Introduction to Transportation Engineering
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Lecture - 7
Intersection Control and Signalization

Lesson 2.6 Intersection control and signalization.

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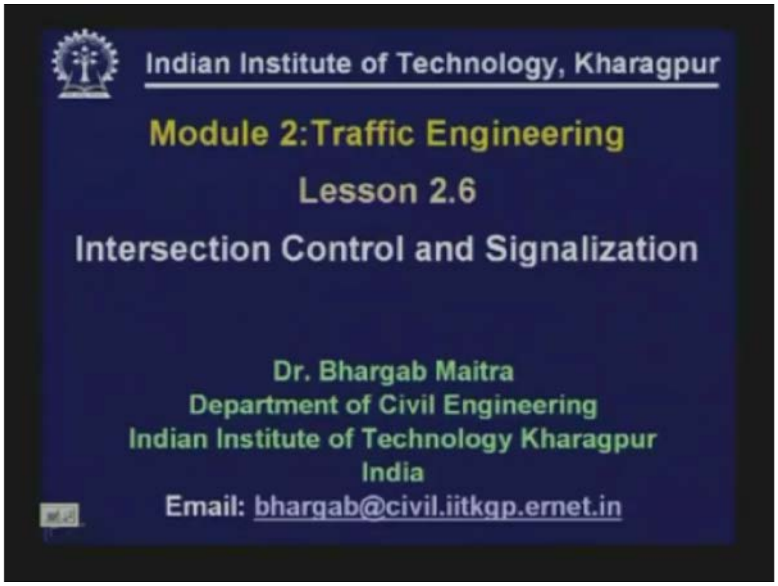

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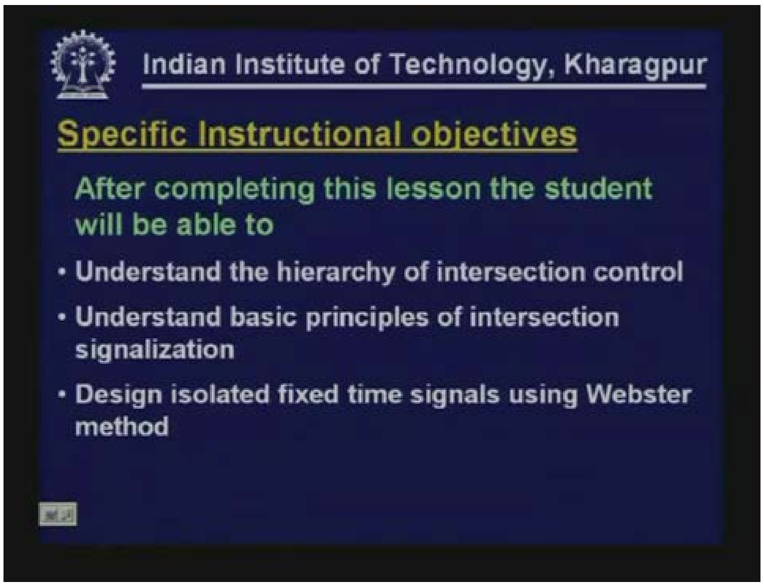

This is the last lecture under module 2, Traffic Engineering. After completing this lesson, the student will be able to understand, the hierarchy of intersection control, understand basic principles of intersection signalization, there are several aspects, several key issues involved and at least the elementary issues will be discussed so that the student will be able to understand the principles, the student will be able to design isolated fixed time signals using Webster method. It is one of the approaches of Signal time design.

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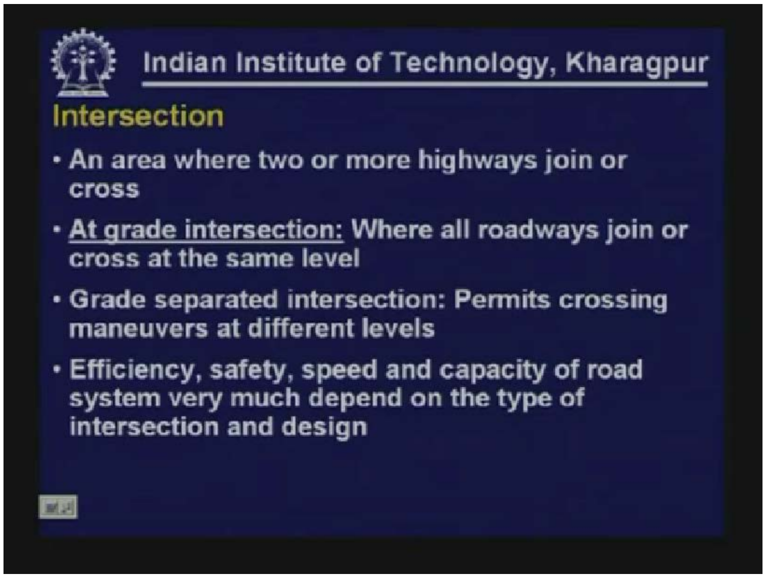

What is intersection? All of you know that in a given route network, we will have mid block section and intersection block. Intersection is simply 2 or more roads meeting at a point or an area. So intersection is an area where 2 or more highways join or cross. There are basically 2 types of intersections. One is called At grade intersection, which means all roads are meeting at the same level. All mobiles are using a common area of intersection. These are roads which are meeting at the grid or at the same level. Whereas, in grade separated intersection, it permits crossing maneuvers at different levels. Of course Grade separated intersections are better but you find mostly the At grade intersections, because grade separated intersections are capital intensive structures, capital intensive projects and unless and until the chaos, the traffic, the delay is at that level, we normally do not go for Grade separated intersections. We find normally At grade intersections where are all roads join or cross at the same level. So our focus today is on the At grade intersection. Efficiency, Safety, Speed and Capacity of road system depend on the type of intersection and design. When we talk about these two parameters, it is important to consider all these parameters.

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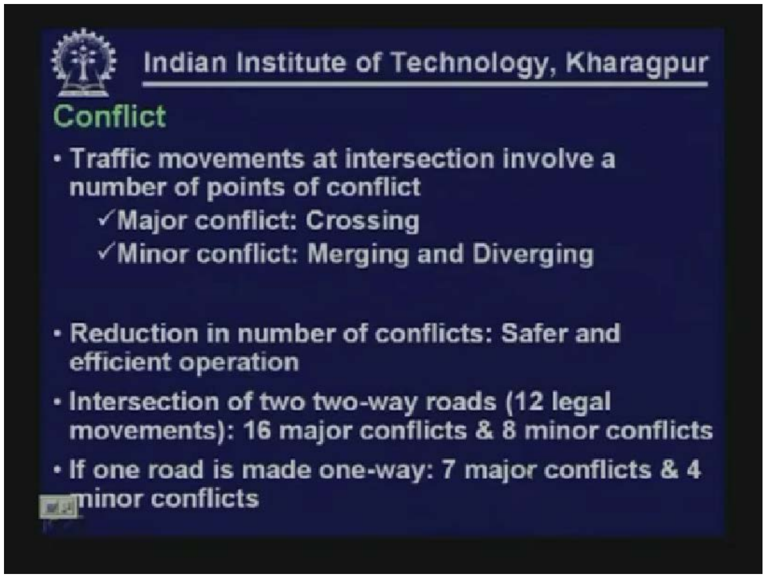

An important concept related to intersection operation is the concept of conflict. Traffic movements at intersection involve a number of points of conflicts. They are classified as Major conflict and Minor conflict. Crossing conflicts are normally considered as major conflicts. Merging and diverging conflicts are also possible and are classified under minor conflicts. Suppose a vehicle goes like this and another one like this (Refer Slide Time: 05:33), then this is the conflict point, a crossing conflict and is classified as Major conflict. 2 vehicles are using the same route. This is called the merging conflict. In a road similarly, one traffic is taking the left and the other, right. This conflict is called the diverging conflict. Merging and Diverging conflicts are considered as minor conflicts because they are relatively less critical. Crossing conflicts are most severe and hence is called as major conflict. Obviously reduction in number of conflicts means safer and efficient operation. By any means if we can reduce the conflict then we are going for a safer and efficient operation. Now to explain this part further, let us explain 2 roads which are meeting at an intersection. There are 4 approaches essentially, if we consider 3, then all 3 movements are allowed from each approach, i.e., Left turning, Right turning and straight, vehicles are allowed.

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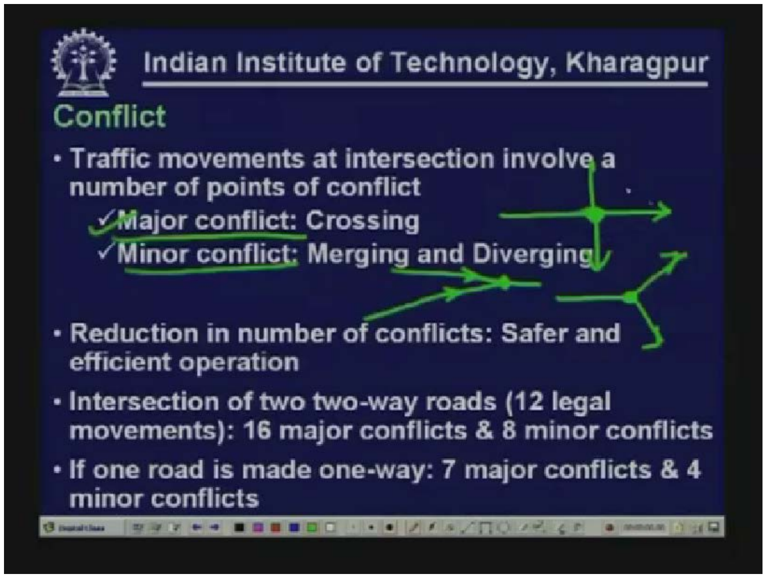

Then from each approach there are 3 possible movements and 4 approaches so there are 12 legalized movements. I am using the term legalized because I mean to say all movements are allowed. If there occurs a position like that (Refer Slide Time: 07:41), then there occurs are the conflicts. So, if you calculate, there will be 16 major conflicts and 8 minor conflicts and together 24 conflicts in the intersection area. The job of traffic engineer is basically to reduce the conflicts, to make the operation efficient. These can be done by making the 2 way roads as one way roads. Suppose for the example discussed if there are 2 way movements for both roads. If one road is made one way, then the numbers of conflicts will come down from 24 to 11. Out of those 11, 7 will be major conflicts and 4 will be minor conflicts. That is the reason that making it a one way (not every situation requires a one way road though), is used as a tool to improve the efficiency and safety of traffic operations at signals.

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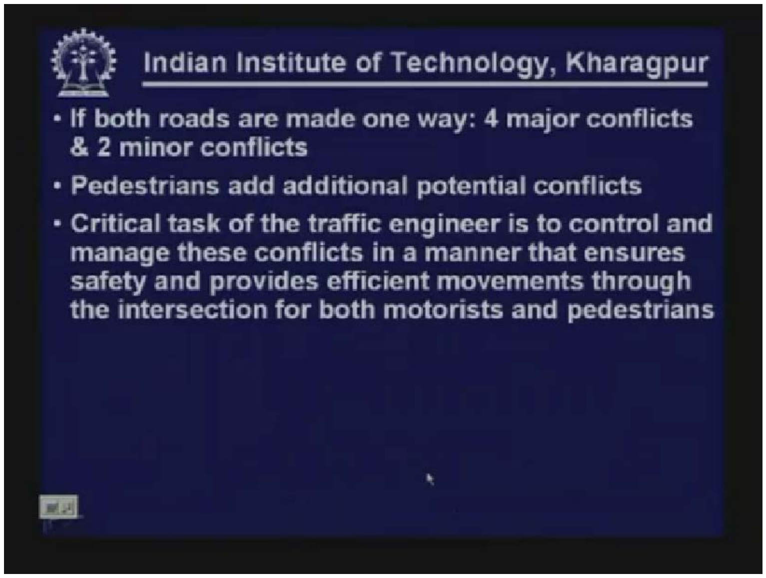

Suppose we make both roads, one way, there will be further reduction in the number of conflicts. You will find only 6 conflicts out of which 4 will be major and 2 will be minor. This is a typical example of 4 approach intersection (Refer Slide Time: 09:30) with 2 way traffic movement on both roads, one way traffic movement on one road and one way traffic movement on both roads. We have seen how the conflicts modes are reduced. If there are pedestrian movements then the pedestrians are trying to cross, vehicles are moving too, so this will also generate conflicts so pedestrians add additional potential conflicts.

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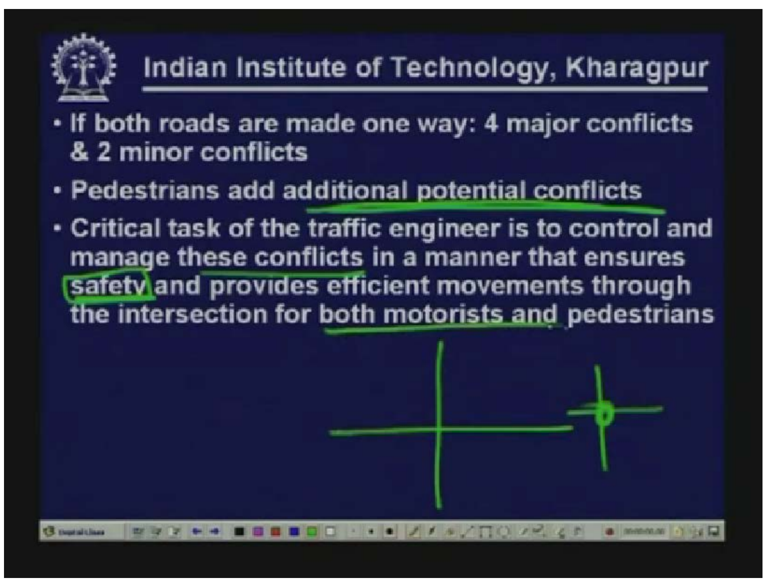

So the critical task of traffic engineer is basically to control and manage these conflicts in a manner that ensures safety and provides efficient movements through the intersection for both motorists and pedestrians. So traffic engineer's focus is not on motorized cars or other vehicles but pedestrians are important elements in overall traffic engineering concepts. The task is basically to manage this conflict to ensure safety and efficient operations of traffic and pedestrians.

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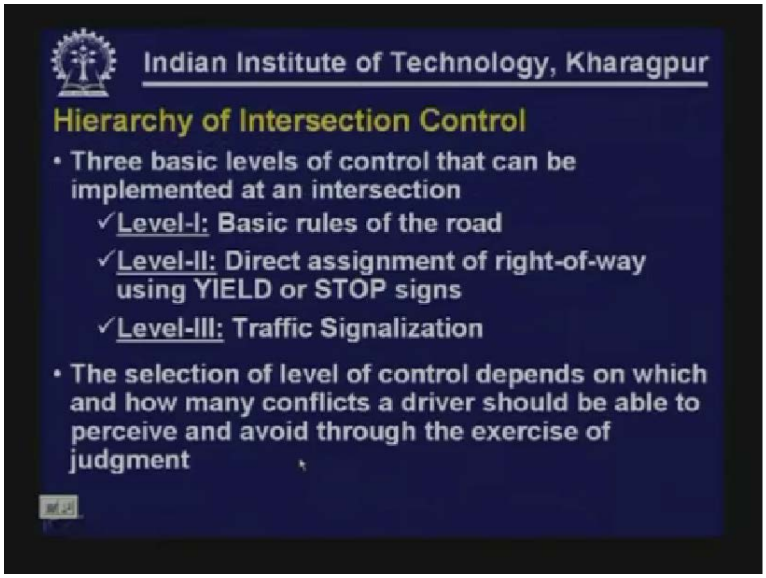

With this background you know that intersection area is a very complex situation where you have vehicle movements,' different types of vehicle movements, different legalized movements, conflicts and also conflicts created by pedestrians. Altogether they add to the complex task. The complexity change form situation to situation. From past experience we know that not all intersections are equally critical. Some cases appear to be alright, some where you find traffic condition is really chaotic and unsafe for both pedestrians and vehicle traffic.

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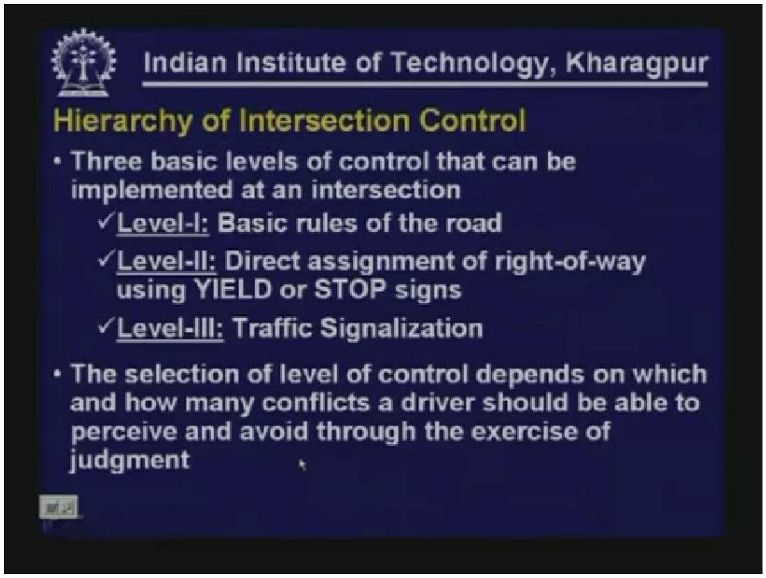

So we need to understand the hierarchy of intersection control just as a concept. There are 3 basic levels of control that can be implemented at an intersection. Level 1, level 2 and level 3. This goes in this order (Refer Slide Time: 12:21). Level 1 is okay, situation is more complex and you go for level 2, further complex operation go for level 3. Even then if it does not bring down the chaotic situation, we have to then think of grade Separated intersection. Level 1 is based on basic rules of the road, i.e., we don't impose anything on vehicular permit. We don't stop vehicle by sign or signal, by giving a red signal or stop sign or anything. We expect the system to operate based on basic rules of the road.

Now, what are the basic rules? When licenses are given to drivers, they are supposed to know the basic rules; they are supposed to qualify based on the general knowledge. Every state has its own set of driving rules. It is expected that the driver will know the basic rules, the traffic rules, pedestrians know how to cross and will cross as per the rules and regulations. It is essentially the basic and fundamental rules of the road that if everybody follows then operation will go fine under certain situation. So, in level 1 we do not impose anything, no traffic signal, sign, (sign maybe there to indicate that you are approaching intersection. That kind of signs are fine), informative signs are fine, and it does not mean any imposition. So we can still consider that it is operating under the basic rules of the road.

In some cases however, you may find that it is left to the judgment and the basic rule i.e., when a vehicle is approaching from left or right or whether we should cross or march. The drivers will be able to apply judgment and you will have the ability and the situation or the context will also help him make a decision. When the traffic volume is more, when the situation becomes more complex, then you cannot just leave it to the basic rules of the route. So once you find the level 1 is not adequate, and then the next stage, we will go for is level 2. The direct assignment of right-of-way using YIELD or STOP signs. You maybe be familiar with STOP signs and YIELD sign. STOP signs means a vehicle has to stop at a STOP sign when it approaching a minor road, then look for a gap, then March or take a turn in main traffic street. YIELD sign is also another form of control, but we expect minor state vehicles to give priority to the major state traffic, so he may or may not stop depending on the situation.

If there is not traffic on the major road, he can straightaway take a turn but if he finds vehicle approaching on the major road, he has to stop and wait until he finds a suitable gap. That means, priority is more for major state traffic movement and less for minor state traffic movement. But this may also not work. You may find the traffic volume grows complexity grows, more pedestrians, more traffic so then you may find the STOP and YIELD sign not to be adequate. So now we go for level 3, where we go for Traffic Signalization. That means you install traffic signal, you share the times for certain movements.

Maybe major road traffic or minor road traffic, you stop at one road or both roads maybe of equal priority. You allow movements at other road; stop the movement at one road and vice versa, like that traffic signalization uses essentially the same space and same area can be used for certain type of movement at certain type. Not all movements take place at the same type, some movements; take place at one time and certain others at other times. That is Signalization.

In simple form, you may try with level 1, and when you don't find it adequate, you go for level 2, and if you still don't find it adequate, you for level 3. Further, there are a lot of procedures, types of signal operation is possible, isolated signal design, individual signals etc. You then try to coordinate the signals, this is a vast topic area and there are lot procedural areas, a lot of concepts to understand, and with this you still find that you are still not able to manage traffic or ensure safety and efficiency then one has to go for Grade separated intersection. But out main focus in today's lecture is basically at grade intersection.

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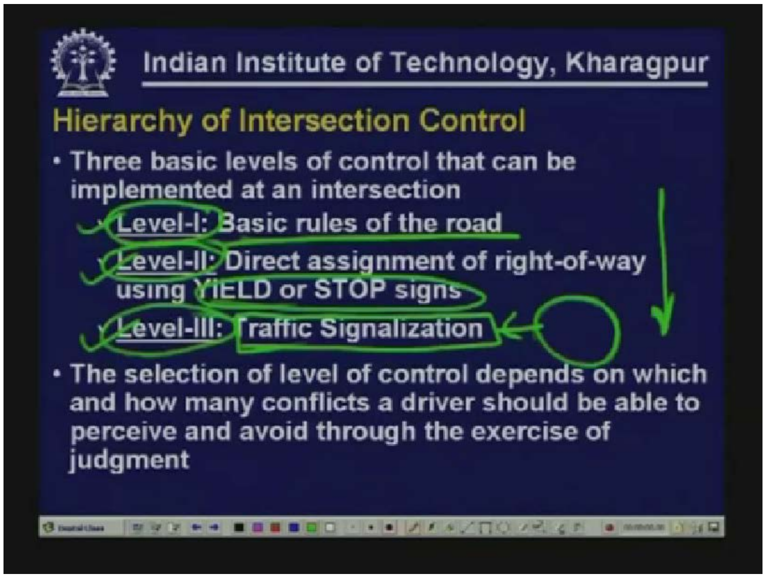

Further we shall move to Traffic Signalization. We have Levels 1, 2 and 3. The selection of level on control depends on which and how many conflicts a driver should be able to perceive and avoid through the exercise of judgment. So like I said, carefully observe this part. What type of conflicts and how many conflicts, both are important. Like I said, there are major and minor conflicts. So what are the types of conflicts and how many conflicts are present? You expect the driver to perceive and then avoid without making a crash or an accident through the exercise of judgment. If you find the type and number to be good enough, much lower and lesser and they don't impose essentially that level of effective problem, then you may go with level 1. Otherwise go for level 2, still if the situation is not under control, go for level 3. Where it is not reasonable due to complexity of the situation and operation, to expect a driver to perceive and avoid conflict, traffic control must be imposed. Control means by importing a STOP sign, YIELD and further by putting traffic signals. There are 2 factors that primarily affect a driver's ability to avoid conflicts:

1. The driver must be able to see a potentially conflicting object to implement an avoidance maneuver. This essentially means basically, the geometric design of intersection. A driver approaching from one approach firstly should be able to judge the vehicle coming from the other side. So intersection side distance, safe distance ensures safe operation of traffic at an intersection. This is an intersection, (Refer Slide Time: 21:16), he should be able to see a vehicle from this direction and another from this direction. So if this vehicle requires this distance to stop and this vehicle requires this distance to stop (Refer Slide Time: 21:28) then this area (Refer Slide Time: 21:34) should be free from obstruction because this is the line of sight. We will have further discussion on geometric design part about the intersection side distance. So this essentially pointing out the need for adequate intersection side distance. First of all the driver must be able to see a potentially conflicting vehicle. If he fails to see a tall building or a obstruction in the middle of intersection, then unless you reach the middle of the intersection, you cannot see the vehicle coming from the other side.
2. The volume levels that exist must present reasonable opportunities for a safe maneuver. This is another aspect that we are trying to point out. What does it mean?

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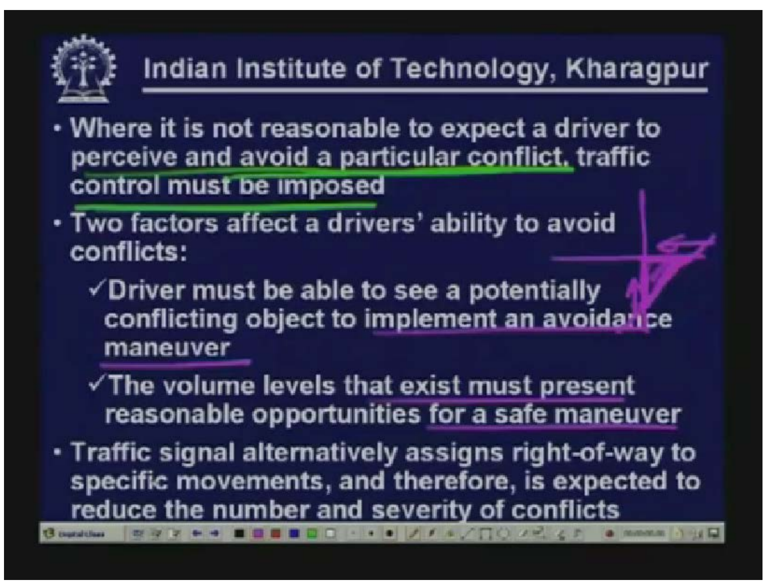

You have adequate side distance, let us suppose a vehicle is approaching from a minor road, the driver is able to see, but has to get an opportunity to cross or march towards the main traffic stream. He waits but does not find any gap, because the volume is so heavy that he keeps waiting for a long time. He is unable to perform the maneuver that he intends to do. In that case, the volume level is critical and is beyond certain value, all the approach volume for different roads. Then the driver may not get reasonable opportunities for a safe maneuver. Looking at the side distance and the traffic intersection, both of them affect the driver's ability to avoid conflict. Because if there is a reasonable gap and the traffic volume is not that heavy, driver may have the patience to wait otherwise, he will try to take risk and will eliminate the opportunity, he may try to march in to the traffic stream or enter into the traffic stream. So that may cause potential safety problem.

Traffic signal alternatively assigns right-of-way to specific movements, as I indicated and some movements are allowed at some times, other movements are stopped. Some movements that are allowed earlier will be stopped, other movements will be allowed. So it is therefore expected to deduce the number and severity of conflicts.

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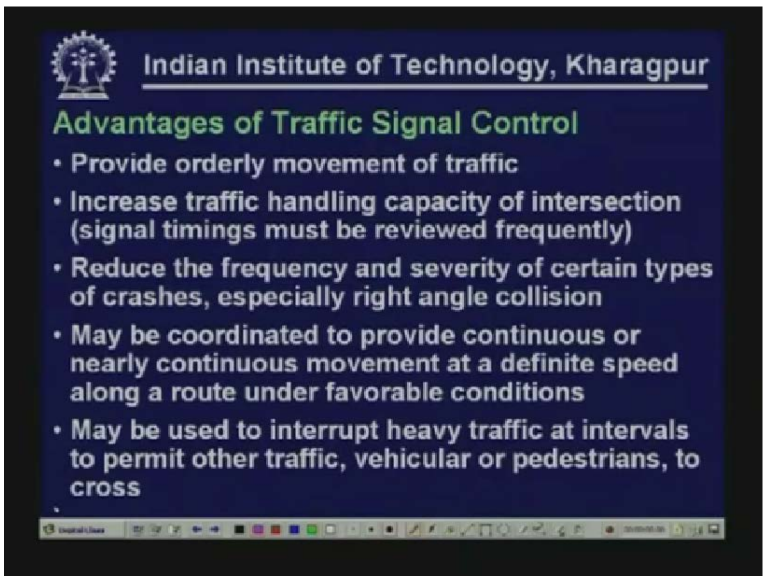

There are certain advantages of traffic signal controls. Maybe they are obvious based on our earlier discussion, but however I will still try to make certain points. Traffic signals provide orderly movement of traffic. Chaos is eliminated, because some movements are allowed at some time and other at other times. Not all movements are taking place at the same time. It provides orderly movements. To increase in traffic handling capacity of intersection, it is important to reduce the signal timings frequently. This part is very important.

Not only this but, it is necessary to ensure that Geometric design of intersection is proper. That is another key aspect. One geometric design part is ensured and you have adequate and efficient design standard, then if you just design signal once and leave it, that may not give the required efficiency, because over a period of time, the traffic volume may change, the traffic volume from different approaches may change. Most of them are applicable to fixed time signals which are very common in most of the cases.

Most situations you may find pre time fixed signals. It is necessary to update this signal time because what you will today is based on today's traffic condition. But maybe after one year, the traffic volume, the approach volume may change, so it is necessary to review with time to time. To do that you may provide the best traffic handling capacity. The signal reduces the frequency and severity of certain types of crashes, especially the right angle collision because the movements are assured of time. Signals may be coordinated to provide continuous or nearly continuous, at a definite speed along a route under favorable conditions. This is importantly noted as there are a lot of complexities, a lot of aspects that have to be taken into consideration, and then it is possible that you give smooth traffic movement along the directions of major traffic flow. So the priority can be decided, movements and flow can be much better provided, under favorable conditions and other aspects. Though it may be conceptually sound, there involves a lot of issues when we try to implement it and it comes during the advanced stage of the discussion or the Traffic engineering component.

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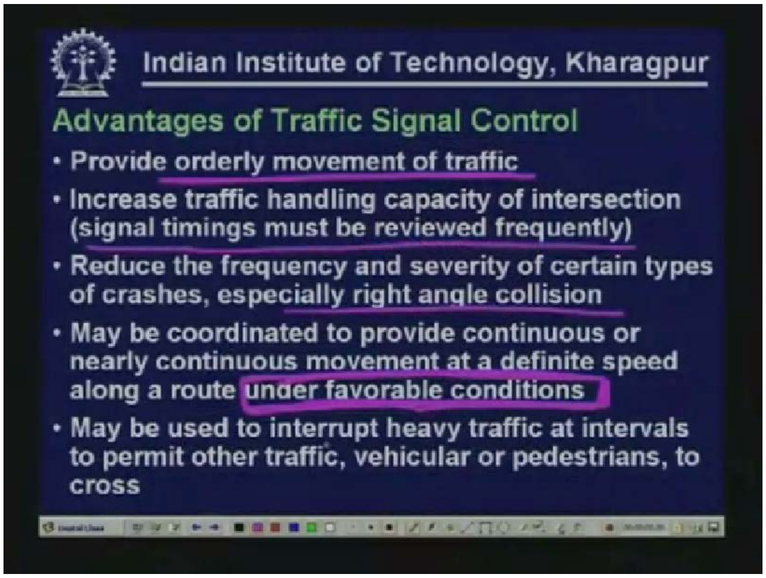

Signals may be used to interrupt heavy traffic at intervals to permit other traffic, both vehicular and pedestrians to cross. In some cases you may find heavy traffic and small vehicles moving and it is not safe to cross. So you intermittently wait so that other vehicles or pedestrians can cross efficiently and safely.

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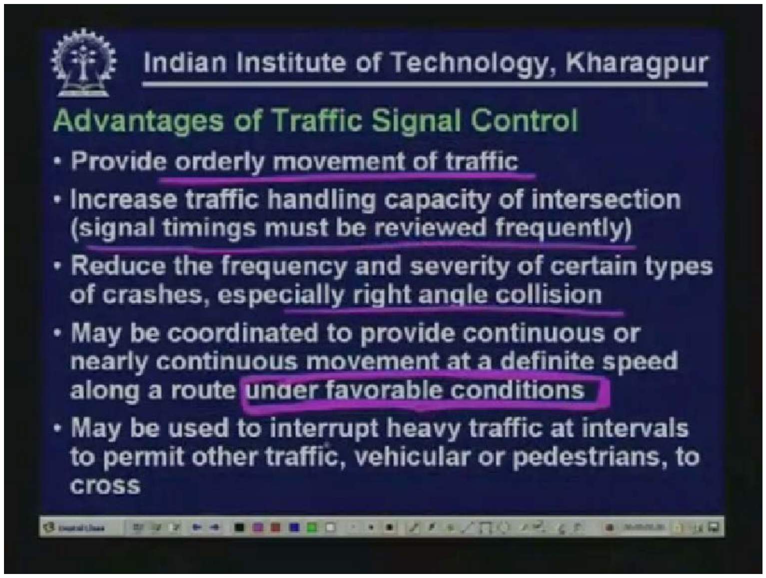

There are also disadvantages associated along the traffic signal coordination, as indicated that if you don't update the signal time for fixed time or pre time signal, then the delay maybe more. In some cases people may try to avoid routes which may have signals. In some cases people may take a different route so the route distribution may change. So it is necessary to maintain the signals to ensure that you update the timings at regular intervals.

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Next, coming to Principles of Intersection traffic signal, this involves the decision to install traffic signal. It depends on a large number of factors and is also a complex task. Combinations of traffic volumes, potential conflicts both nature and number of conflicts, what is the present overall safety of operation? What is the present efficiency of operation? What is the level of driver convenience and inconvenience? All these combining will decide whether you need to go for signalization. There are different warrants. Different countries, states, local bodies will have different warrants, under which condition; a traffic signal is really acceptable. In most of the cases the values and levels may change. But generally, Combinations of traffic volumes, potential conflicts, overall safety of operation, and efficiency of operation, driver convenience and inconvenience are all important to understand the principles of signalization, we will learn the different terms and definitions some of which will already be known to you. We will try to create an understanding about the terms and definitions and through that we will try to understand the basic principles of signalization.

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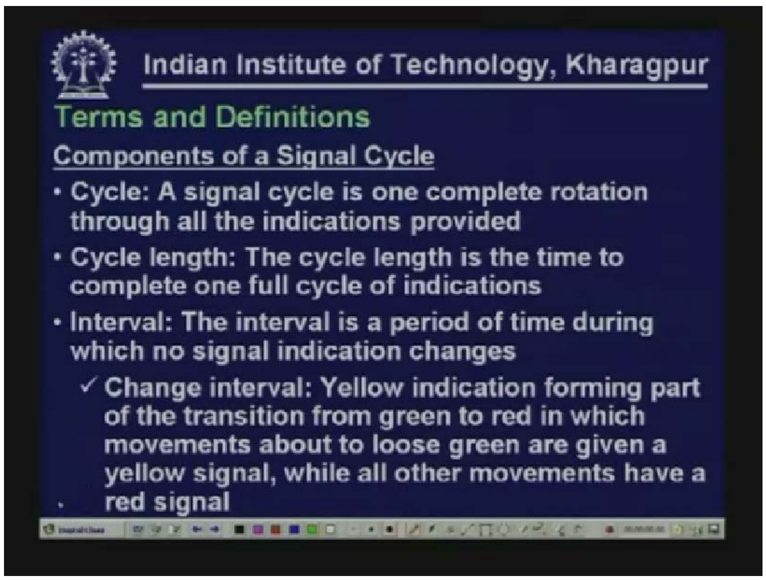

First is the component related Signal cycle. What exactly is Signal cycle? A signal cycle is one which has complete rotation through all the indications provided. You are familiar with traffic signals? If you are moving sometimes, it is red, amber or green. So a complete rotation through all the indication is provided by the signal cycle.

Next is the Cycle length. It is the time to complete one full cycle of indications. So, what is the time required to provide one full cycle of indication? That is essentially cycle length.

Next comes the concept of Interval. The interval is a period of time during which no signal indication changes. Suppose you are operating, and it is red, as long as it remains red, it is an interval. It does not change from Red to amber or green, green to amber or red to green. So interval is a period of time during which no signal indication changes. There are different types of interval. One is change interval. Normally, yellow indication forming part of transition from green to red in which movements about to loose green are given a yellow signal, while all other movements have a red signal. Let me try to explain to you further.

Suppose the green is given, vehicles move freely. Suppose if you give red, it suddenly becomes difficult for the vehicle to stop. So you have to follow a yellow indication in between green and red indications, yellow or amber. At indications from green to red in which movements about to loose green are given which means earlier it was green now it turns to become amber. So movements about to become green are given yellow signal. All other movements still have red signal.

When a particular movement under consideration shows green, all other movements still have red signal. When this movement is given amber or yellow signal still all other movements are given red signal and the red signal is essentially continued. Therefore that yellow signal interval is called the changed interval.

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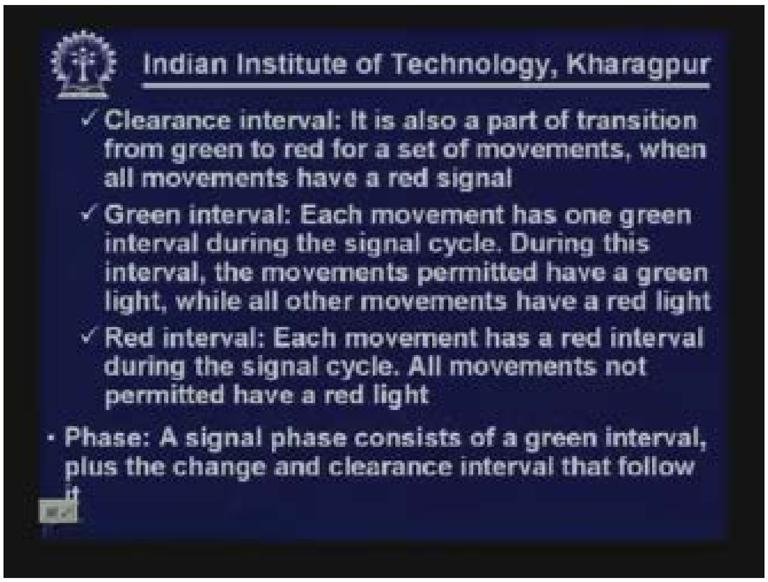

Then we have the clearance interval. Clearance interval is also part of transition from green to red for a set of movements when all movements have red signal. It is essentially indicating all red kind of a situation. Hence all movements have a red signal because even in amber also some vehicles will move and those vehicles should be able to cross the intersection safely before another movement is allowed or vehicles allowed from other approaches. If not there might be problems in safety once again. This is the clearance interval.

Then we have the green interval. For each movement at least there is one green interval during the signal cycle because in signal cycle all movements are allowed sometime during the signal cycle. So each movement has one green interval during the signal cycle. During this interval the movements permitted have a green light so only the movements which are permitted will have a green light while all other movements will have a red light.

Similarly for the red interval each movement has a red interval during the signal cycle. Like during the signal cycle each movement will get a green interval and each movement will also get red interval. So during the red interval the movements that are not permitted have a red light so they will not be able to move. These are the concepts of interval and different types of interval.

Now let us look into the concept of phase. A signal phase consists of a green interval plus change and clearance interval that follows it. Essentially in a phase we divide the movements.

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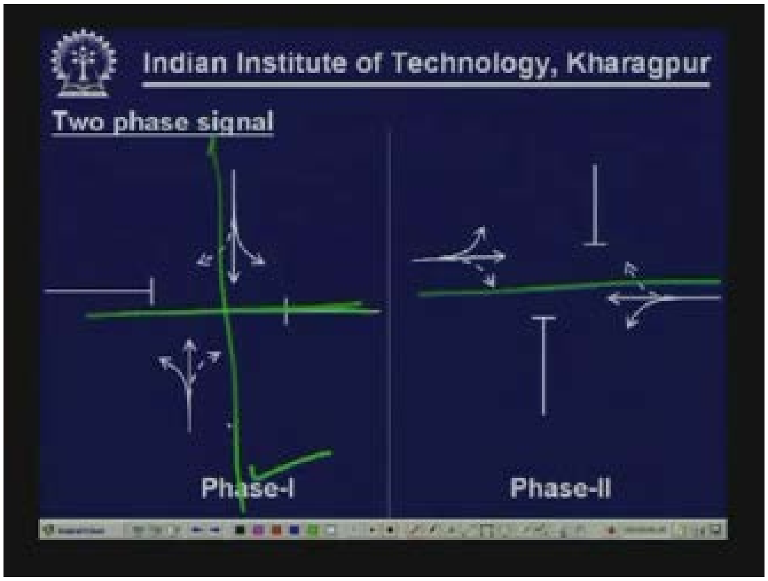

Suppose this is a simple two phase signal and there are also three or a four phase signal but let us now take the example of a two phase signal. These are the two roads which are meeting. So obviously when you have a signal you do not allow all movements to take place at the same time. So given the signal time you divide the signal time into different phases. Suppose this is a two phase signal then this is phase I (Refer Slide Time: 37:02) where you don't allow any movement on the east west road. Let us consider that this is the east west road and this is the north south road (Refer Slide Time: 37:12). So for the east west no movement is allowed and only for the north south road all movements are allowed whereas basically allowing six legalized movements. From this approach it is left, straight, right and from the other approach also it is left, straight and right. This is phase I.

In phase II you don't allow movements on the north south road but you allow the movement only for the east west road. So for this road only the movements are allowed. So here again from each approach you are allowing all the three movements. So phase I and phase II is one cycle.

Now you might be thinking that here also we are allowing the right turn traffic (Refer Slide Time: 38:04) and the straight lane traffic is also allowed from the other direction so there may be potential conflicts. Yes, in the phase II operation in this particular operation we are allowing those conflicts but these kinds of things may be still okay where the right traffic volume and the straight traffic volume are not significant because altogether the traffic volume for the right turn and straight traffic for the opposite direction are not heavy and suitable gaps may be obtained by the right turning traffic because there may be only few vehicles so they can still get a gap within that phase for a safe right turn. But as the traffic volume increases and the right turning traffic and the straight lane traffic is also more then you need to provide a separate phase. In that case we may go for a three phase signal.

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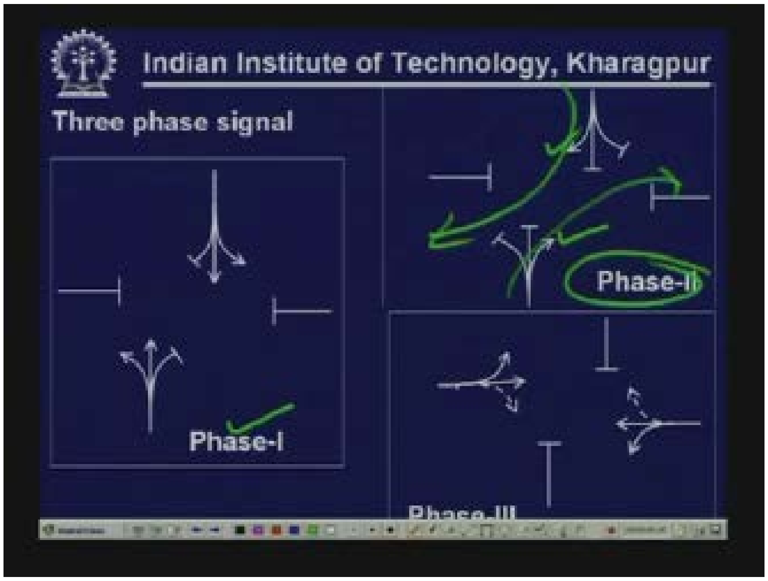

Here you can see that again in phase I the east west road movement is stopped and all movements are stopped and only for the north south road we are allowing movement. Here we are allowing the left turn and straight lane traffic and here also we are allowing left turn and straight lane traffic so there is no conflict. Here also this right turn traffic is stopped and the right turn from the opposite direction is also stopped so there is no conflict here again. This is phase I. In phase II just clear these two right turn traffic movements assuming that north south is the major road and east west is the minor road. We assume that there is very little right turning traffic in the east west road, it often happens that way that both roads may not have equal priority so one road is considered as the major road and the other one may be a small cross road.

In this example let us consider that the north south road is a major road so you have lot of right turning traffic. So we are giving a separate phase that is phase II for right turn. So this right turn is taking place and this right turn is taking place and only right turning vehicles are allowed so there is generally no confusion.

In phase III we stop the movement on the north south road and the movements are allowed on the east west road and like in the earlier examples we are now allowing all the three movements assuming that the right turning traffic is not significant since it is a minor road so they can somehow find a suitable gap and safely turn. So this is an example of a three phase signal.

If you find that both the roads are equally important then like I have done for phase I and phase II for north south traffic so it may be a total of another two phases so you may design a four phase signal for that kind of a situation.

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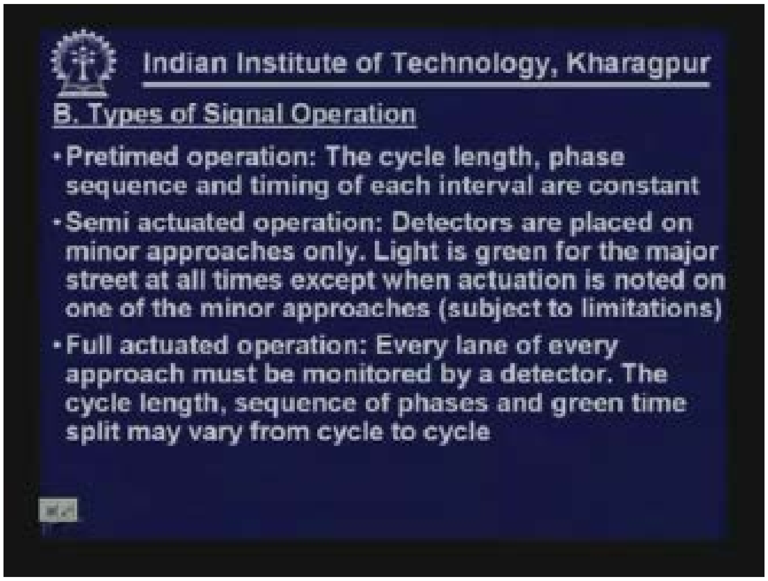

Now coming to signal operation there are three types of operation such as pretimed operation, semi actuated operation and full actuated operation.

In pretimed operation the cycle length, phase sequence and timing of each interval are constant during that period. So do not consider short fluctuation in traffic demand, total and approach volumes.

In semi actuated operations detectors are placed in minor approaches only so semi actuated operation is suitable when you have a major road and a minor road. So all the time it will be green for the major road movement and detectors are placed for minor road approaches. If actuations are noted from one of the minor approaches then the traffic signal may turn red for the major road and may become green for the minor road but they are subject to limitations as to how much minimum green time should be given for the major road traffic and what is the maximum time given for the minor road traffic under all conditions.

When both the roads are important then we may go for the full actuated operation where every lane of every approach must be monitored by a detector and accordingly the signal cycle, the sequence, green time split etc may be calculated and all these may vary from cycle to cycle.

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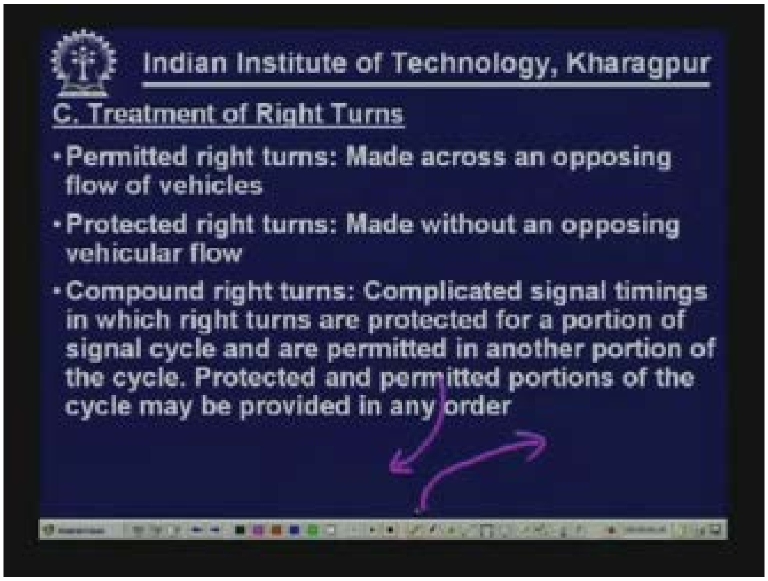

Coming to treatment of right turns we have seen that the right turning traffic are the problematic ones. In phase design we saw that in one case of the two phase signal design we have allowed right turn when the opposite traffic was also there and in the three phase design we have not allowed the right turn when the straight traffic from the opposite direction was allowed. So basically there are two types of treatment. One is permitted right turns where right turns are made without an opposing vehicular flow. That means in a situation like this you have a right turn and also you have vehicles from the opposite direction so this is the permitted right turn.

Protected right turn is made without opposing vehicular flow. That means when these right turns are taking place then there is no vehicle from the opposite direction. So it is a situation like I have shown here (Refer Slide Time: 43:46). Here it is a protected right turn, the right turn is taken and there is no straight movement here.

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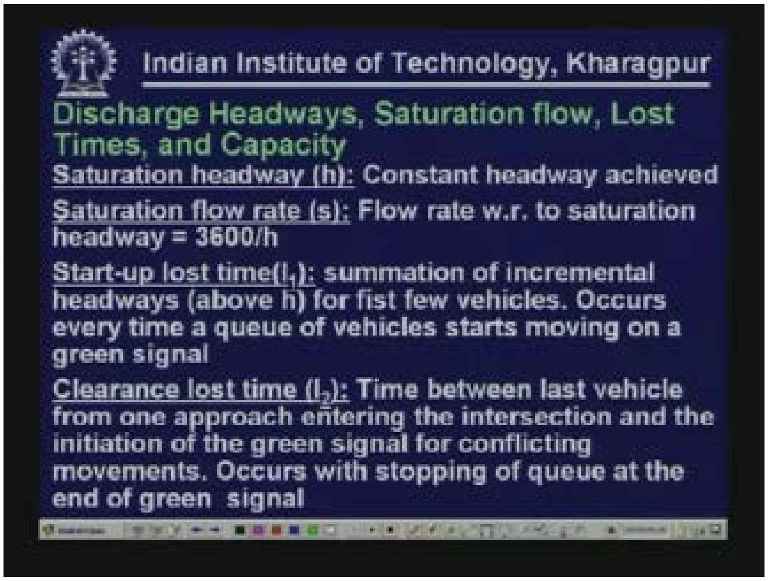

Coming to the concept of discharge headways, saturation flow, lost times and capacity you are already familiar with the concept. I have discussed in other lessons.

Saturation headway is one is which constant headway is achieved.

Saturation flow rate is the flow rate with respect to saturation headway.

We also discussed about the start-up lost time and clearance lost time.

Start-up lost time is the summation of incremental headways above h for the first few vehicles. This is applicable, they will have longer headways than the saturation headway. And the start-up lost time occurs every time a sequence of vehicles starts moving on a green signal. So every time the vehicles start moving in green signal the start-up lost time occurs.

Similarly the clearance lost time is the time between the last vehicle from one approach entering the intersection and the initiation of the green signal for conflicting movements. So the clearance lost time occurs with the stopping of queue at the end of green signal.

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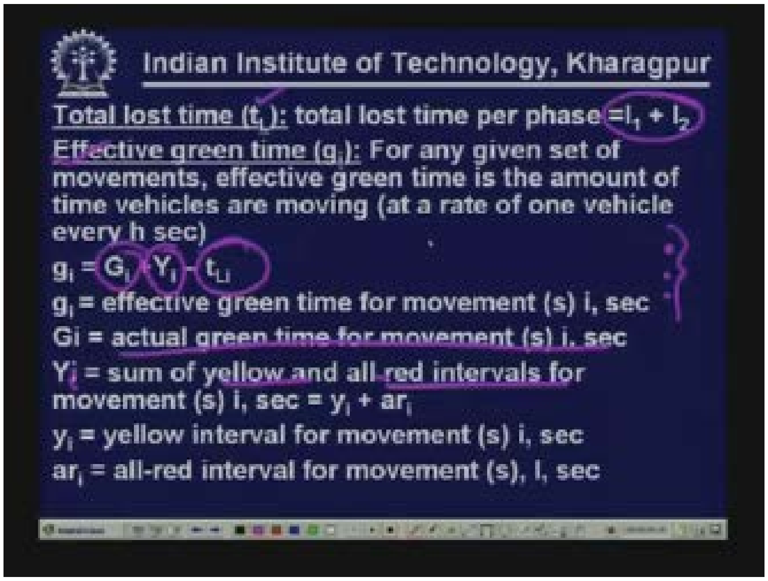

Now we have the total lost time. This is basically the start-up lost time plus the clearance lost time. So it is l1 + l2 and (……..45:21).

Effective green time is a new concept. For any given set of movement effective green time is actually the amount of time vehicles are moving at a rate of one vehicle every h second. That means during the whole period not that always vehicles are moving with one vehicle every h second. That is happening when the headway is operation under the saturation condition. But if you take the complete time then you can calculate the effective green time where during this time we can assume that vehicles are flowing at a rate of one vehicle every h second. This is normally denoted as small g_i. How can we calculate that? This is basically the total green time given for movement i plus yellow and all red intervals for that movement Y_i minus the total time lost. Therefore the total time lost is nothing but $l_1 + l_2$.

Basically you have green time, amber, all red etc. so during this whole time the flow is not taking place at one vehicle every h second so this is the total time the green + yellow + amber minus the total lost time. So that is the effective green time where we can assume that vehicles are moving at a rate of one vehicle every h second.

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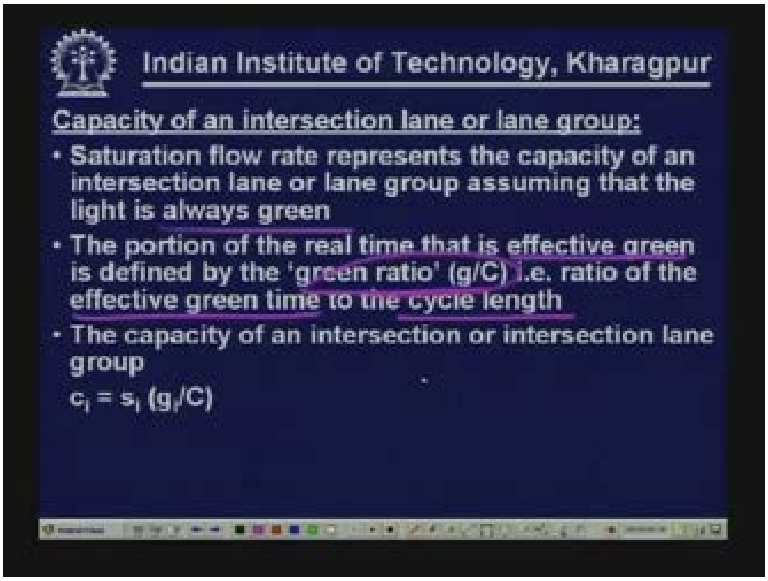

Now the capacity of an intersection lane or lane group may be calculated now easily. Remember that the saturation flow rate represents the capacity of the intersection lane or lane group assuming that the light is always green. But this is not the case in reality. The light is not always green so the portion of the real time that is the effective green is defined by the green ratio.

What is green ratio? Green ratio is the ratio of the effective green time to the total cycle length. Therefore effective green time is defined as the amount of equivalent green time where we can assume that flow is taking place at one vehicle every h second where h is the saturation period. Therefore this is the effective green time to cycle time and that ratio is termed as the green ratio. So obviously with the saturation flow for a given approach or lane or lane group if we multiply it with this g/C ratio the green ratio then we will get the correct ratio. Let us now take a small example.

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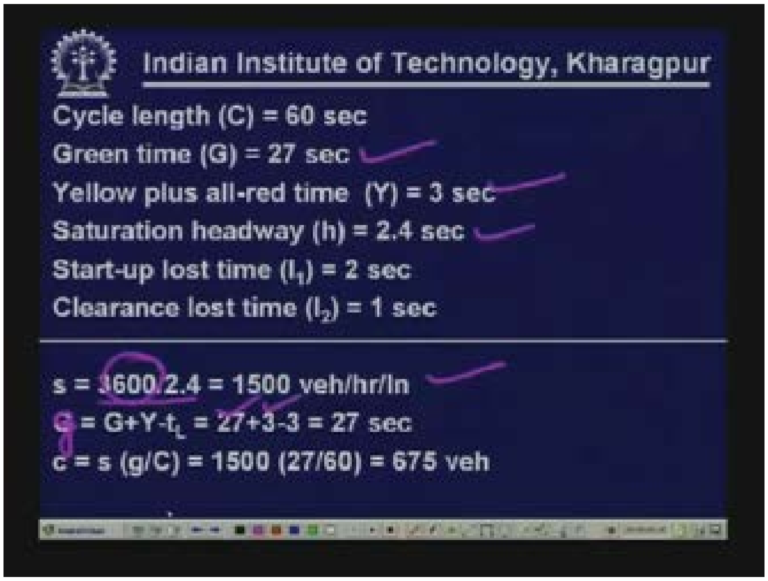

If the cycle length is 60 seconds then the green time will be 27 seconds, the yellow plus all-red time may be 3 seconds and saturation headway may be estimated as 2.4 seconds, start-up lost time is 2 seconds and clearance lost time is 1 second. Then how can we calculate the capacity. First we will calculate the saturation flow rate 3600 seconds in an hour divided by the saturation headway that is 1500 vehicles per hour per lane then this small g = G the total green time 27 seconds plus yellow plus all-red time 3 seconds minus start-up lost time minus clearance lost time or the total lost time. So it is totally 3 = 2 + 1 = 27 seconds so now the capacity is saturation flow because saturation flow is applicable for continuous green signal so this will be multiplied by g/C ratio the green time so 27/60 = 675 vehicles.

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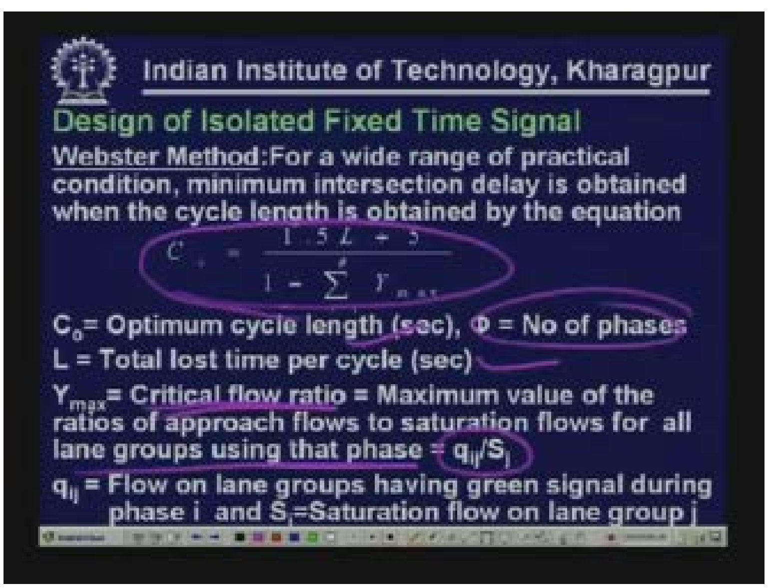

Now let us look at the Design of Isolated fixed time signals. There are a variety of approaches available from the simplest to the most complicated in this design. Let us therefore cover the simplest one which is used in many places that is Webster method. Essentially using the Webster method we try to find out the optimum cycle time that will minimize the total time.

For a wide range of practical conditions this Webster method is applicable and minimum intersection delay is obtained when the cycle length is given by this formula. So this is calculated as 1.5 L + 5/1 – sum over Y_{max} sum over I = 1 to 5. Co is the optimum cycle length and again phi is the number of phases, L is the total lost time of cycle and Y_{max} is the critical flow ratio. This is a slightly new concept. It is the maximum value of ratios of approach flows to saturation flow for all lane groups using that phase. That is q_{ij}/S_j where S_j is the saturation flow for lane group and q_{ij} is the flow on lane groups having green signal during phase i. Therefore by this way we get the critical flow and once you get the critical flow ratio you can calculate optimum cycle length. And once the cycle time is calculated the green time may be calculated. Let us see a very simple example.

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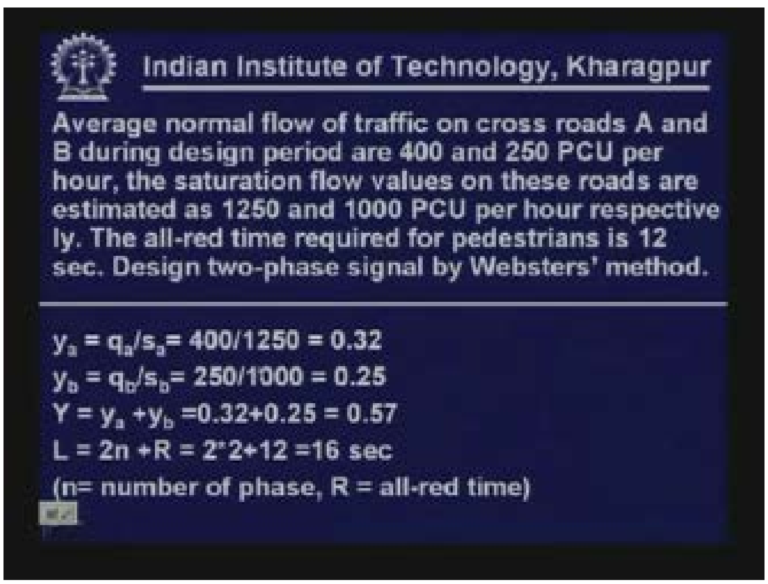

Average normal flow of traffic on cross roads A and B during designs are 400 and 250 PCU per hour. The saturation flow values for these two roads are estimated as 1250 and 1000 PCU per hour respectively. The all-red time required for pedestrian is 12 seconds. This is a very simple example we have taken just to show you the calculation. We calculate Y_a which is the critical flow ratio and in this case only one value is given so $Y_a = q_a/S_a$ so qa is 400 and corresponding saturation ratio is 1250 so you get 0.32 as the ratio similarly y_b is 0.25 and y is sum over $y_a + y_b$ so 0.57 and the total lost time is 2n + R so 2 into 2 + 12 seconds which is the all-red time and there are two lengths so there are 16 seconds.

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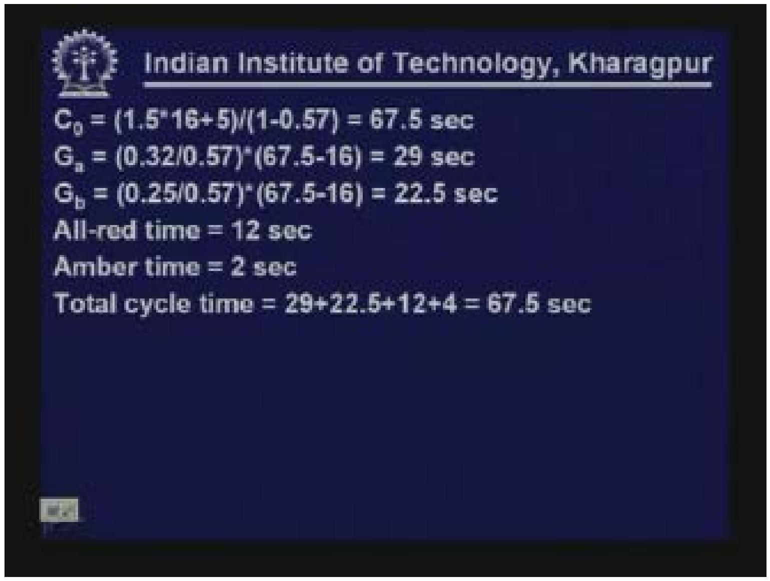

Once you calculate that using the given formula you can calculate the C_o value which is the total cycle length which will optimize the total delay that is 67.5 seconds. Now the green time for approach A will be a ratio of 0.32 Y_a/sum over Y because sum over Y is 025 seconds and out of that for approach A it is 0.32 so 0.32/0.57 seconds multiplied by not 67.5 but 67.5 – 16 where we are assuming amber time as 2 seconds so there is a phase of 2 into 2 which is 4 seconds plus all-red time is 12 seconds which makes it 16 seconds and this multiplied by 0.32/0.57 so 29 seconds and for approach B the green time is 22.5 seconds.

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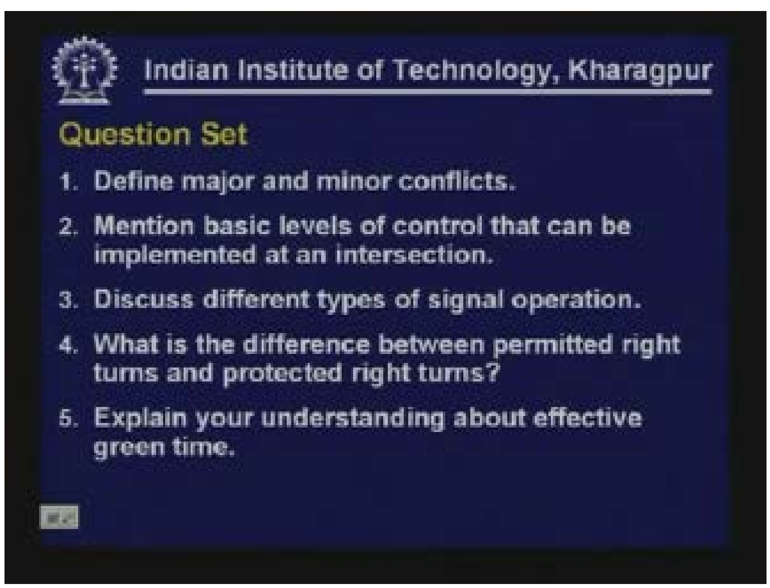

Question Set:
Define major and minor conflicts:
Mention the basic levels of control that may be implemented at an intersection:
Define different types of signal operation:
What is the difference between permitted right turn and protected right turns?
Explain your understanding about effective green time:

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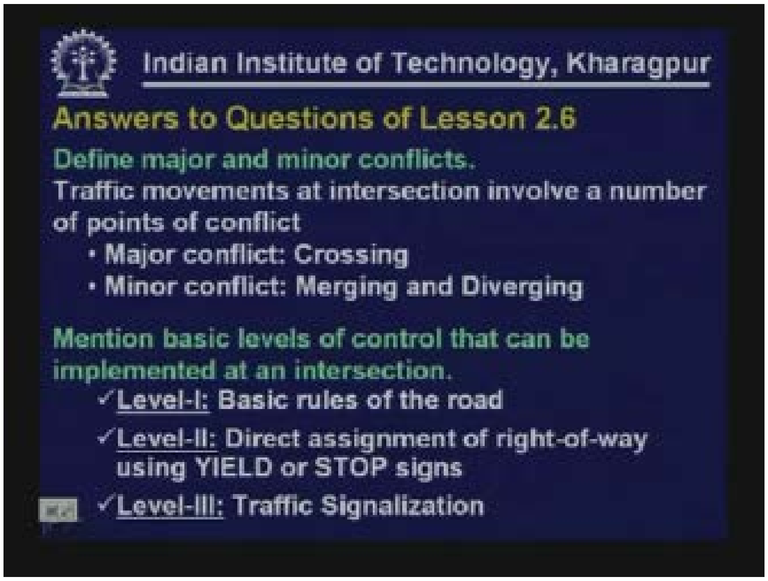

Answers to Questions:

Define capacity and level of service:
Describe different traffic factors affecting capacity: Primarily the percentage of commercial vehicle is very important and the directional distribution. These are the two major traffic factors that are affecting capacity.
How the free flow speed is estimated from the basic free flow speed for freeway and multilane highways?
How much is basic free flow speed and then that is reduced considering the relevant factors?
The correction factors for freeways are adjustment for lane width, adjustment for right shoulder lateral clearance, adjustment for number for lanes and adjustment for interchange density form.
For multilane highways the required adjustments are due to lane width, lateral clearance, for median type and also for access points.

What are the MOEs considered while estimating capacity of lane highways? There are two types of lane highways namely class I and class II. For class I efficient mobility is paramount so LOS is defined in terms of both percent time-spent-following and average travel speed. For class II highway the mobility is less critical therefore LOS is defined only in terms of percent time-spent-following without considering the average travel speed. Since this is the last lesson under this module I am also trying to answer quickly the questions I raised for this lesson. For major and minor conflicts crossing is the major conflict and merging and diverging are considered as the minor conflicts.

Mention the basic levels of control that may be implemented at an intersection.

There are three levels.