Introduction to Transportation Engineering
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Lecture - 3
Traffic Stream Characteristics

Traffic Stream Characteristics, this is module 2.2.

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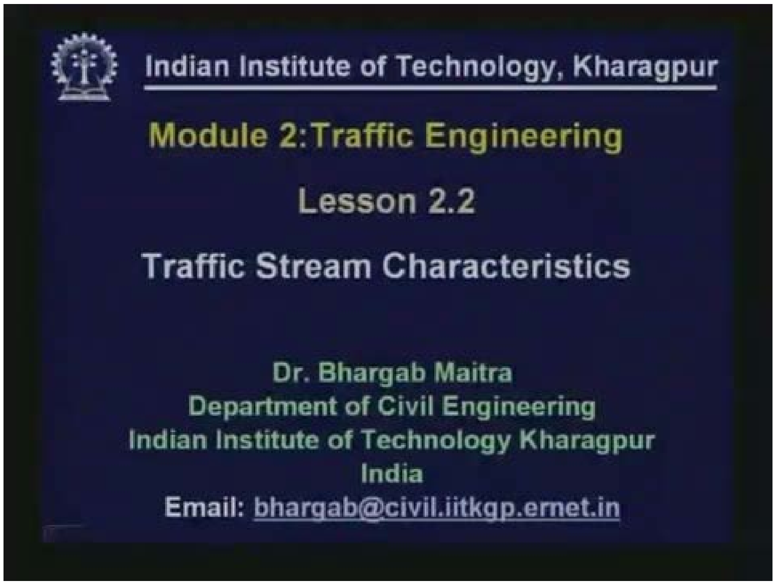

After completing this lesson the student will be able to distinguish between interrupted and uninterrupted flow facilities, understand the characteristics of uninterrupted as well as interrupted traffic flows, understand the concept of Passenger Car Equivalency and identify various factors which are affecting the PCE values Passenger Car Equivalency values.

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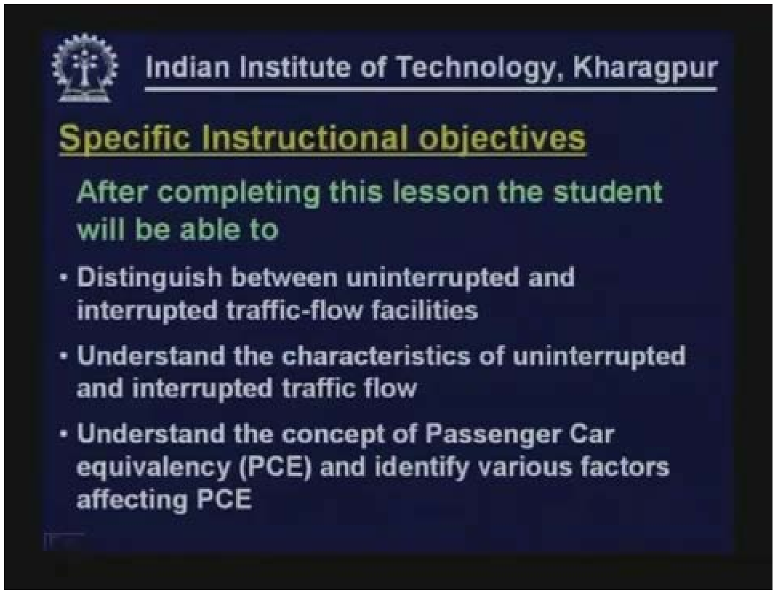

First of all let us see traffic streams, how we define traffic streams where individual drivers and vehicles interact in unique ways with each other and also with elements of roadway environment.

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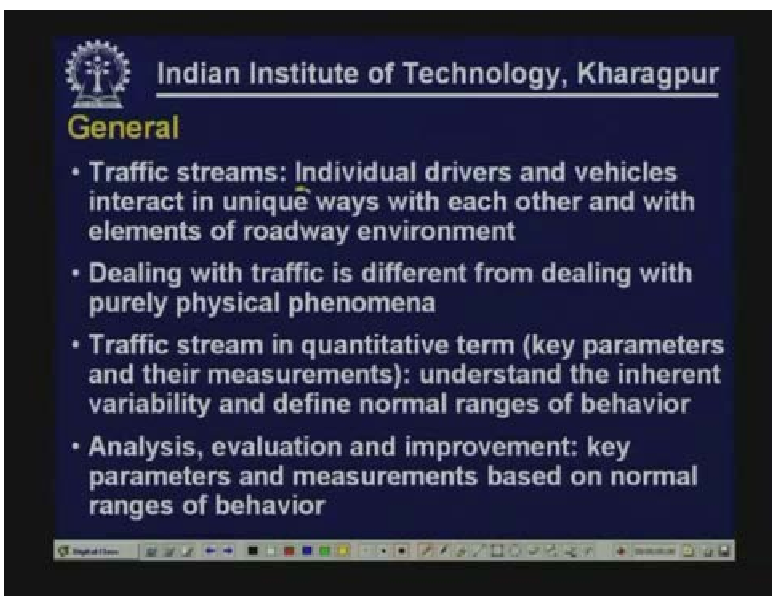

So, if we are talking about traffic streams we have individual drivers and vehicles, they are interacting or they interact in unique ways with each other and also with the elements of roadway environment. Remember that dealing with traffic is entirely different from dealing with any physical phenomenon. This is primarily due to the fact that you have human components involved in the overall process. there are drivers they behave in different manners not that each and every driver behave exactly in the same manner so human component is involved which makes traffic engineering different from any other or most of the other engineering disciplines or even it makes traffic engineering phenomena different from purely physical phenomenon.

We try to define traffic stream in quantitative terms. Quantitative terms means essentially key parameters and their measurements. Basically we try to do that to understand the inherent variability and define normal ranges of behavior. Carefully observe this statement, normal ranges of behavior. Just now I indicated that traffic is different from dealing with purely physical phenomenon because the drivers do not behave exactly in the same manner. but still when we try to define traffic stream in terms of quantitative measures the key parameters and their measures we essentially try to tell or try to see the change as appropriate in the normal ranges of behavior may be vehicles are moving at different speeds may be let us consider speed as a parameter so then it is not that all drivers will travel in the same speed it is not possible but you will find that most of the drivers follow speed in a certain range.

Now if you improve the facility, widen the roads, remove on street parking and do some other thing according to your level of improvement you will still find that not all drivers will behave in the same manner but the normal range of behavior that is may be the average speed stream speed which most drivers of the vehicles follow that range might have changed and you will find probably a higher operating speed.

For analysis, evaluation and also for justifying improvement we need key parameters and their measurements based on normal ranges of behavior. Again and again i would like to emphasize on this particular aspect as we are trying to talk about normal ranges of behavior and we do not expect each and every vehicle to follow the same behavior or use the same behavior but it is the normal range of behavior and due to policy due to other improvement measures what is the change in the normal range in behavior. If there is a change in the normal range in behavior we can relate it to the proposed policy or the activities.

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Now with this background let us try to understand traffic facilities. Two types of traffic facilities are normally there. They are uninterrupted traffic flow facilities and interrupted traffic flow facilities. You should carefully try to understand what is meant by uninterrupted flow facilities. Commonly by the term uninterrupted means we feel that every vehicle should move probably at a very high speed and even if there is a speed reduction due to change in traffic volume or increase in traffic volume we probably tend to interpret it as interrupted because traffic status is interrupted but actually the meaning is not so. So you must be careful and understand how we define uninterrupted flow facilities and interrupted flow facilities. You must carefully understand the thing and the difference.

In uninterrupted flow facilities there is no external factors, remember that. We are talking about external factors and that’s the basis for defining uninterrupted or interrupted flow facilities. In uninterrupted traffic flow facilities there is no factor to cause periodic interruption to the traffic stream. Now what could be the external factors?

External factors could be traffic signals could be stop or yield signs, could be uncontrolled access anywhere and everywhere vehicles are entering into the road and leaving the road so that is creating disturbance. Hence in uninterrupted flow facilities there is no external factor to cause periodic interruptions to the traffic stream. Still the internal factors remain. That means there may not be any traffic signal, may not be any uncontrolled access but still as you increase traffic volume based on the interactions among the vehicles within a traffic stream there could be speed reduction. But still the facility will be considered as uninterrupted flow facility because there are no external factors like signals or uncontrolled access causing traffic stream damage or reduction in speed. But it is due to the internal thing.

Therefore even if the speed is reduced it does not matter whatever the operating speed is. If the traffic volume is less the speed may be more or if the volume is more the speed may be less but as long as there is no external factor to cause periodic interruption to the traffic stream the facility will be considered as uninterrupted facility. Now such facilities include freeways and other limited access roads where obviously we have perfect access control and no intersections and no stopping of vehicles due to external results. Sometimes long section of rural highways also may operate as uninterrupted facilities. There might be signals but those signals are spaced at very wide intervals or rather large intervals. So in between two signals practically of substantial length there is no entry or exit of vehicles so you can probably try the facilities operating almost like an uninterrupted facility.

String characteristics in case of uninterrupted flow facility depend on individual vehicles also depend on the geometric and general environment of the roadway but not on external factors again to make it clear.

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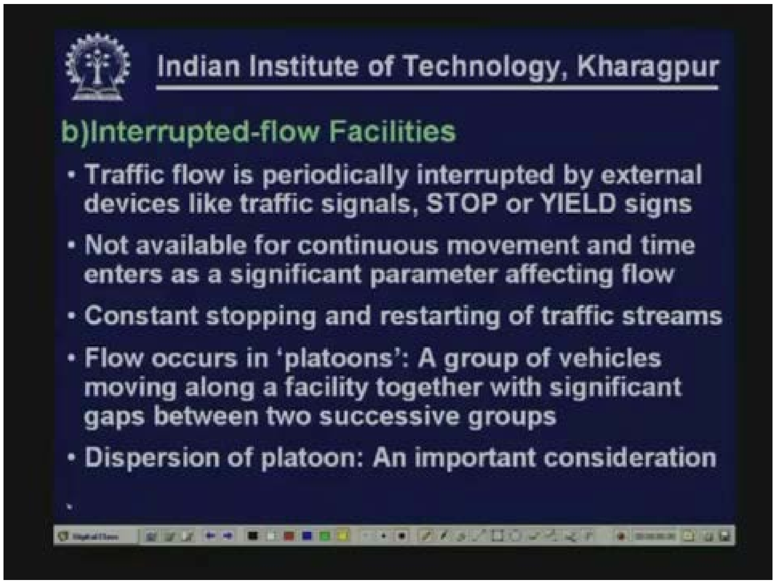

Interrupted flow facilities:
This is the other one just the opposite one where traffic flow is periodically interrupted by external devices like traffic signal, stop or yield signs, uncontrolled access and so on. In this case or for uninterrupted flow facilities the facilities are not available for continuous movement because there is periodic interruption, vehicles do stop and start, vehicles periodically do stop and again they start. Therefore facility is not available for continuous movement and remember that time enters as a significant parameter affecting traffic flow. Thus time is a significant parameter that is entering in the overall process.

We have do deal with traffic where constant stopping and restarting of traffic stream is very common because of this periodic interruption vehicle do stop and start again so it is constant stopping and restarting. Then flow occurs in a platoon where platoon generally means that a bunch of vehicles are moving together. just consider any signalized intersection the moment the signal is green during the green period that you will find one bunch of vehicles pass the intersection then again you have red so no vehicle is passing again the signal becomes green so again a bunch of vehicle passes and this is what we call as the vehicles are moving in platoons.

If you want to define it properly you can define it like this. It is a group of vehicles moving along a facility together with significant gaps between two successive groups. Significant gaps means once you have green may be a bunch of vehicle goes then again red so there is no vehicle again green comes then it is again a bunch of vehicles so it is a group of vehicles moving along a facility together and there are significant gaps between two successive groups that's what is defined as platoon. The dispersion of platoon is an important consideration.

Let us consider a bunch of vehicles leaving the intersection and if you start observing the vehicles leaving the intersection from a distance then you will find that as the vehicle moves away from intersection the platoons disperse. That means may be the length or the distance between the first vehicle and the last vehicle in the platoon will increase what we say a phenomena called platoon dispersion and that's why say if there are signals which are closely spaced you may observe that still the facility may operate as interrupted facilities. But if there is signals on highways where we have generally access control and signals are placed at wide intervals there away from signal if you operate the traffic you will not observe it to be like platoons so you may find they are just moving and it is not representing a platoon behavior and almost it may operate at that point like uninterrupted flow facility. That's why I indicated earlier also signal spacing is also an important consideration.

With this background let us now try to see the traffic stream parameters. There are three macroscopic measures. You understand the word macro and micro. Why we say macroscopic measures is because it is described by a single value of each which applies to the traffic stream as a whole.

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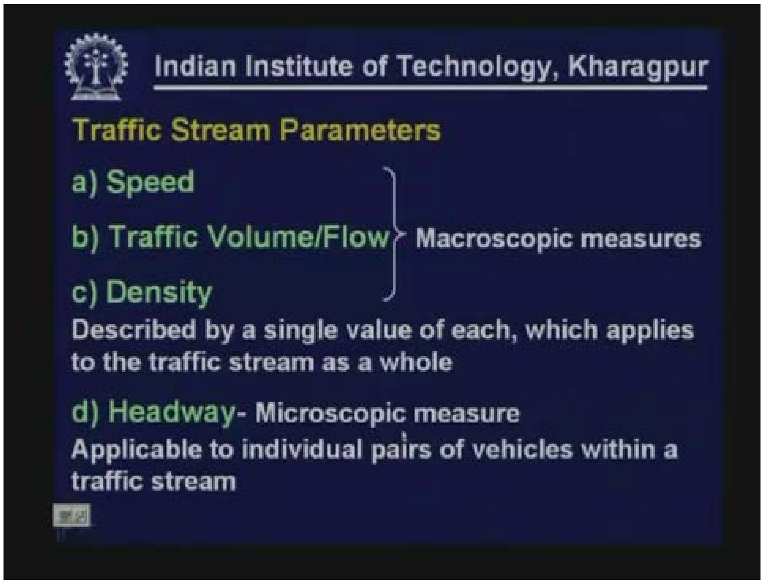

So for the whole traffic stream there is a single value namely major macroscopic measures are speed, traffic volume or flow and density. So, for the whole traffic stream we try to define a single value of speed, a single value of flow and a single value of density and that's why we call them as macroscopic measures that means described by a single value of each which applies to the whole traffic stream.

There is also another parameter which is often used because there are two types of headways and we call headway as microscopic measure because headway is applicable to individual pairs of vehicle within a traffic stream and not a single value for the whole traffic stream rather it is between two vehicles. We define headway which is valid generally between two vehicles so they are called microscopic measures but speed, flow and density are macroscopic measures defining traffic signal analysis.

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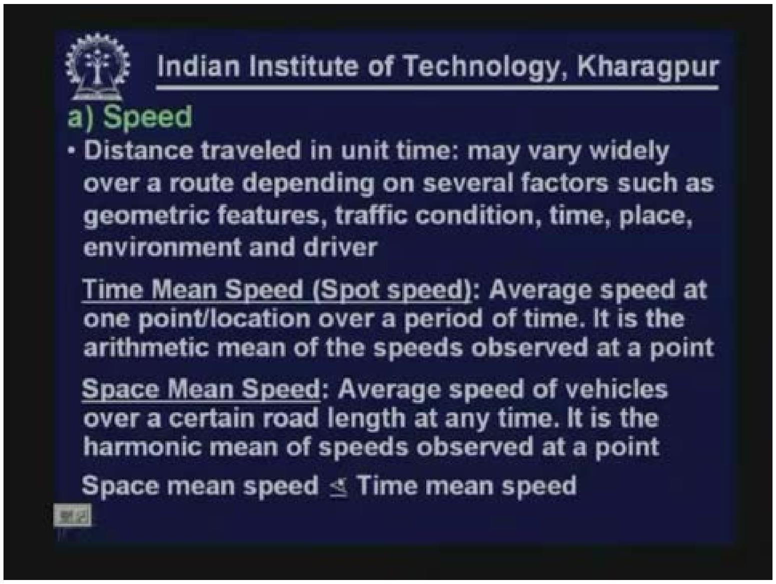

Now let us see how we define speed. Speed is normally the distance traveled in unit time so what is the distance that is traveled during the unit time that's what we define in speed. it may vary widely over the route and not that at every segment of the road drivers will enjoy the same speed it is not possible probably or it may vary at least often because of the change in roadway environment, sometimes the width is changing, sometimes [not audible 16.35] land use is changing, sometimes you find pedestrians are there, sometimes you find a parking so there is a combination of all these so the speed may very along the length of the road so it may not be exactly the same for the complete route stretch.

It varies depending on the time also. Sometimes you may find that a route section is taking ten minutes but at peak hour the same road section may take twenty minutes or thirty minutes so all these factors are present. Now two types of speed measurement we normally use in traffic engineering. One is the Time Mean Speed and the other is the Space Mean Speed these are very important. The Time Mean Speed is often called as spot speed so we call this as TMS Time Mean Speed or spot speed and another is the Space Mean Speed commonly referred to as SMS Space Mean Speed.

The Time Mean Speed is the average speed at one point or location over a period of time. It carefully observes the time mean that means we are averaging it at a place over a time so it is measured at a point or at a fixed location and it is measured over a period of time and we take the average of that. So it is average speed at one point or location over a period of time. We will see that it is arithmetic mean of the speed observed at a point.

Space Mean Speed is the average speed of vehicles over a certain length of road at any time. it is averaged over the distance that's why it is called Space Mean Speed. If you take a distance what is the average speed that can describe the travel over this distance. So it is averaged over distance that's why you call it as Space Mean Speed. We can show that Space Mean Speed is the

harmonic mean of speed observed at a point. We shall show it with an example also. Remember that Space Mean Speed is always less than equal to Time Mean Speed. Let us take an example.
Let us consider that there are three cars moving at a speed of 20 Km per hour 40 Km per hour and 60 Km per hour and traversing a length of D. So at any point let us consider they are traveling at uniform speed twenty kilometer means first vehicle is traveling at 20 Km per hour uniform speed over the length D.

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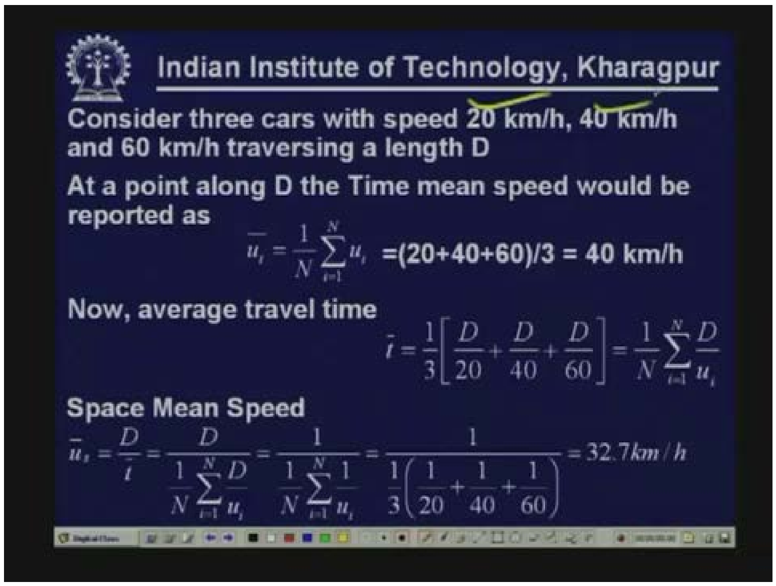

The second vehicle is traveling at 40 Km per hour uniform speed over the length D and so on. Therefore at a point D what is the Time Mean Speed? We have observed three vehicles one is traveling at 20 Km per hour, another is traveling at 40 Km per hour and another is 60 Km per hour so the Time Mean Speed uT is nothing but 20 + 40 + 60 by 3 so it is 40 Km per hour. So it is nothing but if Ui is the speed of vehicle i then it is sum over Ui where i = 1 to N divided by the number of vehicles N. That way we can write so this expression holds good. It is the arithmetic mean of speed observed at a point as we have shown here.

Now each vehicle is traveling a distance D so what is the average travel time? First vehicle takes time D by 20, the second vehicle takes time D by 40 and the third vehicle takes D by 60. So, what is the average travel time? It is 1 by 3 because we have three numbers of vehicles so it is essentially 1 by N sum over D by Ui where Ui is the same speed 20, 40 and 60. So it is 1 by N sum over D by Ui and i vary from 1 to N. So what is the Space Mean Speed? Space Mean Speed distance is D and it is covered at t bar time so D by T bar is nothing but D by 1 by N sum over D by Ui. Therefore essentially you get it like this 1 by 1 by N sum over 1 by Ui where Ui = 1 to N and where N is the number of vehicles and in this case you calculate it at 32.7 km. So now what we indicated is we told that Space Mean Speed is the harmonic mean of speed observed at a point that's what we have shown here, it is the harmonic mean of speed observed at a point. We have observed speed at a point is Ui so it is the harmonic mean 1 by 1 by N sum over 1 by Ui where i varies from 1 to N.

Here also you can see that Time Mean Speed is 40 Km per hour, Space Mean Speed is 30.7 Km per hour so you can find Space Mean Speed is lesser than Time Mean Speed it is always so, at best it may be equal. I leave it to you think where these two speeds could be equal when TMS will be equal to SMS, just think this part. Relationships do exist between the Time Mean Speed and the Space Mean Speed. Sometimes you might have measurements of the Time Mean Speed for different vehicles and sometimes you may have the observed Space Mean Speed also. So if we one that means if we know the individual Time Mean Speed the mean and the variance then we can calculate the Space Mean Speed and if we know the Space Mean Speed again the mean and the variance we can calculate the dynamic speed.

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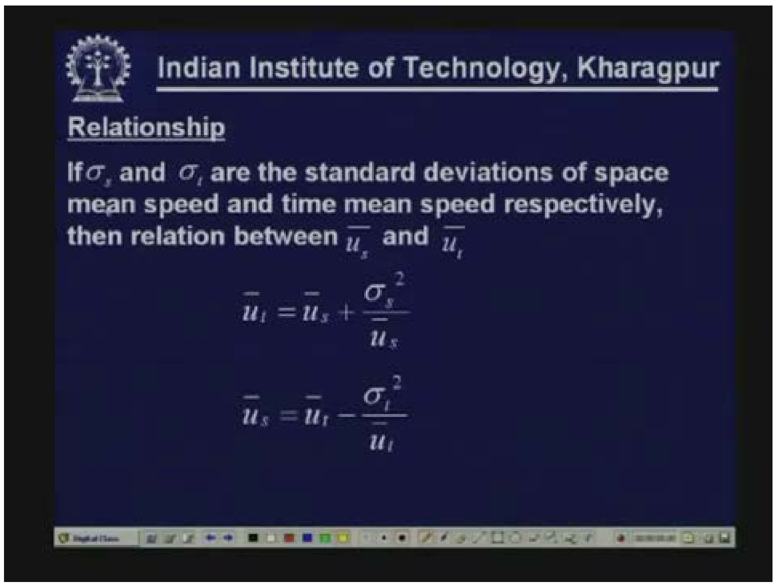

The following two relationships may be used. Let us consider the variance of mean with respect to the Space Mean Speed with respect to the Time Mean Speed then you can use both these relationships. If you know the mean and the variance of the Space Mean Speed you can calculate the Time Mean Speed if you know the mean and the variance, this is the variance of the Time Mean Speed then you can calculate the Space Mean Speed. So these two equations one can remember and get Time Mean Speed when the Space Mean Speed and its variance is known and other way round. That is if you know the Time Mean Speed and its variance you can calculate the Space Mean Speed. We also refer the other types of speed sometimes. One we call as running speed and the other one we call as the journey speed.

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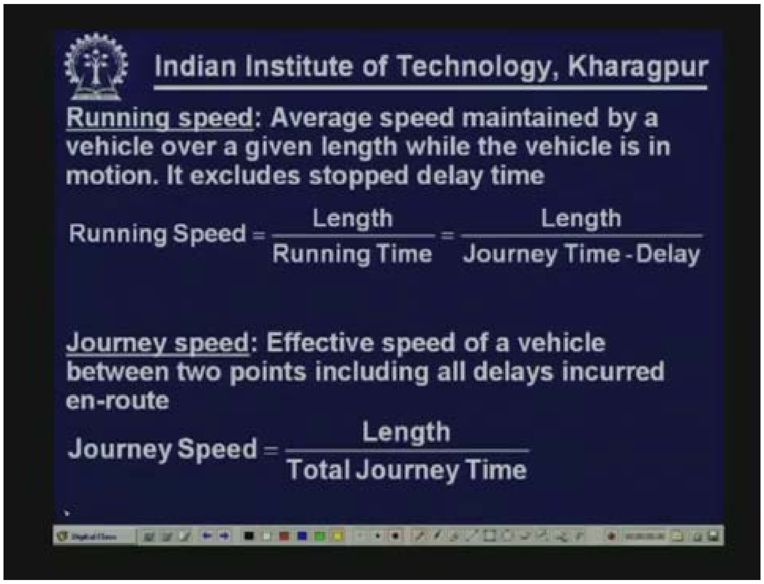

The running speed is the average speed maintained by a vehicle over a given length while the vehicle is in motion. This is interesting carefully observe that. While the vehicle is in motion that means you exclude stop delay. So, when the vehicle is traveling from A to B if you have the total time and then if you know what is the stop delay then the total time minus stop delay is the running time. Hence the length divided by the running time gives you the running speed. So running speed is length divided by running time and running time is the journey time minus delay. Journey time is the total time taken to travel across these two points defining this particular length, journey time minus delay.

Journey speed on the other hand does not leave this delay component. It is the effective speed of a vehicle between the two points and it includes all delays incurred in route. So it is the length divided by total journey time and not the running time. In this case it is the running time so it is running speed, it is the journey time including all the delays so it is the journey speed, that's all. Often we use Time Mean Speed, we use Space Mean Speed and sometimes we also use running speed refereed to running speed and also the journey speed.

Now traffic volume we normally measure in terms of number of vehicles passing a particular point of roadway during unit time and traffic volume is normally expressed in terms of vehicles per hour or vehicles per day. We express traffic volume in terms of daily volumes which is normally used in highway planning.

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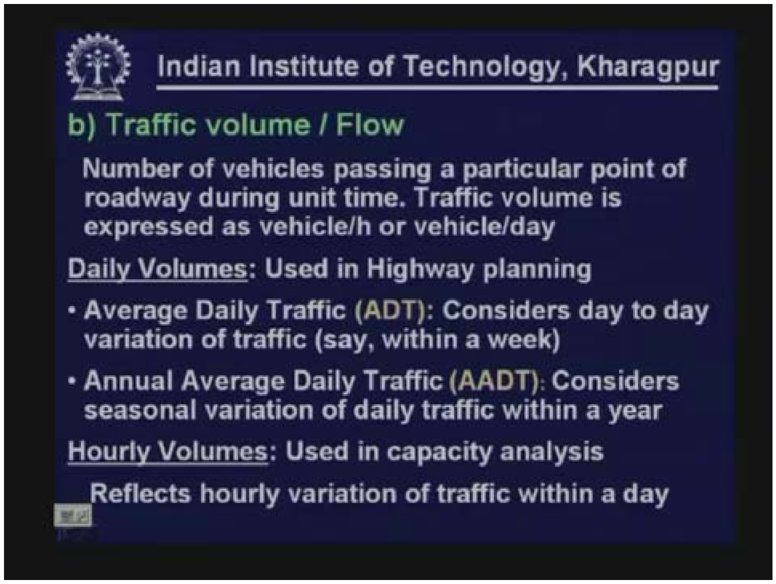

Normally two types of measurements we use for representing the daily volume. One is called the ADT commonly known as ADT that is the Average Daily Traffic which considers generally the day to day variation of traffic within a week. So we take the traffic measurement for seven days and take the average of that. So we do consider the variation of traffic within a week. Then there is another measurement of daily volume that is known as annual average daily traffic or AADT annual average daily traffic. So, if we measure the traffic volume over the year all the three sixty five days may be you have permanent count station you can get traffic volume throughout the year. So if you take the yearly traffic three sixty five days divided by three sixty five days then also you get daily traffic. That is, annual average daily traffic AADT when we take the measurement for three sixty five days. And this traffic volume even takes into consideration the seasonal variation of traffic. sometimes we find traffic more in winter less may be in the rainy season, moderate may be during the summer so all sorts of seasonal variations are also reflected in terms of AADT or AADT measurement but ADT do not reflect the change of traffic from one season to another.

We also expressed traffic volume in terms of hourly volume and this is normally used for capacity analysis. This normally reflects hourly traffic variation within a day. So you may find that may be within a day during the peak hours from nine to ten in the morning may be again five to six o clock in the evening you have heavy traffic. So we can use that type of measurement for capacity analysis.

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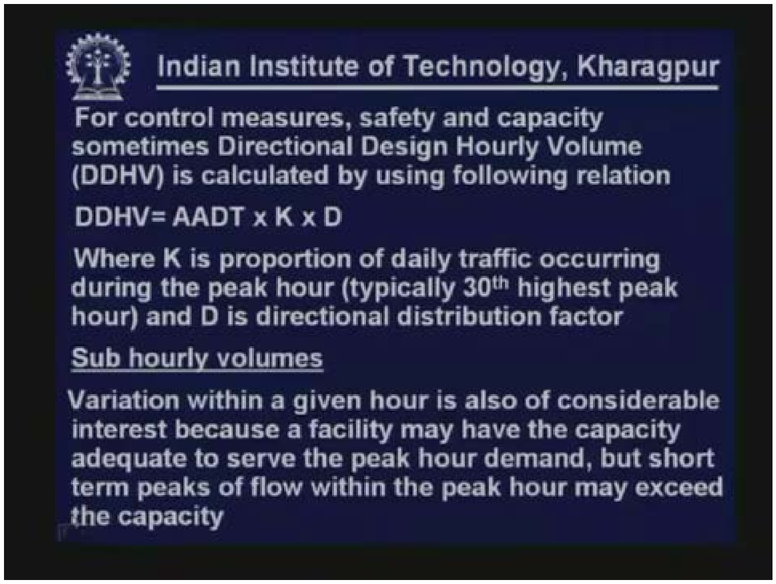

Sometimes we express traffic volume in terms of directional design hourly volume, design hourly volume is fine then the added thing is the directional part. Because in both directions if traffic is not balanced then sometimes we use it for control measures, for safety analysis and also for capacity analysis we sometimes use it so DDHV Directional Design Hourly volume is expressed by AADT multiplied by K multiplied by D where K is the proportion of daily traffic occurring during the peak hour. So AADT is the daily traffic how much percentage of that is occurring during a peak hour that is expressed as K factor. It is normally or typically the thirtieth highest volume. We shall make elaborate discussion about this K factor or thirtieth hourly volume later in some other lesson and D is the directional distribution factor.

Sometimes we even see the sub hourly volumes because variation within a given hour may be important. Because you may find the facility may have the capacity which is adequate to serve the peak hour demand but short term peaks of flow within the peak hour may exceed the capacity. Therefore we may need to look at the sub hourly volume also. There in that context we use this peak hour factor. Peak hour factor is nothing but hourly volume you take measurements for an hour and then maximum flow rate is normally based on fifteen minute traffic count. So peak hour flow is hourly volume that you have really observed over one hour and then take fifteen minute traffic volume multiplied by four that means maximum flow rate based on fifteen minute traffic flow. Therefore you can get the peak hour factor. Often in signal design you will see that we use this peak hour factor.

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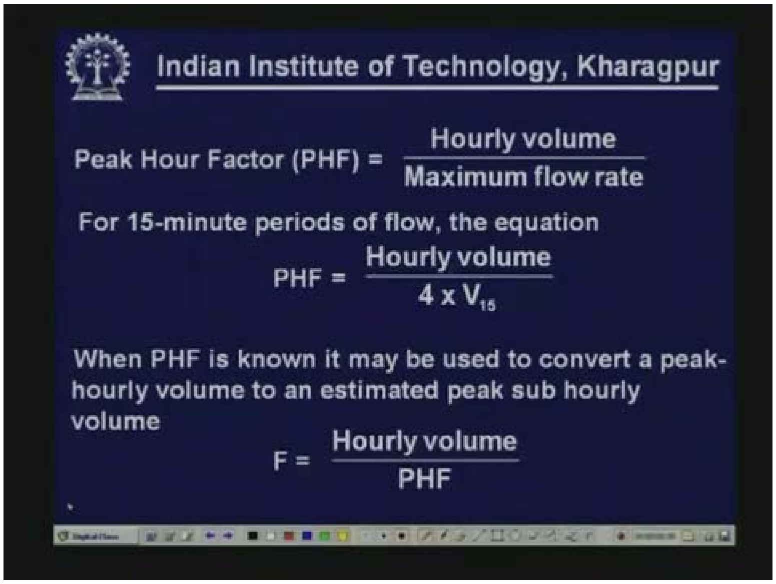

When peak hour factor is known sometimes may be you have already studied some of the intersections and you know the peak hour factor so then that may be used to convert a peak hour volume to estimated peak sub hourly volume, it is just reversed. So in that case peak hour factor is known, hourly volume is known so you calculate maximum flow rate it is nothing but hourly volume divided by the peak hour factor. So that way one can calculate the peak hourly factor. All these are necessary because this kind of short variation or variation of traffic flow may happen within an hour also so that because important particularly when you go for the signal design so there it is really meaningful.

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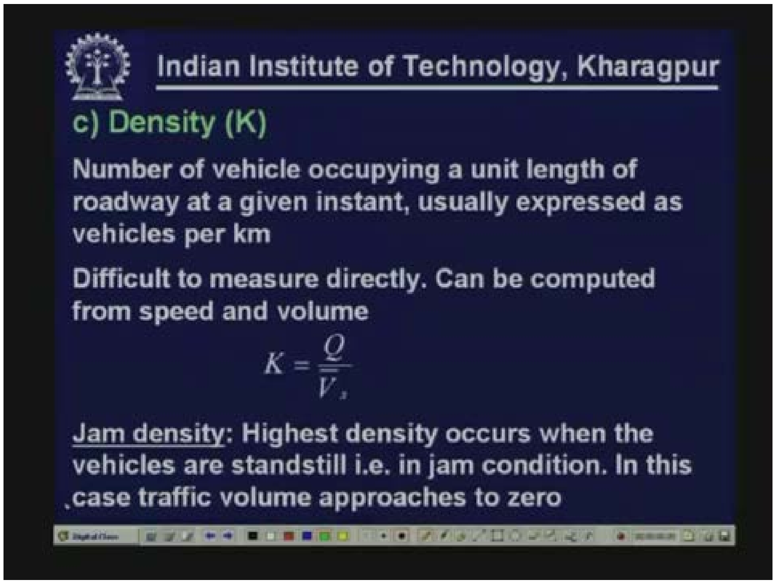

Now let us look at density which is the third microscopic measurement. It is basically the number of vehicles occupying a unit length of the roadway at a given instant. It is usually expressed as to how many vehicles per kilometer, over a length take a length of 1 Km so calculate how many vehicles are there so it is N vehicles per kilometer and that's what the density is. It is difficult to measure directly often we calculate it indirectly using this relationship density equal to flow by specimen speed. So if we know the traffic stream flow and traffic stream specimen speed we look at the derivation.

The density we often refer to as jam density. Jam density is the highest density occurred. Obviously when it will occur is in the worst affected hours, in the peak hour when the congestion is severe. You have vehicles bumper to bumper so that's the maximum density that can occur so we can call it as jam density. So jam density is the highest density when vehicles are standstill that is the jam condition and in this case the traffic volume approaches to zero. Why traffic volume approaches to zero? It is because you will find that vehicles are almost standstill that's the level of density obviously because they are so much packed and the speed or the flow has virtually come down to zero. So during the jam hour also you try to measure how many vehicles are crossing at a particular location you will get almost nil or very little number.

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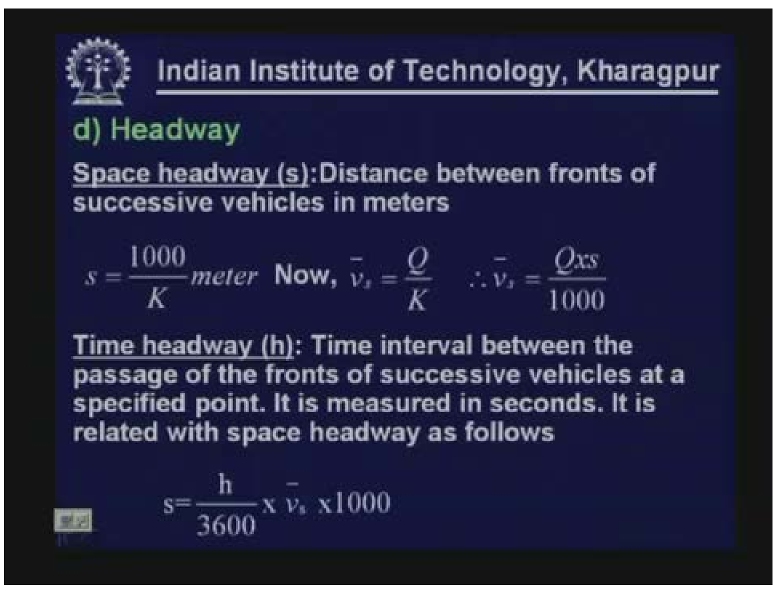

Now the other microscopic measure is the headway. Here we do two types of headway measurement sometimes we call it time headway and space headway and sometimes space headway is often referred to as spacing. Time headway means the time gap between the passing of two vehicles and space headway is the spacing means. Space headway is the distance between the fronts of successive vehicles. So space headway we are referring to as distance between fronts of successive vehicles. So if you have densities K so you have K vehicles per kilometer so what the average spacing will be is thousand meter by K. This is in meter and that is the spacing.
Now you have this relationship Q = K into Vs that means flow equal to speed into density. So speed you can again express in terms of flow and you can replace this k by 1000 by s so you can get this relationship. Similarly the time headway, the time headway is the time interval between

the passage of the fronts of the successive vehicles at a specified point and it is measured in second. So time headway is measured in meter and space headway is measured in second. It is reflected with space headway. It may be related to the space headway as follows using this simple flow equal to speed that is Space Mean Speed into density. So using that basic relationship you can relate the time headway and space headway with this relationship. Therefore it is space headway equal to time headway by 3600 into Space Mean Speed into 1000 that's what is the basic relationship. It is simple; you can derive this relationship using the basic fundamental relation that is flow equal to speed into density.

Coming to the characteristics of uninterrupted flow we have already told that for uninterrupted flow it is flow equal to speed into density. So we can try to show you that derivation. Let us consider a 1 Km road on which all vehicles are traveling at the same speed. This is just for assumption to show you simple formulation. The parameters K, Q and V are concentration in vehicle per kilometer. Q represents flow in vehicle per hour and V represents the Space Mean Speed in kilometer per hour. So you have practically 1 Km length of the road that's what we have tried to show, the density is K so we have K number of vehicles, this is the first vehicle, the second vehicle, third vehicle and so on and this is the Kth vehicle because density is K.

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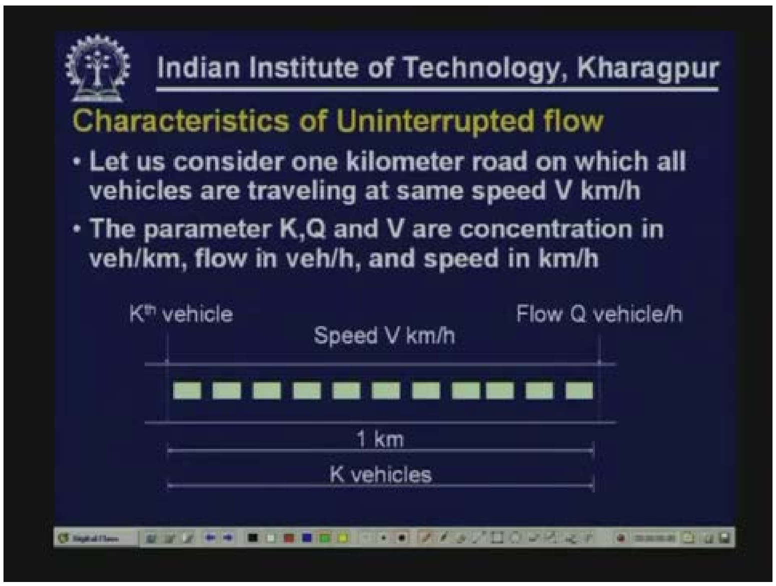

If you measure the flow here you can find the per hour Q number of vehicles going each with a speed of V kilometer per hour. Now by definition there are K vehicles each with speed V kilometer per hour in one kilometer of road at any instant that's what will define speed, flow and density. If flow is recorded at the end of one kilometer you will observe probably Q vehicles per hour. Let us consider a vehicle at the start of 1 Km, how much time it will take? Speed is V kilometer per hour so to cover 1 Km how much time a vehicle will take? Obviously it is 1 by V hour. Again you have K vehicle, because the density is K you have K vehicles spaced over a length of one kilometer so how much the kth vehicle will take. First vehicle will take 1 by Q hour, second vehicle will take 2 by Q hour to reach to that point so how much time kth vehicle will take? It will take K by Q hour and how much distance it is covering? You have K vehicles in

1 Km so essentially in K by Q hour also it is covering 1 Km. Therefore one way we find that a vehicle will take 1 by V hour to reach the end and Kth vehicle will also take K by Q hour to reach to the end. Therefore 1 by V equal to K by Q and here you find Q equal to flow equal to Space Mean Speed multiplied by the density so that way one can show this relationship.

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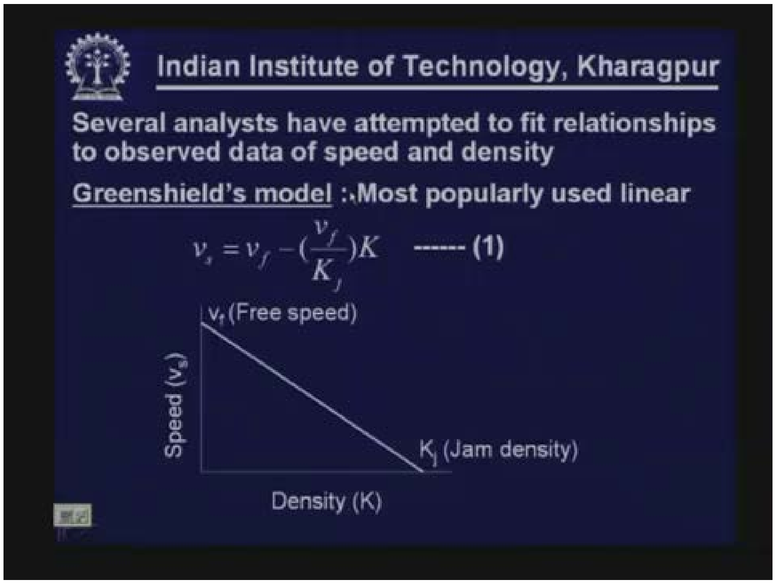

Now several analysts have attempted to fit to relationship to observe data of speed and density. it is not only for speed and density they have tried to observe the relationship between speed and density, speed and flow and then flow and density. So we are trying to show some of the speed density relationship. The most popular one is the linear relationship between the speed and density and this is given by Greenshield. So this is popularly known as Greenshield's model.

Here I have shown the linearity relationship with a graph and in this way the density is increasing and the speed is increasing this way so where your density is zero there are very few vehicles the speed is maximum that is the free speed or the free flow speed and as density increases the speed will come down because more vehicles are there so there will be interaction among vehicles, there will be loss in freedom of movement and the speed will come down. Finally you will find when there is jam density when the traffic is totally jam packed then the speed is zero and this is following a linear relationship given by this equation 1. So Kj is constant it is the jam density for a given road section which is constant, Vf is the free flow speed it is also constant so Vs = Vf – Vf by Kj into K all are constant multiplied by K so this is essentially a linear relationship.

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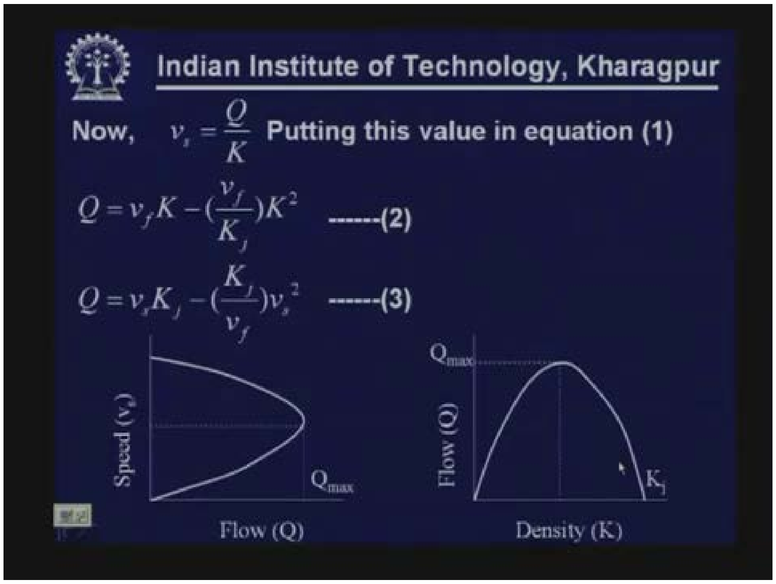

Now what will be the speed flow relationship and flow density relationship based on the above mentioned speed density relationship?

Again use the basic relationship flow equal to speed into density so using that we can show that Q = Vf into K. Now what is K? K is here you can find Vs by Vf – Vf by Kj. So if you show this relationship you can get equation 2 to represent the relation between flow and the density K. That is the corresponding flow density relationship. Similarly you can show what is the relationship between the flow and the speed represented by Vs. So once you know any one of this relationship in this case we have started with the relationship between speed and density, once you know the relationship between speed and density and we know this basic equation flow equal to speed into density then we can calculate it or we can derive the relationship between flow and density and also flow and speed and those are plotted here.

You can consider here any speed flow car you have two domains the upper part represents the almost stable operation where speed is maximum here as we are increasing the traffic volume, flow is increasing so the speed is coming down and you have a lower part which is often shown as the dotted line because this is the unstable operation. We will have more discussions about this relationship later. But obviously if you try to plot equation 2 you will get like this Q and K relationship and if you plot this equation 3 Q and Vs then you will get this kind of a relationship. So here also you have two domains.

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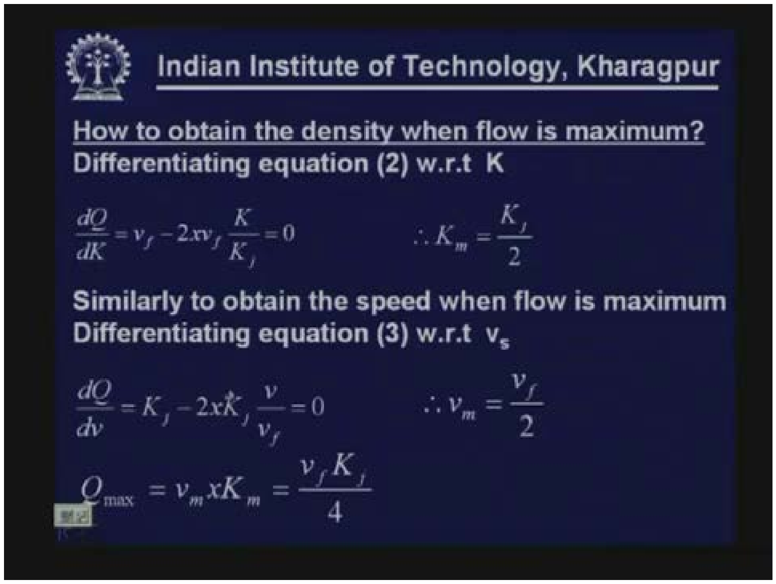

Now how to obtain the density when the flow is at maximum?

It is very simple you can get it easily. From the above relationship you can find the flow and density. When the flow is maximum it means that dQ dK = 0 so take the derivative dQ dK = 0 and if you put that you will find density at capacity if you define it as Km density as capacity is nothing but Kj by 2. Similarly what is the speed at capacity at the maximum flow? Again you take the derivative dQ with respect to V. So dQ dV earlier case what is the density and capacity flow you get dQ dK = 0. In this case again you take the derivative dQ dV = 0 and you find Vm the speed at capacity or maximum flow is Vf by 2, it is a simple derivation and that way you can find Q equal to again speed into density so it is maximum flow equal to speed at maximum flow multiplied by density at maximum flow so you find it is essentially Vf into Kj by 4. So if the linear relationship holds good then we can show that the maximum flow can be expressed as Vf into Kj by 4 where Vf is the free flow speed and Kj is the jam density.

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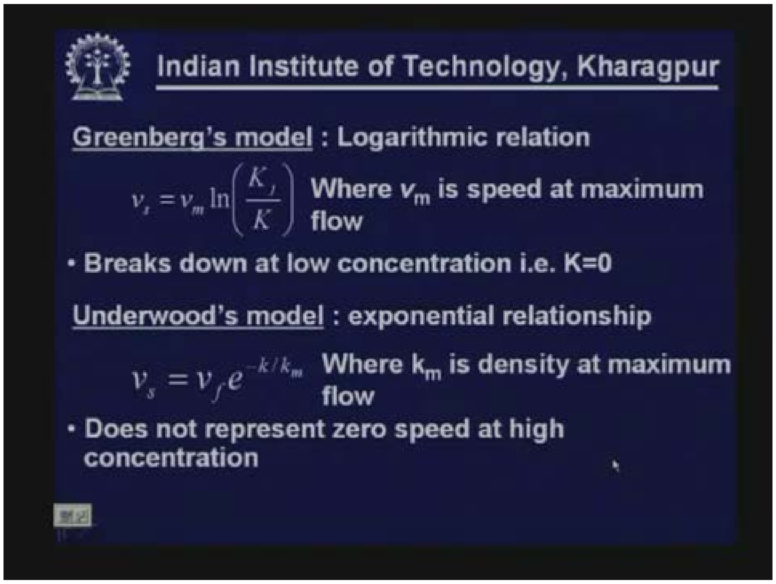

Now there are other relationships like Greenberg's logarithm relationships and Underwood's model. There have been number of relationships that have been developed by researchers over a period of time. Some of the relationships I have shown here, this is the Greenberg's model, this is logarithmic model. You can clearly see from this equation that this equation breaks down at low concentration when k = 0. If you put k = 0 the relationship breaks down. Similarly this Underwood's exponential relationship does not represent 0 speed at high concentration whatever may be the value of k it does not represent exactly 0 speed as it was represented by Greenshield's linear model. There are so many other models you can refer to any textbooks also if you are interested to know about other types of model.

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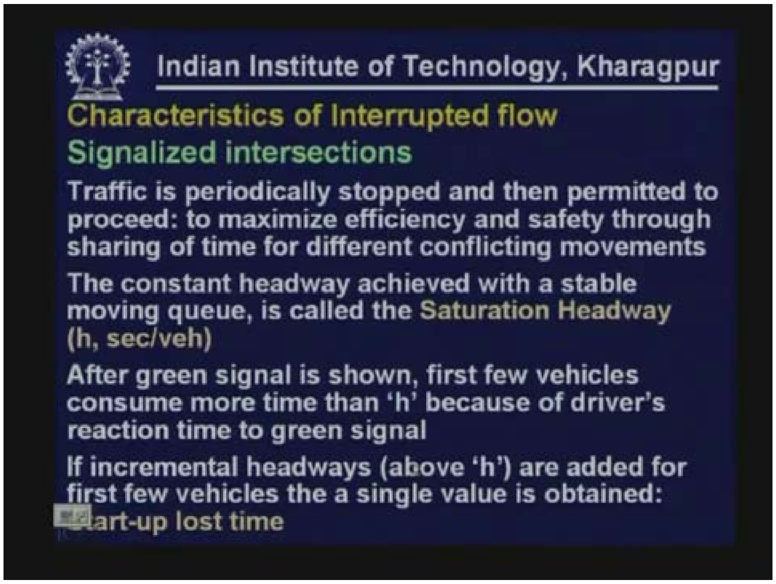

Now coming to the characteristics of interrupted flow here vehicles move in platoon and traffic signal is a major cause. Let us consider signalized intersection. Traffic is periodically stopped and then permitted to proceed. It is done basically to maximize the efficiency and safety through sharing for different conflicting movements. The same space it is shared for different conflicting movement. So you separate the conflicting movements by time. We allow some conflicting movements to take place at certain time then we stop those movements put red to those approaches and then we allow other movements to occur. So that way we try to maximize efficiency and safety at the same time. And you already know what headway is, it is the time gap between the passage of two vehicles. So here once you consider a signalized intersection the constant headway achieved with a stable moving queue carefully observe stable moving queue is known as saturation headway. Earlier we told what headway is but now we define saturation headway.

What is saturation headway?

Saturation headway is the constant headway achieved with a stable moving queue. initially the moment signal becomes green, initially a few vehicles may take much longer time and then after some time you will find that the queue will stabilize so it will move almost at uniform rate and there with stable moving queue the constant headway you get is known as saturation headway. Now obviously after green signal is shown first few vehicles consume more than h where h is the saturation headway they consume more than h because of drivers reaction time to green signal. so if incremental headways are added that means above h for the first few vehicles then what is the extra time over each, if we add all of them then that is known as start-up lost time so carefully observe this terminology. So if incremental headway above h are added for first few vehicles then a single value you can get what is known as start-up lost time. That’s what is shown here.

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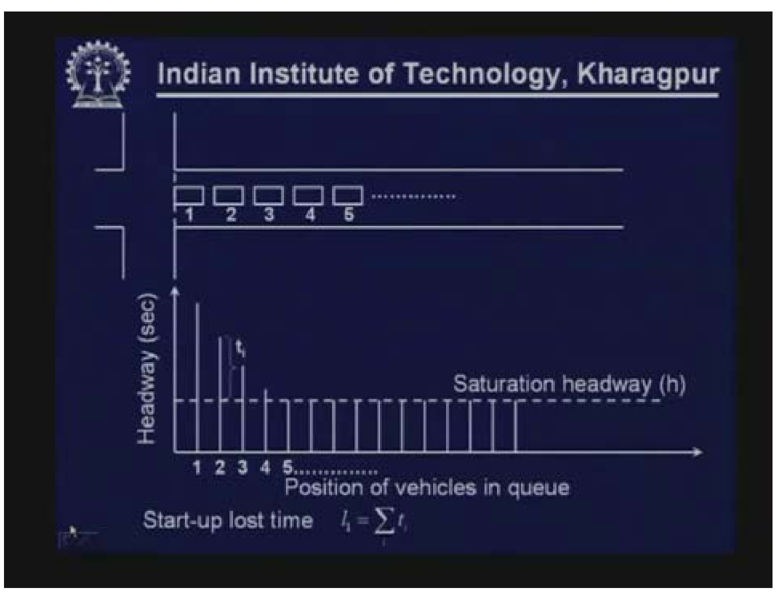

This is the signal vehicles are stopped here so once you give green signal vehicles start moving so you find that initially for the first few vehicles the headways are more as indicated here but gradually it is coming down and beyond certain vehicles as the stable queue movement has occurred you will find that everybody is taking h amount of time, the passage of two vehicles. So this h is the saturation headway.

Now if you take the first few vehicles this vehicle let us consider if this is the ith vehicle how much extra time it has taken it has taken this much extra time if we denote it as Ti then start-up lost time is sum over Ti i = 1 to n and even if you make it n this gives you the same value because for all these vehicles practically this T = 0. So if you take the first few vehicles you take the total start-up lost time that's what is shown here. Now there is also a clearance lost time or end lost time that is defined as time between the last vehicle from one approach it just becomes red so it is the last vehicle between one approach entering into intersection and the initiation of green signal for the conflicting movement.

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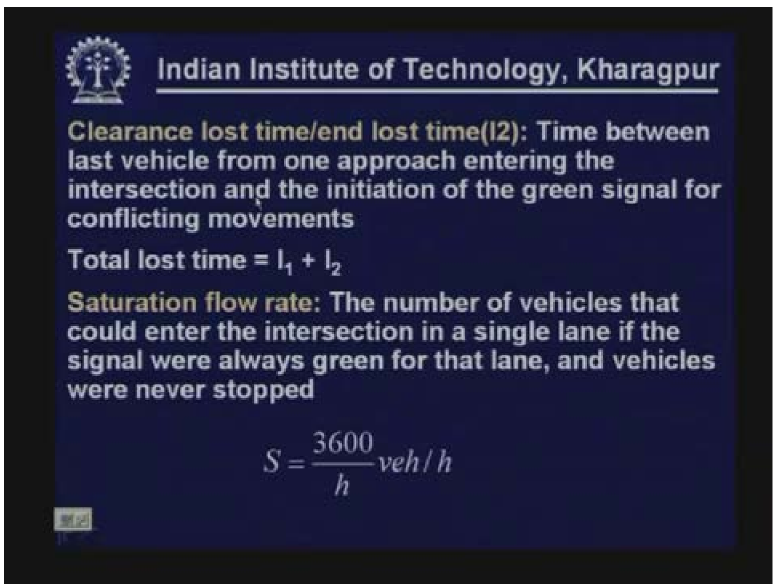

One approach you are just making red so the last vehicle goes, another approach you are making green but you want to keep certain minimum gap so that the last vehicle can cross the intersection area safely before another vehicle from another approach comes to that intersection getting the green signal. So that total lost time is basically known as clearance lost time or end lost time and denoted as l2. So this total loss time is l1 plus l2 in the initial period and towards the end.

Then saturation flow rate you can calculate it if you know the saturation headway then passage of two vehicles each so it is basically 3600 by h. So if you know the saturation headway you can easily find what is the flow corresponding to saturation headway. So the number of vehicles that could enter the intersection single line if the signal were always green for that then that means a stable condition exist and the vehicles never stop, that's what gives you saturation flow, again this is important if you go for the design of signal.

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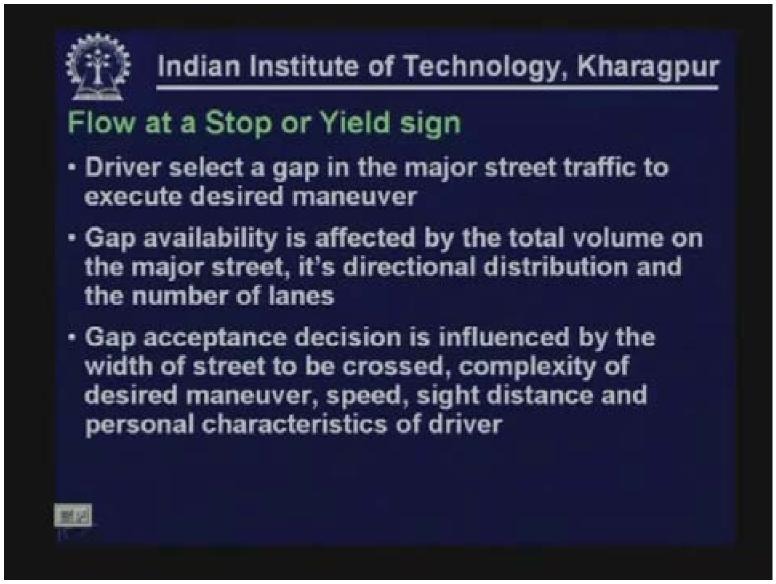

Flow at a stop or yield sign: That also may be part of this interrupted flow facility so driver selects a gap in the major street traffic to execute the desired maneuver and gap availability is accepted by the total volume in the major streets its directional distribution and the number of levels. Sometimes for interrupted flow facilities measures such as speed or density are not sufficient to fully describe the quality of flow or service provided by the facility so we use different forms of delay.

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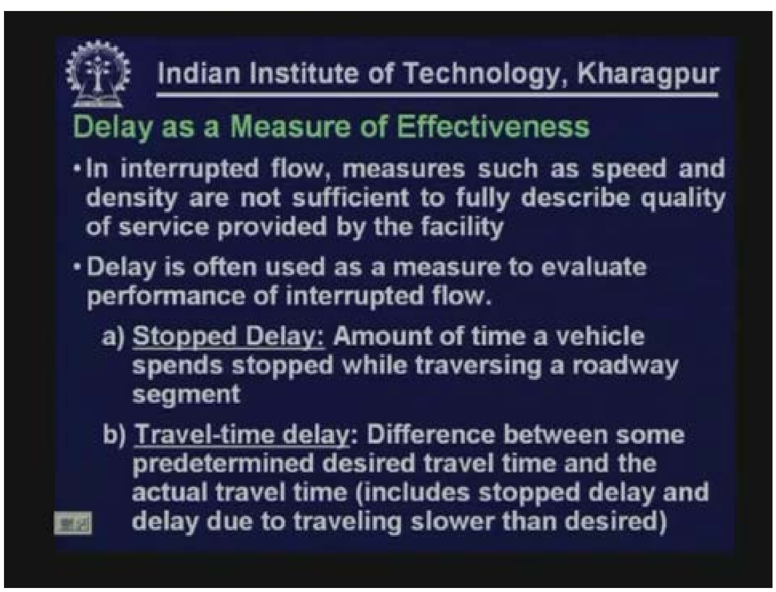

What is stopped-delay? Stopped-delays may be amount of time the vehicle stops while traversing a roadway segment. What is the travel-time delay? We take the difference between the desired travel time may be that's what we expect or is desirable considering high speed and then whatever actual time the vehicle has taken. So if you take the difference you get the travel time delay. Sometimes we represent it by the approach delay. That means while vehicles are approaching an intersection what is the total approach delay. It is used particularly as signalized intersection. so it includes stop delays at the intersection plus the time lost in decelerating to a stop and accelerating back to ambient speed as if there is no stopping then what would have been the time and now because of deceleration, stop and acceleration how much time it is taking.

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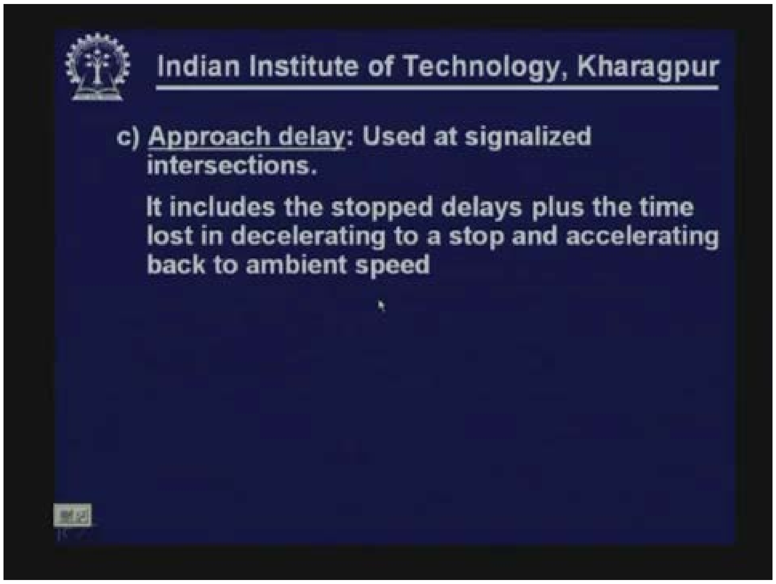

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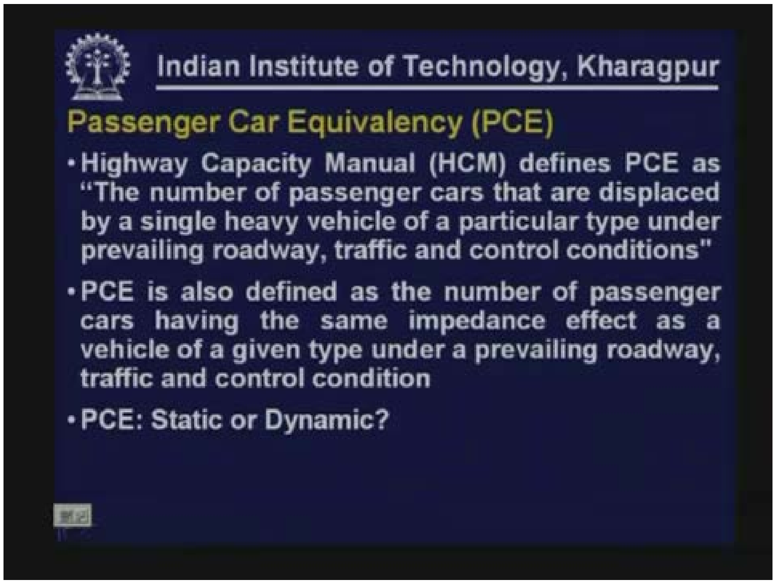

Now coming to the concept of Passenger Car Equivalency you have seen that in most of the developing countries we have mixed traffic operation. So, if you say the number of vehicles is hundred vehicles then it is incomplete we have got hundred cars, hundred buses, hundred two wheelers they are all different they are all a mixture of all these. Therefore this concept of Passenger Car Equivalency is introduced.

Highway capacity manual defines Passenger Car Equivalency as the number of passenger cars that are displaced by single heavy vehicle of a particular type under prevailing roadway traffic and control conditions. So PCE or Passenger Car Equivalency in India we often call it as passenger car unit. It is also defined as the number of passenger cars having the same impedance effect as a vehicle of a given type under prevailing roadway traffic and control condition. The way a track affects if I try to see it is equivalent to how many cars then that will again depend on what the roadway condition is, what is the control condition width in the presence of pedestrian. In the absence of pedestrian you have some parking, you have some other kinds of encroachment roadside activity all these will affect the equivalency. Therefore Vc is always defined with respect to prevailing roadway traffic and control condition. Remember that Vc is influenced by all these factors, a large number of factors will quickly indicate them also.

So equivalency if we say one track is equivalent to how many cars or one bus is equivalent to how many cars it depends on a large number of factors it depends on what the roadway is, what is the environment, what is the control condition, what is the proportion of other vehicle types in the street and what is the traffic volume and so on. Therefore it depends on a large number of factors. So PCE or PCU is not really a static quantity it is essentially dynamic. But till now we do not have norms for dynamic passenger carrying equivalency so what has been done is different static PCU values have been suggested for different roadway facilities. For example, urban area, rural area, again urban intersection area, mid block area which is again free from intersection etc. Like that for different facilities different set of static PCE values have been suggested. But truly PCU is a dynamic quantity.

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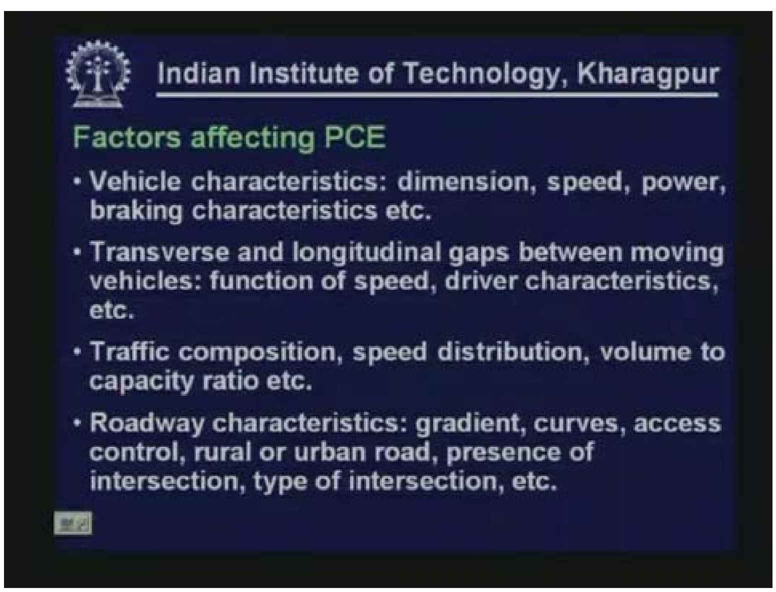

Let us quickly see the factors which are affecting Passenger Car Equivalency.

- Vehicle characteristics like dimension, speed, power, braking characteristics etc.
- Transverse and longitudinal gaps again affect the PCE so basically it is again a function of speed, driver characteristics etc, transverse and longitudinal gaps.
- Traffic composition what are the different vehicle types, what is the speed distribution, what is the traffic volume as compared to capacity all this will affect the PCE just to justify that PCE is really not a static quantity.
- Then it also depends on the roadway characteristics like gradient, curves etc. You have steep gradient the way the truck movement will affect the overall stream. If you have no gradient and if it is a level ground then the effect will be different. So it depends on the grade, it depends on the curve.

So if you provide a sharp curve and then the scenario where some commercial vehicles like trucks come into the picture it will be different again. Therefore you have to know what level of access control is there whether it is rural or urban area, the presence of intersection, and the type of intersection etc are going to affect the PCE.

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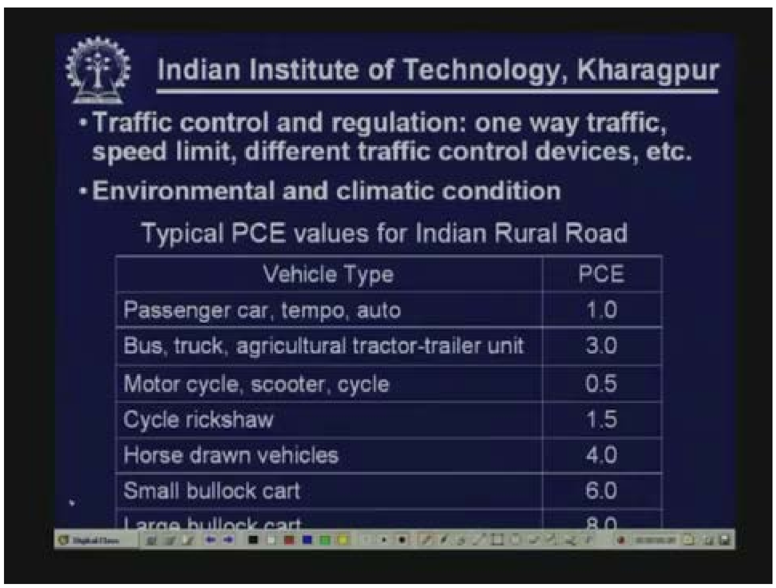

You have traffic control and regulation that also may affect the Passenger Car Equivalency because whether it is one way traffic or two way traffic whether they have posted speed climate, what are the different control devices you have enrolled and also it will get affected by environmental and climatic condition. So you know there are a large number of factors which affect this Passenger Car Equivalency. Here I have shown some typical values of Passenger Car Equivalency for Indian rural roads. you can find with respect to car we define because we say Passenger Car Equivalency so equivalency with respect to car so car is 1, bus truck is normally 3, motor cycle is normally 0.5, cycle rickshaw is 1.5 and I have indicated also higher PCE values for some of the non-motorized vehicles. But these are just indicative and typical you have a number of PCU sets for different types of facilities.

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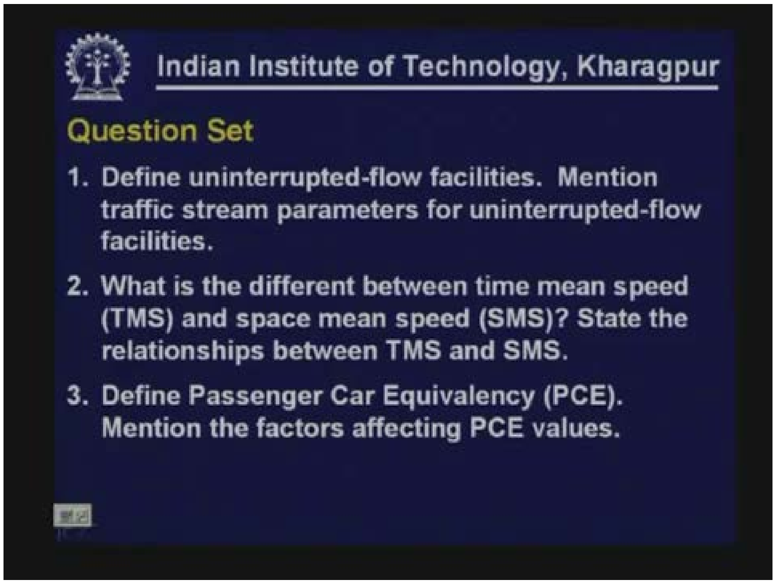

Now let me ask you some of the questions;

1) Define uninterrupted-flow facilities. Mention traffic stream facility for uninterrupted-flow facilities.

2) What is the difference the Time Mean Speed and Space Mean Speed? State the relationship between the Time Mean Speed and the Space Mean Speed.

3) Define Passenger Car Equivalency and mention the factors affecting the PCE values. Show that for Greenshield the linear speed density relationship capacity flow may be expressed as Vf into Kj by 4 where the Vf is the free flow speed and Kj is the jam density.

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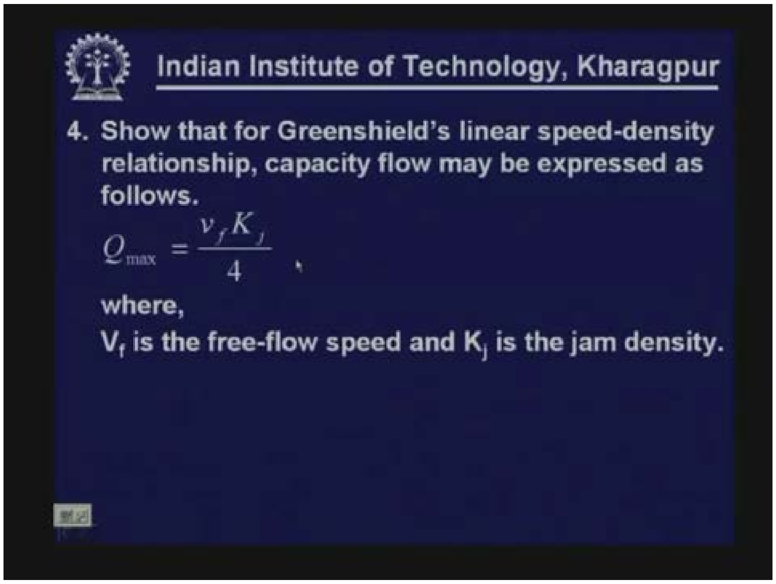

Let us take a quick look at the answers to the questions of the lesson 2.1.

Why it is meaningful to attempt to influence the travel demand. Discuss different ways of influencing the travel demand. In most of the cases you find demand is more than the capacity only for certain hours. So rather than increasing the capacities better to see if we can distribute the demand over a period where even for a small period the demand is more than the capacity then can we instead of adding the capacity or enhancing the capacity can we redistribute the demand and manage with the existing capacity.

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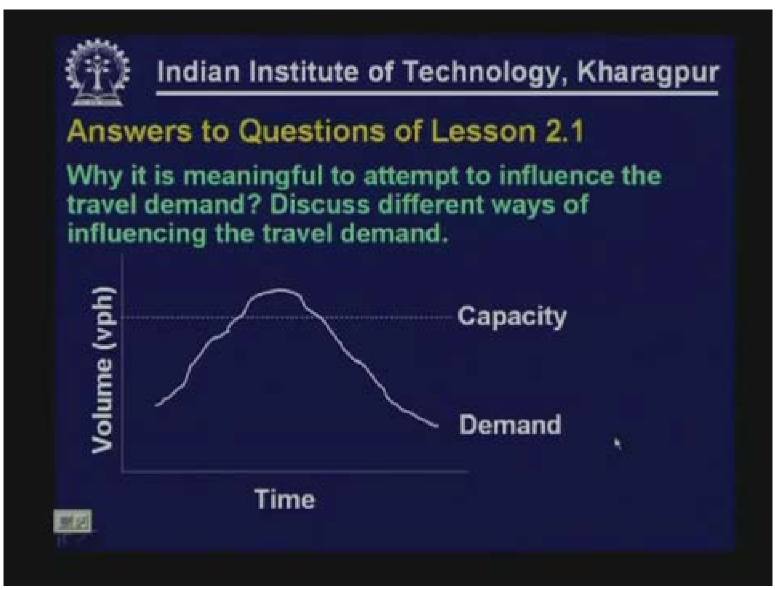

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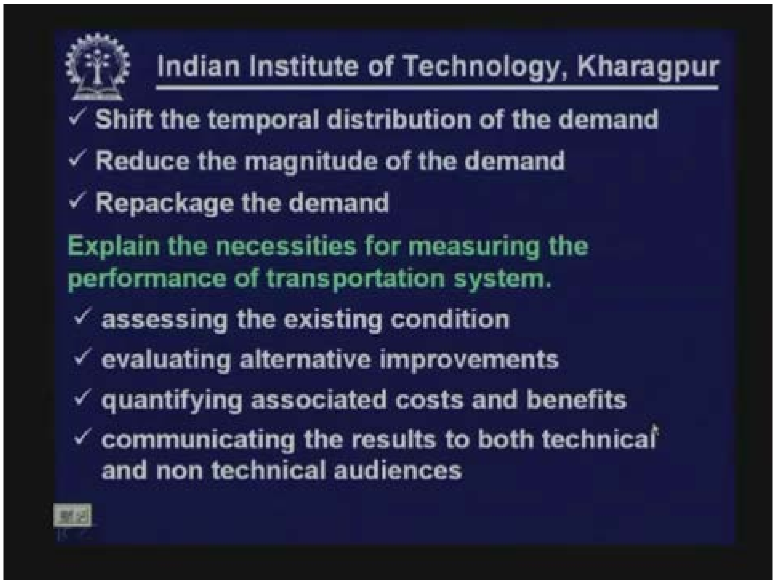

So there are different ways as follows:

- Shift the temporal distribution of the demand
- Reduce the magnitude of the demand
- Repackage the demand

Explain the necessities for measuring the performance of transportation system. There are so many reasons we need to measure the performance. It is for assessing the existing condition, evaluating alternative improvements, quantifying associated cost and benefit and for communicating the results to both technical and non technical audiences.

Explain your understanding about transportation system management, application of methods and procedures for increasing the efficiency and objective is basically from high capital incentive approach to low cost more rapidly implementable projects. These are the major components of traffic system, thank you.

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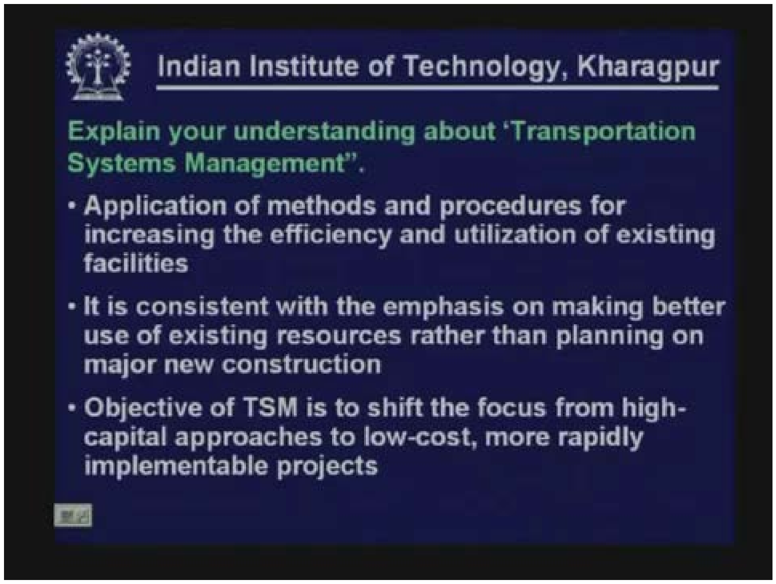

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