Traffic Engineering

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Lecture 16

Basic Concepts

Welcome to module D lecture 1, this module is on capacity and level of service and in today's lecture we shall discuss mostly about the basic concepts.

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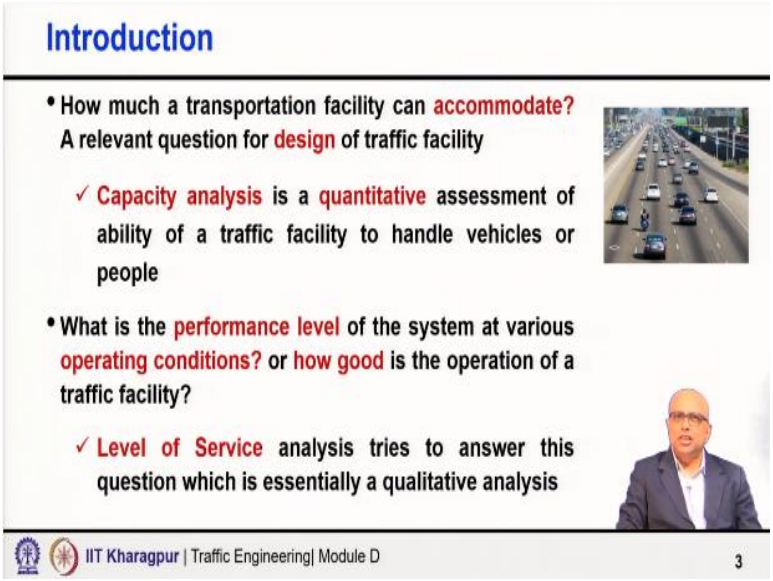

To start with one very relevant question and which we commonly ask when we are designing any traffic facility and the question is how much a transportation facility can accommodate, because the whole design is based on that, so the capacity analysis is a quantitative assessment of the ability of a traffic facility to handle vehicles or people. So, this is an answer to this very important question and relevant question that how much a traffic facility can accommodate.

In the same spirit another very relevant question which we often ask or when we are often required to ask is what is the performance level of a system at various operating conditions or how good is the operation of a traffic facility. Now, the level of service analysis tries to answer to this question which is essentially a kind of qualitative analysis, of course, when we actually demarcate the level

of service we use a quantitative basis, service measures but grossly it is a qualitative analysis. So, that is what the two topics what I said capacity and level of service.

Capacity provides a quantitative assessment of the ability of a traffic facility to handle vehicles or persons and level of service tries to answer to this question how good is the operation of a traffic facility.

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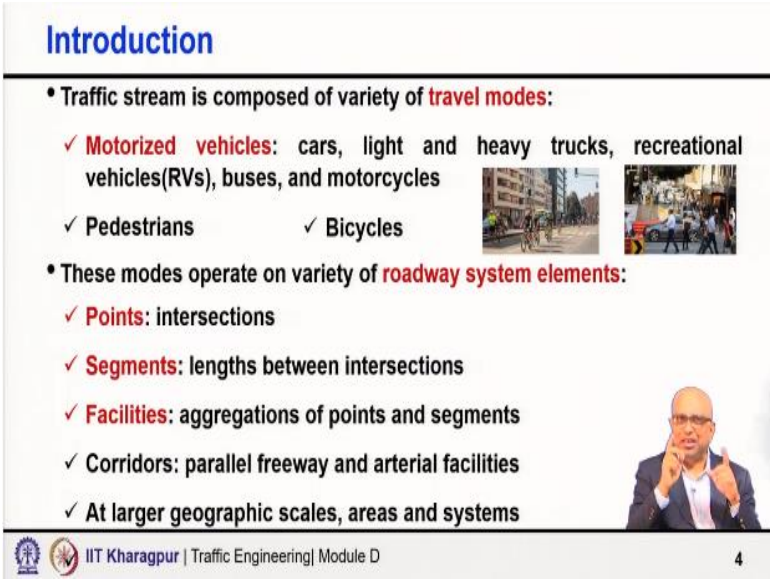

Now, traffic stream is composed of a variety of traffic modes, we have mostly motorized modes like again car, light and heavy commercial vehicles, sometimes recreational vehicles, buses, motorcycles and country to country if you come to India, the traffic is highly heterogeneous, even within the segment of motorized vehicles. These vehicles do not have, all of them do not have the same characteristics, over and above you have non motorized modes for example, pedestrians, for example, bicycles, so that makes the whole traffic stream heterogeneous in nature.

Now, these modes operate on a variety of roadway system elements for example, points which are maybe the example could be intersections, segments which are the lengths between intersections, facilities which include both points and segments, then the corridors, parallel freeway or arterial facilities and also at larger geographical scales areas and systems.

So, one way vehicle type, the other way roadway system elements at which level we are doing the analysis, both are very important when we are talking about capacity and level of service, that

means what type of vehicle category we are talking about and what type of roadway elements or facilities we are talking about.

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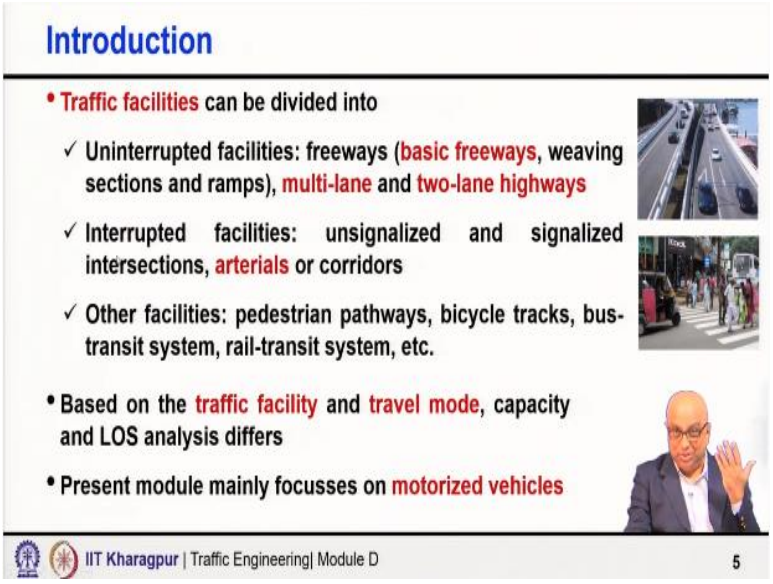

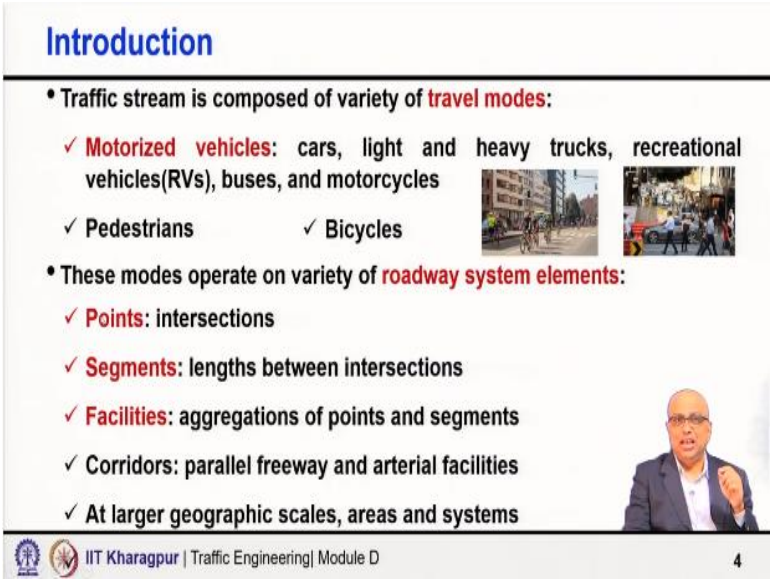

Traffic facilities also can be divided as you know already uninterrupted facilities and interrupted facilities, where there is no external interference to the traffic stream those are uninterrupted facilities for example, basic freeway and sometimes even multi lane highway, even you know other kinds of road elements also could be included under this depending on the context, but ideal definition is freeway or expressway.

Interrupted facilities, unsignalized and signalized intersections, arterials where you have so many intersections along the corridor or it could be even other facilities which do not include directly regular traffic but maybe pedestrian facilities, bicycle tracks, sometimes could be dedicated facilities within motorized, within motorized transport, may be bus transit system, rail transit system, etcetera, based on the traffic facility and traffic mode both are important as I have said, what kind of facilities uninterrupted, interrupted, what kind of elements we are talking whether point, segments or facilities.

The capacity and level of service analysis differs and it is practically not possible to cover all types of facilities, all elements and all vehicle types, both motorized and non motorized. So, present module this point onwards we will grossly restrict our discussion on motorized vehicles.

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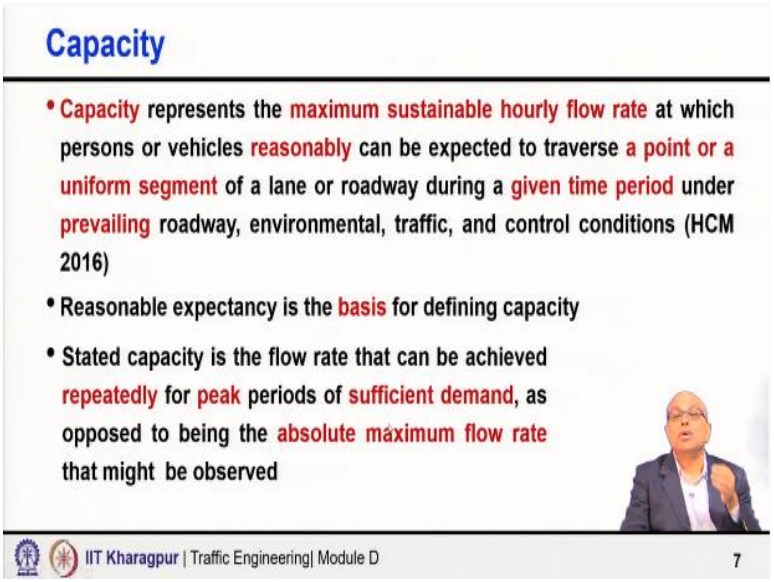

Coming to now the concept of capacity, the definition more importantly the formal definition is very important because every word in this definition is meaningful. Let me read it out, capacity represents the maximum sustainable hourly flow rate, maximum sustainable hourly flow rate at which persons or vehicles. So, we are talking about persons or vehicles reasonably can be expected to traverse, reasonably can be expected to traverse. So, the reasonable expectancy is very important and it is the basis for defining the capacity.

Traverse a point or a uniform segment, point or uniform segments, homogeneity within the segment, the segment must be uniform prevailing, control condition, roadway and control condition does not change within that segment, of a lane or roadway during a given time period under

prevailing roadway environmental, traffic and control conditions. I will discuss each component that is important in the context of capacity, both concept wise and definition wise.

One important point as I already told reasonable expectancy is the basis for defining capacity, what we mean by that, what we say that stated capacity is that flow rate which can be achieved repeatedly for peak periods under sufficient demands. So, if the demand is sufficient during peak periods, multiple days, multiple contexts then repeatedly we should be able to get that capacity flow rate as opposed to being the absolute maximum flow rate that might be observed.

Once in life time I take the data for every hour throughout the year or years after years and I get some maximum value, what is the highest value, that is not the capacity as per the concept. The reasonable expectancy, that means stated capacity is that flow rate which can be achieved repeatedly for peak period when we have sufficient demands, we should be able to get that rate again and again, not the ever highest observed volume that is the difference.

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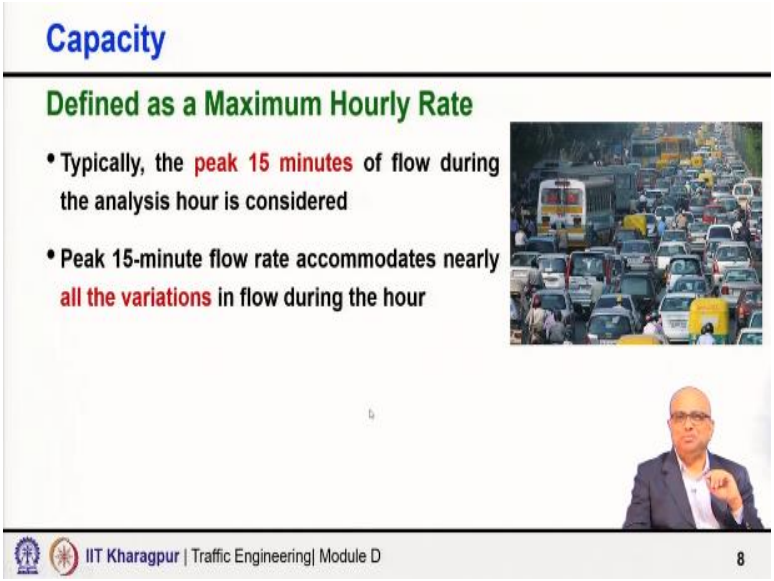

Coming to each component which is important several components which are important, let us go one by one. It is defined as the maximum hourly rate, we are talking about the rate, typically the peak 15 hour of flow during the analysis hour is considered, so we are talking about a flow rate, hourly rate taking 15 minute duration of flow 15 minutes fairly accommodates all the variations in flow during an hour.

So, we often take it 15 minute if you take too less an interval, suppose if I take 1 minute or 2 minute I may get a very high flow rate which will be absurd which we cannot get that flow rate again and again, so the duration is again very important and expressing it in terms of maximum hourly rate.

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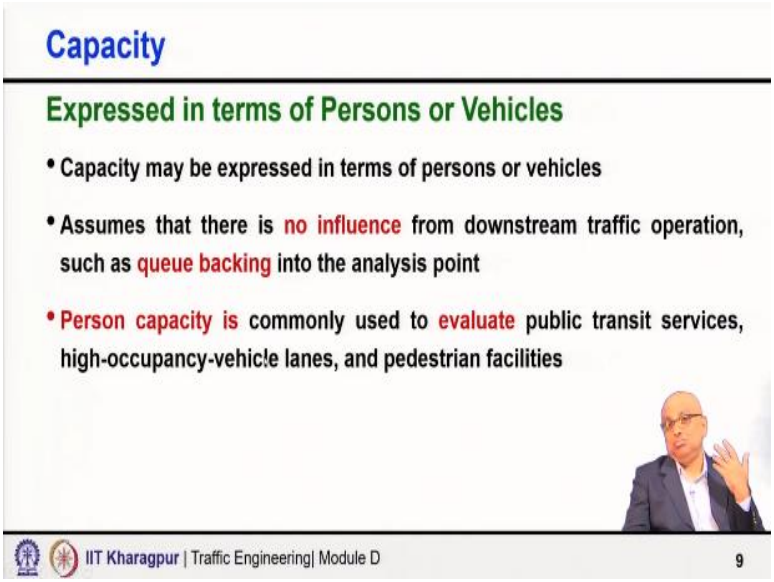

Second, expressed in terms of persons or vehicles. So, capacity may be expressed in terms of persons, in terms of vehicles, often we express it in terms of vehicles also because ultimately the road is getting loaded with vehicles, so we use vehicles or concept like passenger car equivalency or passenger car unit. But person capacity is also sometimes important, particularly, if you are trying to evaluate public transit service because that is the person capacity that is what will matter or high occupancy vehicle lane and even pedestrian facilities.

And in all these cases it is assumed that there is no influence from the downstream traffic operation such as queue backing into the analysis point, that means downstream traffic operation there is no chaos there which is going to influence the flow at the upstream, that kind of influence is not there, its outside that influence area where we are doing the measurements and talking about the capacity.

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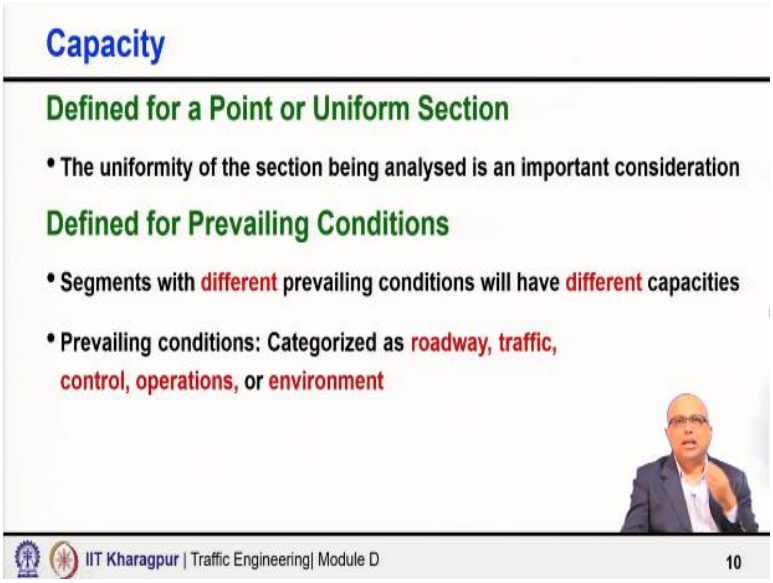

Next, it is defined for a point or uniform section and the next point also will go together defined for prevailing conditions, that means once you take a section that is the condition, that is the prevailing condition and for that we are getting a capacity value and therefore, the uniform section concept is important because we assume that we are actually defining or quantifying capacity for a section which is uniform, it has got a prevailing condition and that prevailing condition is different from an adjacent section and if it is different, then capacity should be defined separately for two sections, because those two sections are not uniform.

So, capacity is at a point or for uniform section and under prevailing condition. So, the prevailing condition changes your uniformity also that is questioned and also the change in the prevailing condition will mean that the capacity will be different. So, segments with different prevailing conditions will have different capacities, prevailing condition may be characterized based on the roadway, traffic, control, operation or environment.

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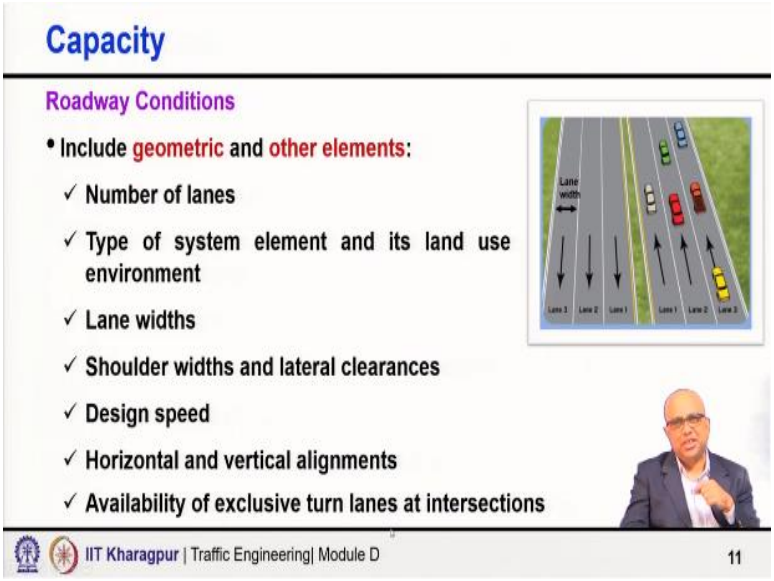

Let us see each of this point. Roadway condition what we mean by roadway, actually roadway conditions include geometric and all other elements. For example, how many number of lengths, so if the number of lane is changing the capacity is going to be different, type of the system element and its use, land use environment, very important.

A road passing through an area where nothing is there on both sides, completely vacant land and passing through an area where both sides are developed and people are walking and activities are happening, side friction is very high, the capacity values are going to be different.

Lane width, if the standard lane width is not maintained, if the lane is narrow for some reason we will lose capacity, we will not get that much value, shoulder width, lateral clearance all every element is important, design speed, horizontal and vertical alignment, availability of exclusive turn lane at intersection, all these will define the roadway condition and if the roadway condition is going to change from one place to another place capacity is also going to be different.

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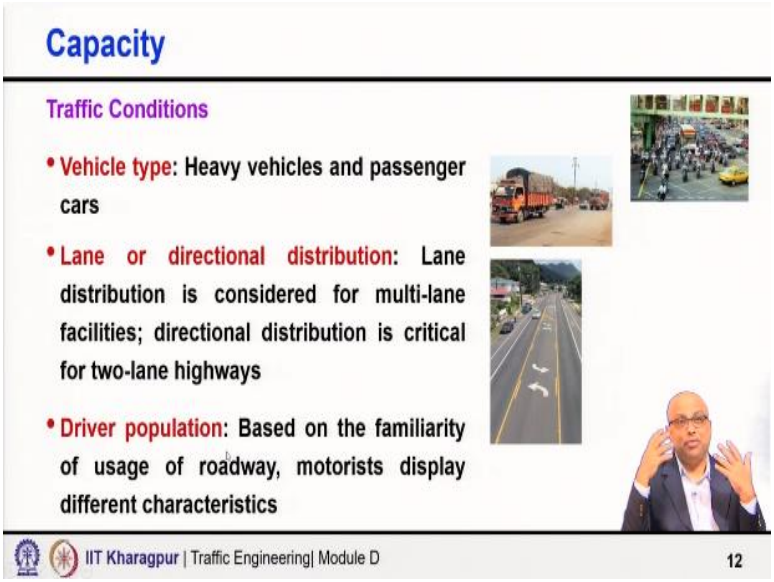

Coming to the traffic conditions. A variety of vehicular traffic, motorized traffic or vehicular traffic is on road, so they may include heavy vehicles, they may include passenger cars, they may include two wheelers, all variety of vehicles. Under heavy vehicles again different categories.

Then lane or directional distribution, multiple lanes are there moving in one direction, how the demand is getting distributed because this demand may not get distributed equally in every length or when the direction is important, how the directional distribution is happening.

So, the lane distribution is considered for multi lane facilities and directional distribution is extremely important in particular for two lane highways, two lane, two-way movement, so it is not exactly fifty-fifty, if it is fifty-fifty, if it is sixty-forty, if it is seventy-thirty that is again going to impact the capacity value.

Then the driver population, how the drivers are familiar with the road environment, are they regular drivers the public transport or some other vehicles, the drivers are there every day travelling in that route, so familiar with the road elements and every road environment, so based on the familiarity of usage of roadway motorists display different characteristics and that is why the driver population in terms of their familiarity to road condition or road environment is very important and going to influence the capacity.

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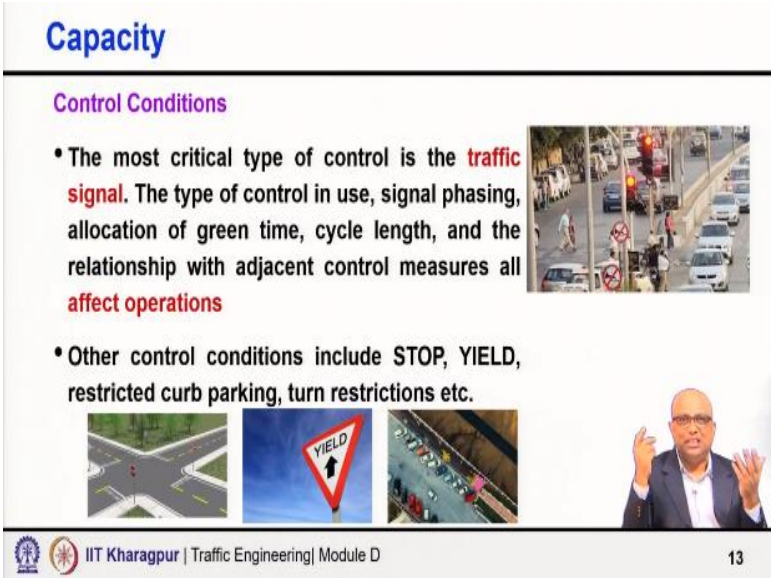

Control condition, the most critical type of control is the traffic signal, the type of control in use signal phasing, allocation of green time, cycle length and every component of traffic signal control and also the relationship with adjacent control measures all affect the operations and also other control such as if there is a stop sign, there is yield sign, if there is restrictions or not for car parking, whether all turns are allowed or there are certain restrictions on certain turns.

So, the capacity concept and the influencing factors are many and the overall the capacity concept is much more complex, it is not like the capacity of a box where you can define the capacity very easily or a bucket.

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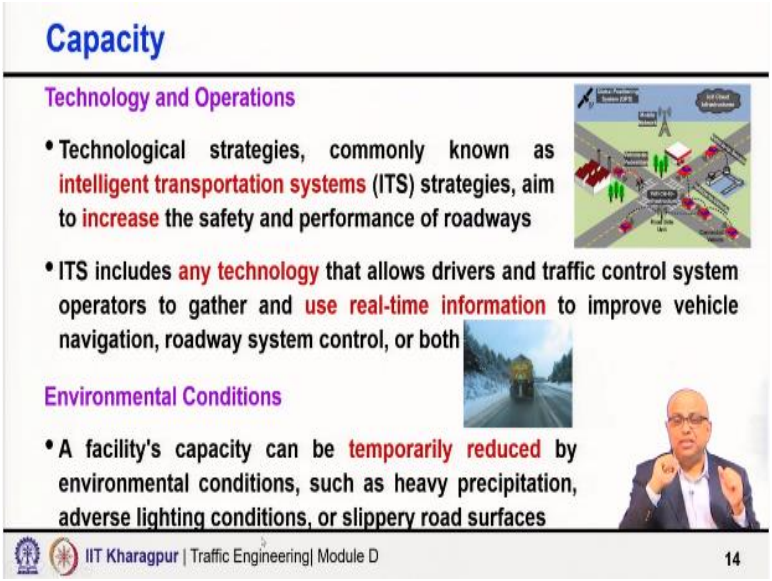

Technology and operation, technological strategies commonly known as intelligent transportation system strategies, ITS strategies aim to increase the safety and performance of the roadways. So, any technology which allows driver and traffic control system operators to gather and use real time information because traffic states change randomly, to improve vehicle navigation roadway system control or both and eventually all these are also going to influence the overall operation and the capacity.

Last but not the least very important is the environmental condition. A facility's capacity can be temporarily reduced by environmental conditions. For example, there is heavy rain or adverse lighting condition or slippery road surface, all these also these are under environmental conditions may also influence the road capacity.

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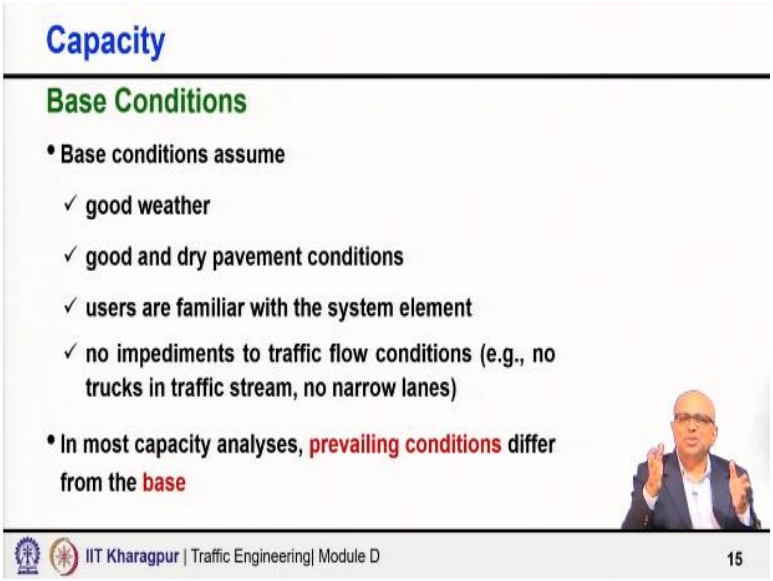

Another very important thing is the base conditions. We shall primarily focus on highway capacity manual 2016 and this HCM 2016 is based on the often use the concept of base conditions. Most of the cases you will find the values are actually given for the base conditions and then prevailing conditions will be different, we can say the base condition is somewhat like idealized condition and the actual condition, prevailing condition will not be that idealized.

So, wherever they will deviate appropriate corrections are to be applied, multiple such corrections we will discuss in subsequent lectures when we talk about say two lane roads or multi lane roads and talk about the capacity and analysis level of service analysis that time will elaborate further.

So, the base condition assumes things like good weather, good and dry pavement condition, users are familiar with the system element, drivers familiarity all are familiar that we assume, no impediments to traffic flow conditions in every sense, that means there is no truck in the traffic stream, no truck or heavy vehicles, no lane narrowing, the ideal shoulder width, the ideal traffic lane width, everything is standard, as per the standard, as per what they should be, as per standard.

There are additional conditions which we will when we discuss different roadway element in that context again I shall mention to you, there are additional points, not only these four points but like this, like good weather, good and dry pavement conditions, drivers are familiar, traffic is homogeneous only consisting of car traffic, drivers are familiar there is all lane width are fine, shoulder widths are as per standards what they should be as per code or as per standards or as per guidelines.

And several such additional elements specific if we are talking about multi lane highways, we are talking about two lane roads, we are talking about other kinds of elements, we may not be able to discuss every or all possible elements, we will restrict our discussion again to a few types of roadway facilities only.

But in most cases the prevailing condition will differ from the base, so the values will be given, whatever capacity and other kinds of values, threshold values will be given for the base condition and then we have to calculate, then what will happen when the condition is prevailing condition, that mean some of these conditions which are assumed under base conditions are not there or they are violated, then appropriate corrections are to be there, several such corrections are given in the highway capacity manual.

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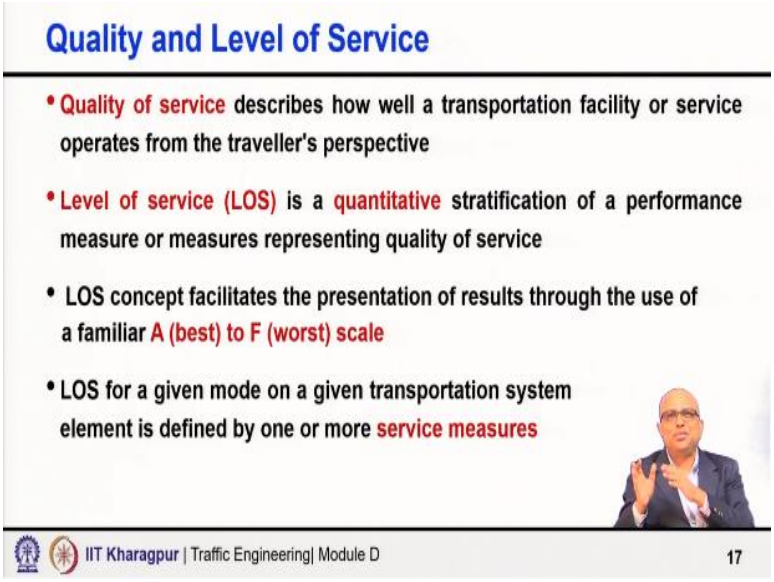

Going to now the quality of service concepts or level of service. First, the quality of service, quality of service describes how well a transportation facility or service operates from the perspective of travelers. We are all travelers, we are travelling on roads, how we feel, how good the system is working or the road elements what we are talking may maybe an intersection, maybe an overall corridor as I have mentioned earlier that different elements are there, so how they are working, so how good or bad they are working as I say point segment facilities.

So, level of service then is a quantitative stratification, the basic concept of quality of service and level of service is qualitative still but it is also a quantitative stratification of a performance measures, when we are grouping them what level of service we are using some measures and

quantitative bases, those measures are basically performance measures or the measure of effectiveness or the measures which are actually is or are actually representing the quality of service.

So, LOS is a quantitative stratification of a performance measure or measures representing quality of service. The LOS concept facilitates the presentation of results through the use of A to F scale, we say A is the best LOS A is the best and LOS F is the worst. So, level of service is defined into six segments A, B, C, D, E, F. A is the best, F is the worst, on what basis we are defining this A, B, C, D, E, F it is based on this performance measure or measures, that is what I have said. LOS for a given mode on a given transportation system element is defined by one or more service measures.

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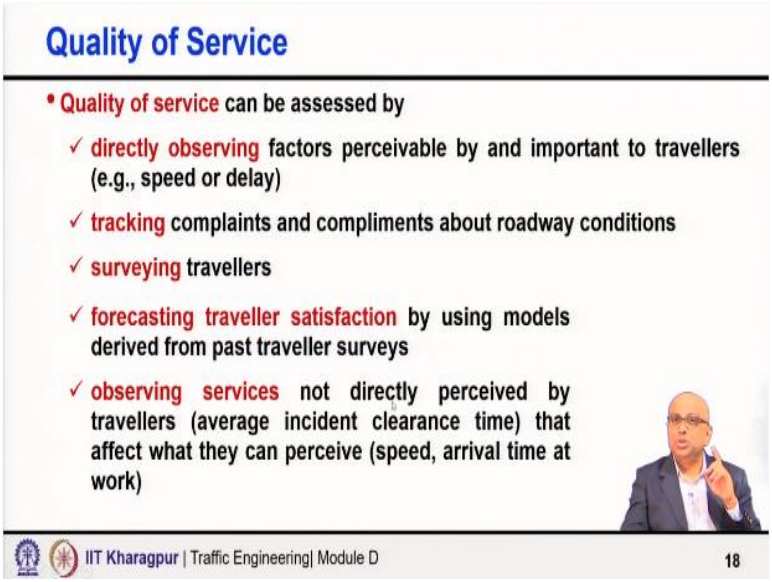

Quality of service can be assessed in so many ways and probably combinations of several things. One, by directly observing factors perceivable by and important to travelers, for example, speed or delay, travelers can perceive this directly and what is the perception of users, how much importance they attach to this aspect, when you are talking about transportation system it may not be only the speed but may be multiple other things. So, one is by directly observing the factors which are perceivable by and which are considered important to travelers.

Second, by tracking complaints and compliments about the roadway conditions, how you are getting the feedback, what is the problem, is there the lot of people are saying that the road condition is very bad and they are facing congestion every time or they are giving compliments about the

roadway condition, that could also be used some form or other. Third, surveying travelers, directly go and survey travelers, intercepts of travelers, take response from them using some well designed questionnaire.

Forecasting traveler satisfaction by using models derived from past travelers survey, you might have already collected such data many such works are being done, I also do many such works, similar works, stated preference, response, reveal preference, stated preference, data analysis you can do that, you develop model you can even forecast using those models, once this models are properly calibrated.

Then observing services not directly perceived by travelers, yes, something we are talking which are not directly perceived by traveler. For example, average incident clearance time, if there is an accident how quickly that vehicle is removed and the road is cleared.

Now, this probably travelers cannot perceive directly but that affect what they can perceive, they can perceive what speed, what is the average speed of travel that they perceive an average speed depends on whenever there is an incident how quickly I am able to clear that incident, arrival time at work they can very well judge whether they are able to reach to the office on time, so observing services which are not directly perceived by travelers that affect what they can perceive.

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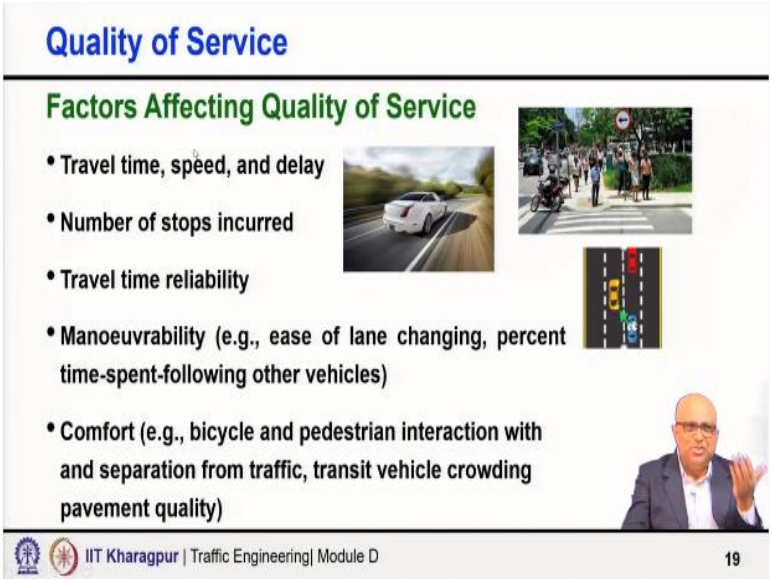

There are several factors affecting the quality of service, I have mentioned some of them here, say travel time, speed, delay very, very relevant, number of stops incurred, how many times a vehicle had to stop, what is the travel time reliability, not only the what is the travel time but what is the travel time reliability, then what is the level of maneuverability.

For example, ease of lane changing, percentage time spent following other vehicles because you are in a queue, you are inside a queue and you are not getting to perform overtaking maneuver and you are forced to follow another vehicle, so how much percentage time you are forced to follow other vehicles, comfort for example bicycle and pedestrian interaction and separation from traffic, transit vehicle crowding, pavement quality all such kind of things may, these are all qualitative, overall comfort of travel is influenced by all such factors.

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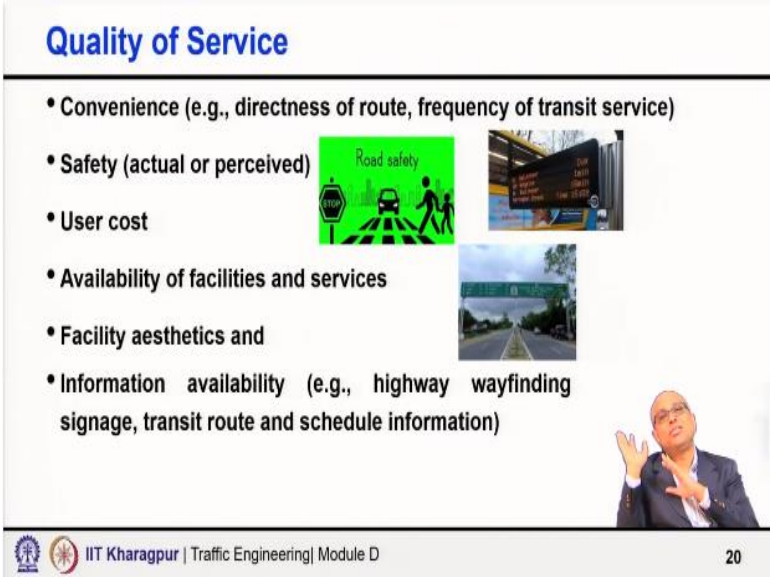

Convenience, directness of the route, frequency of transit service, you can directly travel from point A to point B or you have to transfer twice to reach to the destination. Safety, what is the actual performance or what is the perceived also both are important. User cost, higher the user cost less will be the attraction.

Ability or availability of facilities and services, facility aesthetics, how the overall look like, information availability and am I get able to get the information about the transit route, schedule planned one or the scheduled one or the real time whether the appropriate signage is there for me to direct me to the transit station or ticket counter or to various other facilities whether they are present or not.

So, so many things could be there and not that every user, for every user all these things are important, no, to some segment of use that something may be important, may be the vehicle users to them something is important but the transit users specifically their considerations may be different, a bicycle users perception and requirements and important factors may be different, a pedestrians again it could be different, all these are possible.

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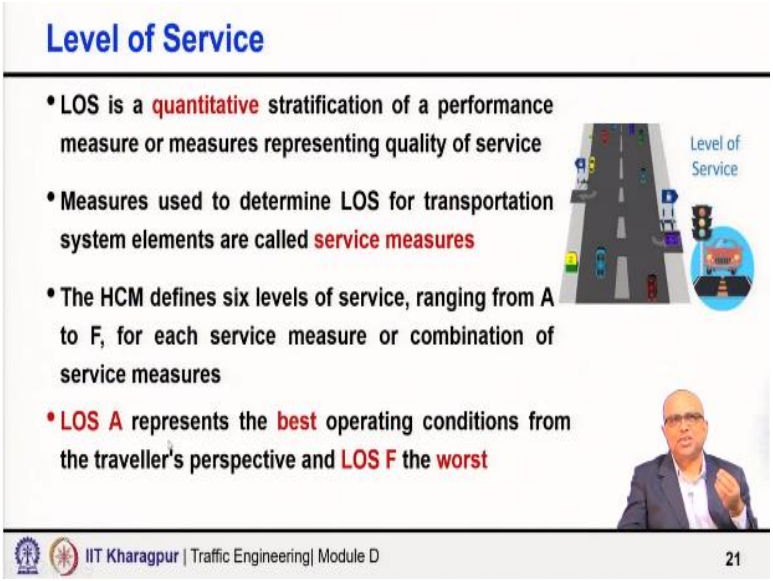

So, overall we can say LOS is a quantitative stratification of a performance measure or measures representing the quality of service, I have told it earlier repeating it once again and measures used to determine the LOS the quantitative basis which is a quantitative stratification, on what basis who is doing that quantitative stratification, it is the service measures based on the value of the service measures or values of the service measures we are deciding whether it will be LOS A or LOS B or LOS C.

Highway capacity manual defines six levels of service as I said ranging from A to F and for each service measure or combination of service measures. LOS A represents the best operating condition and LOS F is the worst.

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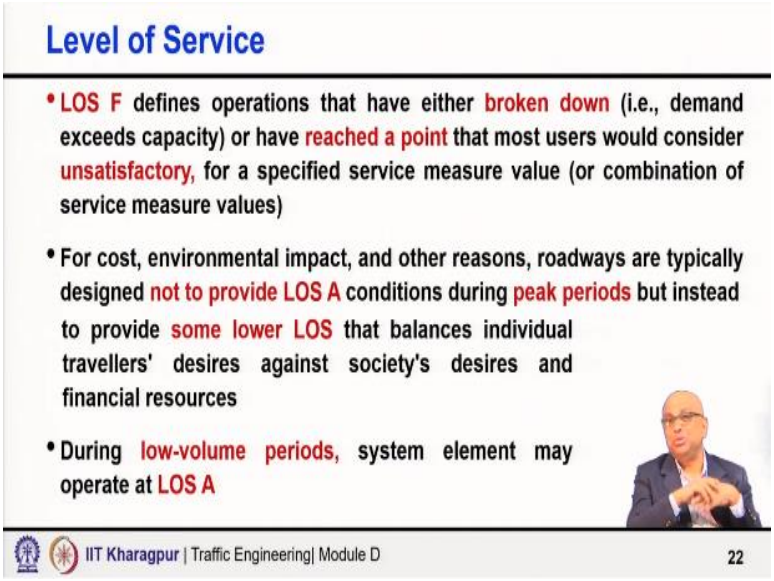

LOS F defines operation that have either broken down that means already you know the forced flow conditions, so often the LOS F is the actually the force flow condition or which have reached a point that most user would consider extremely unsatisfactory for a specified service measure value or combination of service measure values. For cost, environmental impact and other reasons roadways are typically designed not to provide LOS A conditions during peak periods but instead to provide some kind of lower LOS that balances individual travels desire against society's desire and financial resource.

This is again if my expectation is very high, so to meet the same demand I need then more infrastructure but infrastructure you need to build, you can only build by spending society's resource, scarce resource. So, at this everywhere in the peak hour if I expect the best operating conditions, highest level of freedom with level of service A, I probably need much wider road, many additional lens probably which may satisfy my requirement, may give me more satisfaction as the road user but then I am actually using society's scarce resource and financial resource is always limited what is available.

So, you need to strike a balance, so that is why for the peak hour we do not expect to operate the system with LOS A but something lower depending on whether it is mobility is of higher importance or accessibility is higher important, somewhere you may go LOS B, somewhere you will go even LOS C for urban case.

So, that is what it is and obviously, even with that facility when the volume is low, not in the peak hour may be mostly off peak or lower level of volumes under that operating condition probably still the system will operate with level of service A or the highest level of surface.

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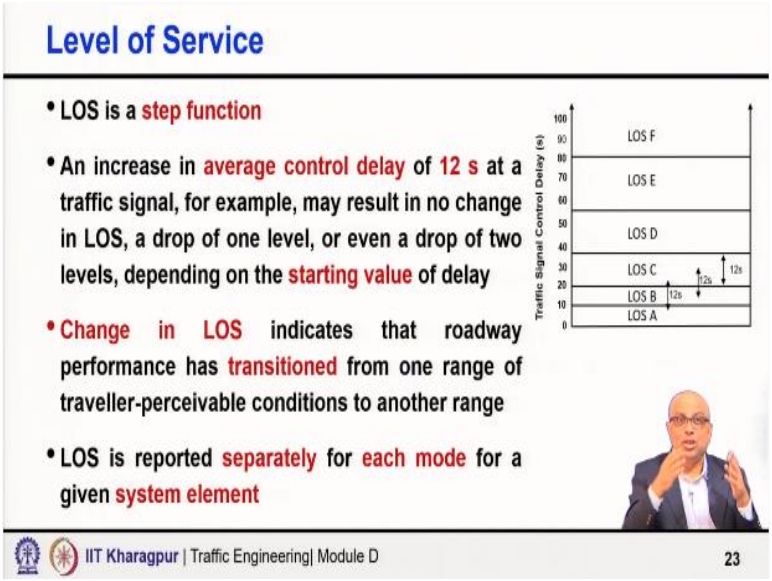

LOS is a step function as I have shown here, this range to this A then suddenly it changes to B up to certain range, then C, then D, then E and beyond that F. So, an increase in average control delay and because it is a step function, say for example, for intersection, signalized intersection the control delay is the service measure, based on control delay the level of service is defined from A to F.

Now, what is shown here that an average control delay of 12 seconds a change, an increase in control will have 12 seconds at a traffic signal may result in no change in LOS, you can see here it will be still within this LOS, it may mean one level change in LOS, it will also mean two level change in LOS and sometimes two operating conditions the difference may be much higher although they are under the same LOS, then two operating conditions the difference is much lower but they are operating one it LOS C, another may be in LOS D or LOS B or LOS C.

So, two points suppose, one point here and one point here, the difference in the measures, service measures could be quite high but both of them might be LOS D and one here and another here little difference, one may be LOS C another may be LOS D, so that kind of things will be there because it is a step function.

So, change in LOS in general indicates that roadway performance has transient from one range of traveler perceivable condition to another range. So, LOS is reported separately for each mode for a given system element, as I said not the same measures and the road users, vehicle user, pedestrians, bicycle user, transit users the measures may not be same, so LOS is actually reported separately for each mode for a given system element.

And also system element to system element because the functionality, the objective what they are supposed to serve an expressway or access control road and a local road or arterial is not going to serve the same purpose. So, even element wise type of road, type of facility wise also it will be different.

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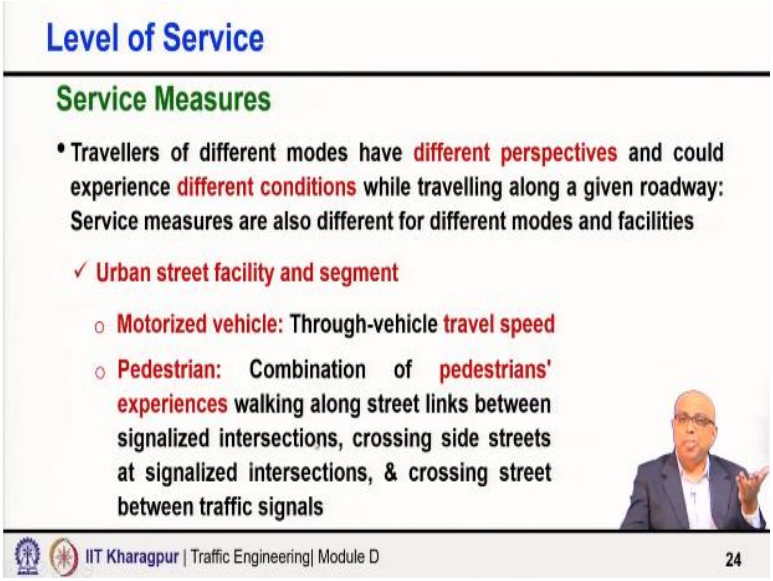

Service measures, travelers of different modes have different perspectives and could experience different conditions, the other is a set what I said while travelling along a given roadway, same roadway used by different road users of different modes or different mode users I can call, they may have different impression about the facilities, it may happen that one mode users or one category of mode users may find it very good but another kind of mode user may find it very bad. So, one may perceive it or experience a LOS B, another road users of different modes may experience LOS D.

Service measures therefore, are also different for different modes and also for different facilities. So, if we take an example that urban state facility segment, then motorized vehicle it is the through vehicles travel speed, to pedestrian it may be combinations of pedestrians experience, walking

along street links between signalized intersections, crossing side street at signalized intersections and also crossing streets between traffic signals or between signalized intersections. So, that may influence the measures which are likely to influence the LOS as perceived by pedestrians but motorized vehicle they consider different, through vehicle travel speed not the same.

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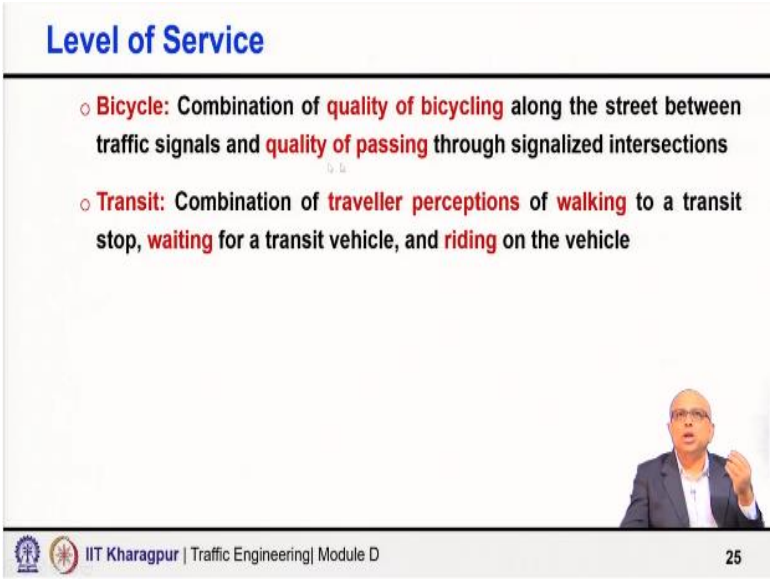

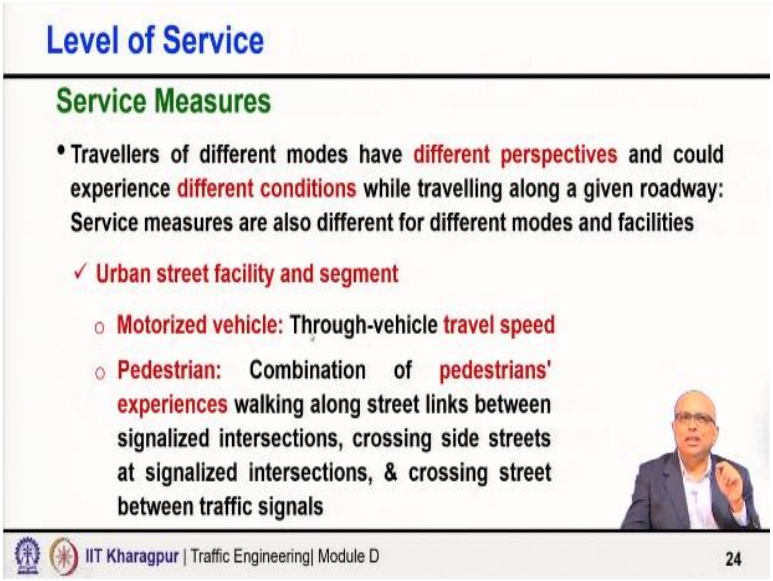

Again if you go to bicycle users same facility, same road system, it may be LOS may depend on combinations of quality of bicycling along the streets between traffic signals and quality of passing through signalized intersections. On the other hand if you go to transit users, the things may be entirely different, the LOS may depend on combinations of traveler perceptions of walking to a

transit stop, waiting at the transit stop for the vehicle to come and then riding on the vehicle, may how much time it is taking, what is the comfort conditions within the vehicle and so on so forth.

So, you can see even though the same element but different mode users their requirements are different, their expectations are different and therefore the measures which are used to define the LOS, the quantitative basis which is provided to define the LOS this basis itself is different.

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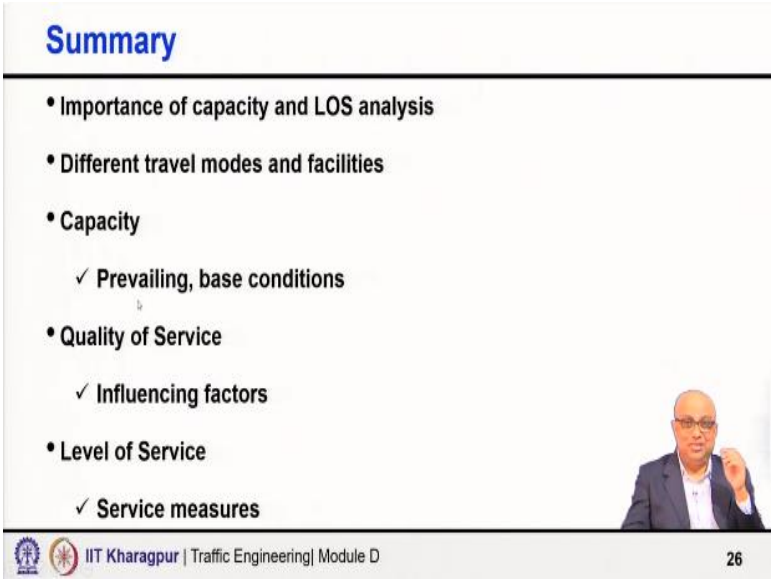

So, altogether what we discussed today is the importance of the capacity and LOS analysis, different modes and facilities, how the things will be different, the concept of capacity, the prevailing condition and the base conditions, quality of service, what are the influencing factors and the concept of level of service and different service measures considering different mode users, with this I close this lecture thank you so much.