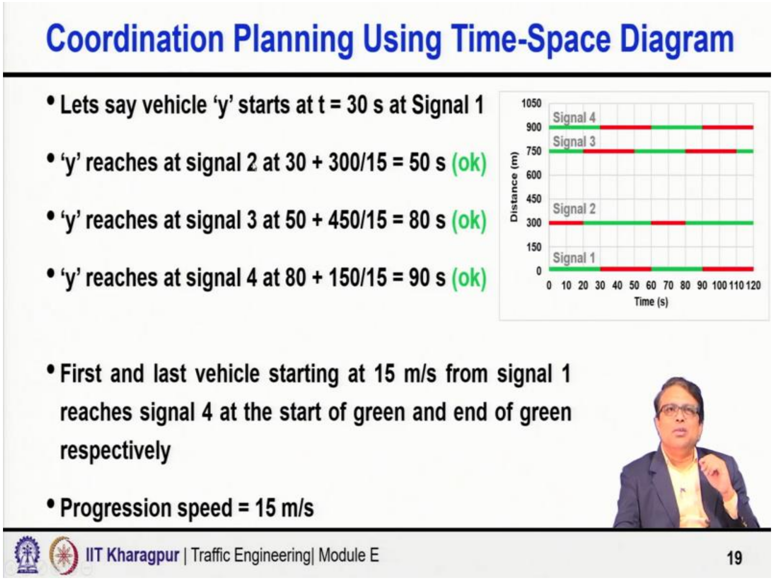

Now let us say, vehicle y starts at t equal to 30 at signal one, here. Now, the first vehicle we have checked. Now the last vehicle, so last vehicle also will start at t equal to 30 because green time is 30 seconds. So, then it reaches at signal two at what? With the same 15 meter per second speed. It reaches after 50 seconds. So, you can see here it closes really at 50 seconds. Here it reaches at 80 seconds, exactly at 80 second, 90 second exactly this is 90 second. So, this is again an ideal condition.

So, the all the vehicles which are starting in the beginning and the last vehicle is which is crossing that signal in the green, last vehicle crossing in green. They will all be able to pass through all the subsequent signal, if they are travelling at 15 meter per seconds. So, the progression speed is 15 meter per second.

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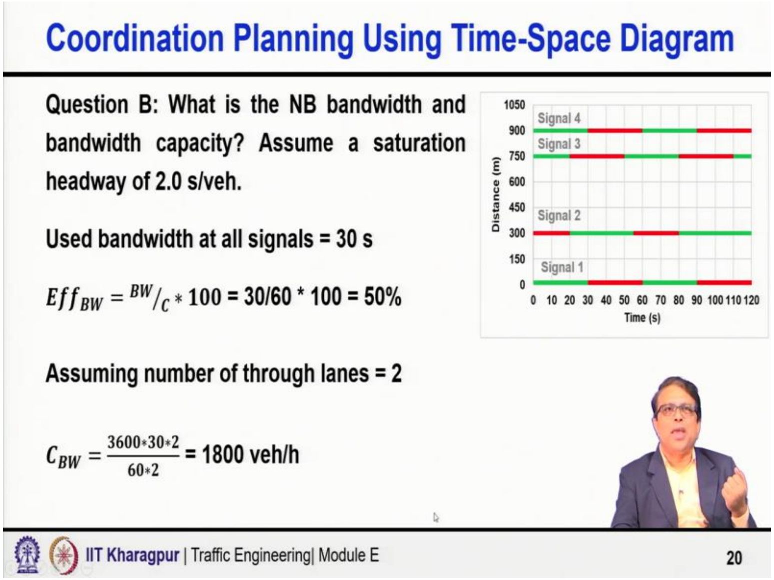

Now, what will happen to the northbound, what is the, sorry, what is then the northbound bandwidth and bandwidth capacity? So, bandwidth obviously in this case is 30 seconds and bandwidth efficiency is 30 by 60, 60 second is the cycle time you can see here 30 seconds green, 30 seconds red, so 60 second. So, bandwidth deficiency is 50 percent and if there are two lanes then you can also calculate the bandwidth capacity.

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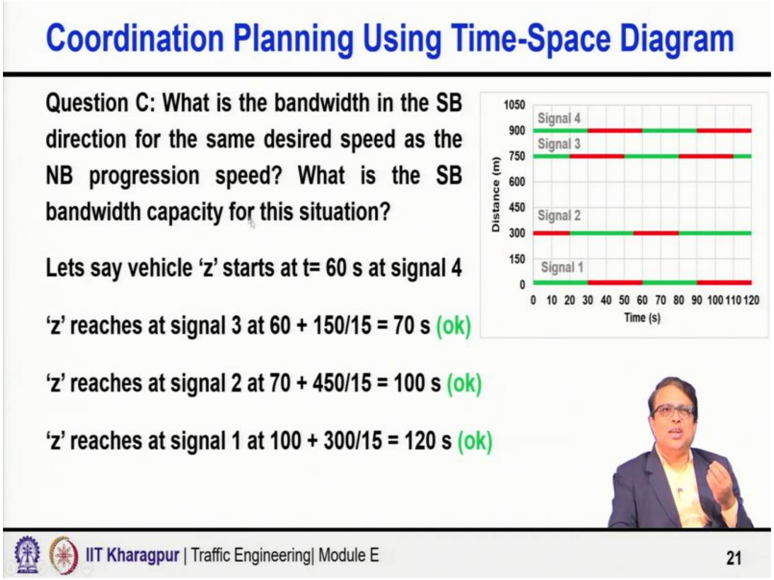

Now question C is, what is the bandwidth in the southbound direction for the same desired speed as the northbound progression speed? What is the southbound bandwidth capacity for this thing? So, so far we have talked about northbound. What will happen to the south bound? So, let us consider that a vehicle z starts at t equal to 60 seconds. Here from it is crossing signal 4, then approaching to signal 3, signal 2 and signal 1. So, if it has started in signal at 60 second then when it will reach to signal 3? 60 second plus what is this distance 150 meter divided by 15, so it will reach signal 3 exactly at 70 seconds.

So, 70 seconds is green, so it can pass through. Signal 2 like that 70 second plus this distance is 450, so 450 meter divided by 15 to 100 seconds. So, you can see here, 100 second is also green and it reaches signal 1 at 100 plus, this distance is 300 divided by 15, so 120 seconds. So, 120 seconds again just the green is starting, I have not shown here but you know the cycle time is 60 seconds so just green will start after 120.

So, fine it is able to pass through but then all the vehicle suppose the vehicle which is clearing starting here at not at 60 seconds but say 90 seconds from signal 4 will that vehicle also will be able to clear all the signals? No. That is where the bandwidth will come. Why? Because that will has to face red when that vehicle will approach signal 3.

So, how many vehicles? For how much? You can see that here the vehicle reaches signal 3 at 70 seconds, this is 70 seconds here reaches. So, green is there for how much time? Only for 10 more seconds. So, any vehicle which is reaching beyond 10 seconds will not be able to pass through and these vehicles have to stop.

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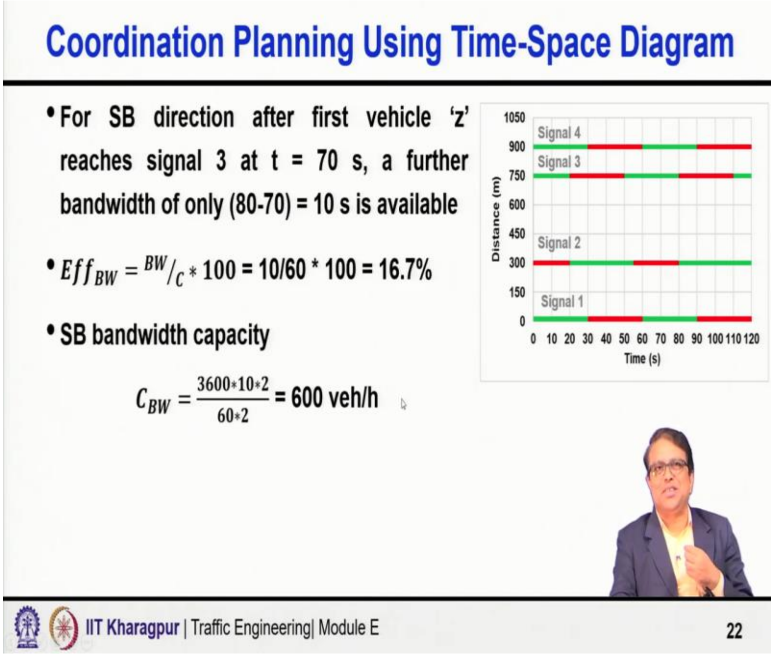

So, the bandwidth here is how much? It is only 10 seconds, in this direction. So, southbound direction it is 10 second. So, once you know this 10 second you can calculate the bandwidth efficiency obviously it will be low because it is only 10 seconds out of 60 second cycle time, bandwidth capacity also will be lower because the bandwidth itself is low.

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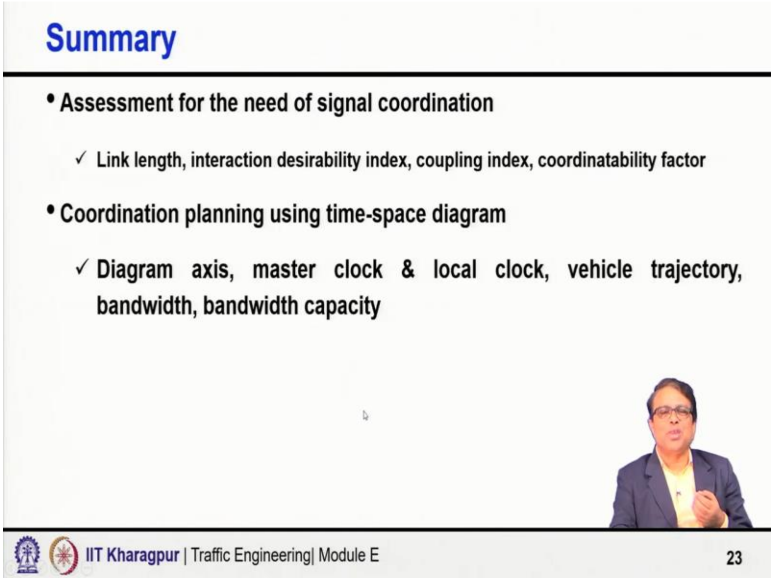

So, what we discussed overall in this lecture? I told you about the various ways we can assess the need for signal coordination, initial understanding, whether it is worth thinking further, investigating further to come out with a complete design for signal coordination. That may be decided based on several parameters based on link length, based on intersection desirability index, coupling index, coordinatability factor. I explained those.

Then I explained you the concept of coordination planning using time space diagram, the diagram access, the master clock, the local clock, the vehicle trajectory, bandwidth, bandwidth deficiency and also the concept of bandwidth capacity. So, with this I close this lecture, we shall continue in the next lecture also about signal coordination. Thank you so much.