

Traffic Engineering
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Lecture 22
Analysis of Urban Street Segments (As per HCM, 2016) - II

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NPTEL Online Certification Course on
Traffic Engineering

Module D
Capacity and Level of Service

Week 5: Lecture D.7
Analysis of Urban street
Segments (As per HCM, 2016) - I

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Welcome to Module D, lecture 7. In this lecture, we shall discuss about analysis of urban street segments as per Highway Capacity Manual, 2016.

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Recap of lecture D.6

- Framework for LOS determination for following two-lane highway classes:
 - ✓ Class I
 - ✓ Class II
 - ✓ Class III
- Computational steps
- Application

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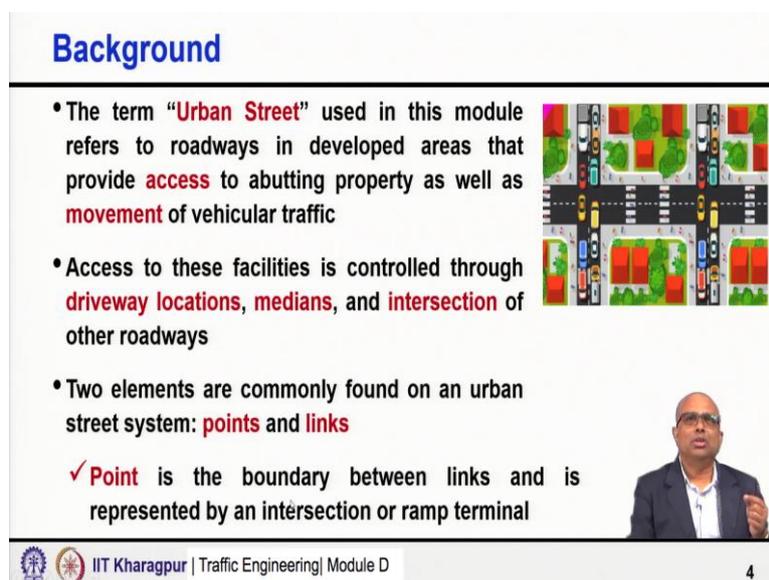
In lecture 5 and lecture 6, we discussed about two-lane highway segments, especially in lecture 6 we discussed about the framework for a LOS determination for class 1, class 2 and class 3

two-lane highways. Then mentioned to you about the computational steps, how stepwise we should do the calculation and then took an example problem to explain you the application. With this background today, we are going to discuss a different types of facility that is urban streets and specifically urban street segments.

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A presentation slide titled "Background" in blue text. A small video inset in the bottom right corner shows a man in a dark suit and glasses speaking. The slide footer contains the IIT Kharagpur logo, the text "IIT Kharagpur | Traffic Engineering | Module D", and the number "3".



A presentation slide titled "Background" in blue text. It features a bulleted list of definitions and characteristics of urban streets, a small diagram of a street intersection, and a video inset of the speaker. The text is as follows:

- The term “**Urban Street**” used in this module refers to roadways in developed areas that provide **access** to abutting property as well as **movement** of vehicular traffic
- Access to these facilities is controlled through **driveway locations, medians, and intersection** of other roadways
- Two elements are commonly found on an urban street system: **points** and **links**
- ✓ **Point** is the boundary between links and is represented by an **intersection or ramp terminal**

The diagram shows a street intersection with various traffic elements like cars, buses, and pedestrians. The slide footer contains the IIT Kharagpur logo, the text "IIT Kharagpur | Traffic Engineering | Module D", and the number "4".

Now, the term urban street is used to refer roadways particularly in developed areas that provide access to abutting properties. Access is important because urban area is normally densely developed and also to provide mobility to recollect traffic and pedestrians are there, vehicular traffic is there, bicycle will be there, transit will be there. So, different modes of transport, both motorized and non-motorized are using such facilities.

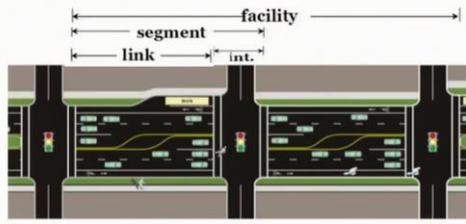
Normally access to these facilities is controlled through driver locations, medians and intersection of other roadways. And in fully developed urban areas, we normally expect a large number of signalized intersections, although there are other types of intersection, stop controlled, YIELD control those will be there, but also a large number of intersections is actually signalized intersections.

Now, the 2 elements which are commonly found in an urban street system, one we can call points and the others we may call as links. Point is the boundary between links and represented by an intersection or sometimes it could be a ramp terminal as well. So, we can say that it is the boundary between links and then what is the link?

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Background

- ✓ A **link** is the **length of roadway between two points** (Distance between two signalized intersections)
- ✓ A **segment** includes a link and its boundary intersections
- ✓ An **urban street facility** is a length of roadway that is composed of contiguous urban street segments and is typically functionally classified as an urban arterial or collector street



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Link is the length of roadway between 2 points. So, generally speaking if intersections are my points, then the distance between 2 signalized intersections is my link and a link and its boundary intersections together a link and its boundary intersections together we may call it a segment. Now, if you look at urban street facility, as I have shown here, how the link is defined, how the segment is defined, then urban street facility is actually linked of roadway that is composed of contiguous urban street segments and is typically functionally classified as an urban arterial or collector streets, what collector street functions.

And for urban arterioles are expected to serve, urban arterial mobility function will be higher than the collector streets. Similarly, the excess function will be higher for collector streets as compared to urban arterioles. Now, we then have a larger of scale we can consider urban street

facility and then at a detail level or at a micro level in that sense, we can say that we have segments.

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Background

Urban Street facilities vs Urban street segments

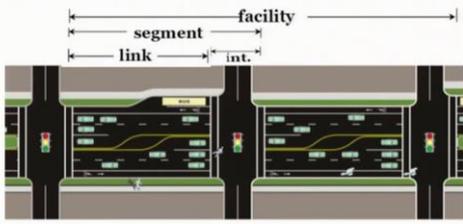
- The focus of the present lecture is on **analysis of urban street segments** and **for motorized vehicles only** (Detailed analysis of signalized intersection will be covered in Module-E)
- The link and its boundary points **are evaluated together** to provide an accurate indication of **overall segment performance**
- For a given direction of travel along the segment, link and downstream point performance measures **are combined to determine overall segment performance**



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Background

- ✓ A **link** is the **length of roadway between two points** (Distance between two signalized intersections)
- ✓ A **segment** includes a link and its boundary intersections
- ✓ An **urban street facility** is a length of roadway that is composed of contiguous urban street segments and is typically functionally classified as an urban arterial or collector street



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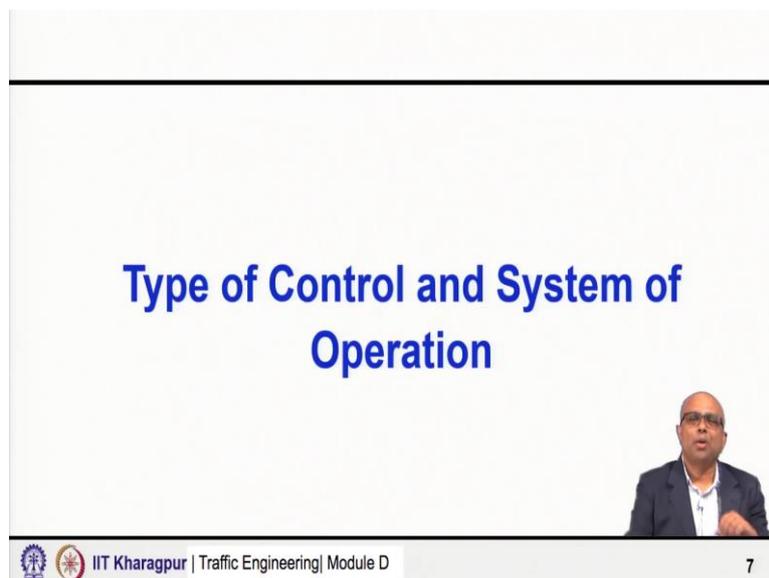
Now, the question is, there are 2 different things, urban street facilities and urban street segments. Particularly, if you try to look at the procedures for analyzing urban street facilities and urban street segments, there are differences. So, what we are going to focus in today's lecture and also maybe the next like 1 or 2 more lectures is on analysis of urban street segments not the facility as a whole not the urban street facilities, we are focusing on specifically urban street segment.

Now, urban street segment like a segment an isolated segment. Similarly, it could be an intersection also similar kind of analysis may be valid for intersections also, but detailed analysis of signalized intersections that we will cover in the next module, which is module-E, and since, we are going to cover the intersections signalized intersections in particular in quite in a detailed manner.

So, we shall skip much discussion related to signalized intersection in this module and our entire focus is specifically on urban street segments for remember that segment includes a link and its boundary intersection. Now, the link and its boundary points are evaluated together or considered together to provide an accurate indication of the overall segment performance. We cannot take out one element from the other.

Here it is important to mention that for a given direction of travel along the segment link and downstream point performance methods are combined more specifically. So, when we are taking a segment, we are taking a link and the downstream point and its performance to combine and therefore, determine the overall segment performance. So, you can consider the link and also the downstream point the performance of both combined together to say what will be the overall performance of the segment.

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Type of Control and System of Operation

- The methodology focuses on evaluation of motorized vehicle performance for a street segment bounded by intersections that can have a variety of **control types** and **systems of operation**
- **Types of control** used at the intersections: signalized, two-way STOP-controlled, all-way STOP controlled, or a roundabout
- **Systems of operation**: Coordinated and non-coordinated
 - ✓ Analysis of coordinated systems **recognizes the influence of an upstream signalized intersection on the performance** of the street segment
 - ✓ Analysis of non-coordinated systems considers that **arrivals to a boundary intersection are random**



Background

Urban Street facilities vs Urban street segments

- The focus of the present lecture is on **analysis of urban street segments and for motorized vehicles only** (Detailed analysis of signalized intersection will be covered in Module-E)
- The link and its boundary points **are evaluated together** to provide an accurate indication of **overall segment performance**
- For a given direction of travel along the segment, link and downstream point performance measures **are combined to determine overall segment performance**



Now, going to type of control and system of operations. When we are talking about the segment specifically our focus is on segment and also probably I missed to highlight this part that also our focus is for motorized vehicles only because urban street segments even also the LOS could be analyzed for motorized vehicle, for pedestrians, for bicycles, for transits. So, we are focusing here only on motorized vehicles, nothing else. So, focus is motorized vehicle performance and on urban street segments.

Now, urban street segments are bounded by intersections, which can have a variety of control types different control types are possible and different systems of operations are also possible. What we mean by different types of control that means an intersection could be signalized, could be to a stop control, could be always stop control and even it could be around about, the methodology may little bit vary depending on what type of control and other factors.

But the type control for such segments and intersections at the use which are actually in use could be different such as I mentioned signalize to a stop control always stop control or even a roundabout. Now, that I said that different types of control and different systems of operation, what I mean by different systems of operations, that means, it could be coordinated could be non-coordinated.

We are going to obviously discuss these things in more detail in a more detailed manner in Module-E, but since I used this terminology coordinated and non-coordinated what I mean that. The intersections will perform just like an isolated intersection that means you take only one urban intersections consider its input and try it to analyze the operation and operation is happening just considering that intersection as an isolated intersection.

That means, we do not bother about other things, we are considering only one intersection at a time. But, what happens that is basically non coordinated operation, but often you will find traffic moves along the corridor and typically the direction of movement is very important, because most of the cases you will find a vehicle or traveling along major arterial towards the city center or CVD. In the evening, the travel is happening mostly in the other direction.

So, the major direction major traffic is traveling in a particular direction at a given time, typically morning peak towards the city or CVD area. And therefore, often we find when signals operate in an isolated or non-coordinated manner, then he will leave one intersection you can see probably the downstream intersection is green, but by the time you reach there, signal turns from green to red.

So, when there was no vehicle because vehicle moves in platoon, platoon get discharged a bunch of vehicle getting discharged from upstream signals and then moving forward and then majority of the vehicle rich together depending on when and how they are getting discharged and what is the length between signals and many other factors.

But they are expected to reach in a bunch and that time signal is red, when probably there is not many vehicle. So, the signal is green at that time. So, what is attempted in a coordinated signal system, the green times of all the signals which are coordinated are adjusted when the green to be given. An attempt is made so that the vehicle once released from an upstream signal, when these vehicles will reach to the downstream signal, signal will give green indication.

So, that majority of the vehicles which are arriving at the time can pass through the signals without stopping. And that should happen for all the signals which are actually coordinated. So, you can the whole corridor you can coordinate. You can do core coordination in one way, you can do coordination in 2 way there are so many other complexities, but that is what we say that system of operations of signals could be coordinated, could be non-coordinated.

Now, here the urban segments street segments can be analyzed for both systems of operation, coordinated operation as well as non-coordinated operation. Now, when we are analyzing, considering coordinated operation, we recognize the influence of an upstream signalized intersection on the performance of the street segments because signals are coordinated.

So, bunch of vehicle getting released and how they are moving. When they are reaching to the downstream signal and then the signal timings are also adjusted the that time only we try to give green, so obviously when we are analyzing coordinated signal system, the methodology or the analysis procedure recognizes the influence of an upstream signalized intersection on the performance of the street segment.

While in case of non-coordinated systems such kind of influence will not be there. So, we can consider that arrival to a boundary intersection are random not like in a platoon with specific pattern every cycle during that analysis period same thing will keep happening. Here we can say that because signals are not coordinated, so arrival is can be considered as random.

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Type of Control and System of Operation

- If the subject **segment is within a coordinated signal system**, the following rules apply when the segment boundaries are identified:
 - ✓ A signalized intersection is always used to define a segment boundary
 - ✓ Only intersections at which the segment through movement is uncontrolled (e.g., a two-way STOP-controlled intersection) can exist along the segment between the boundaries



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Type of Control and System of Operation

- If the subject **segment is not within a coordinated signal system**, the following rules apply when the segment boundaries are identified:
 - ✓ An intersection having a type of control that can impose on the segment through movement a legal requirement to stop or yield must always be used to define a segment boundary
 - ✓ An intersection at which the segment through movement is uncontrolled (e.g., a two-way STOP-controlled intersection) may be used to define a segment boundary, but it is typically not done



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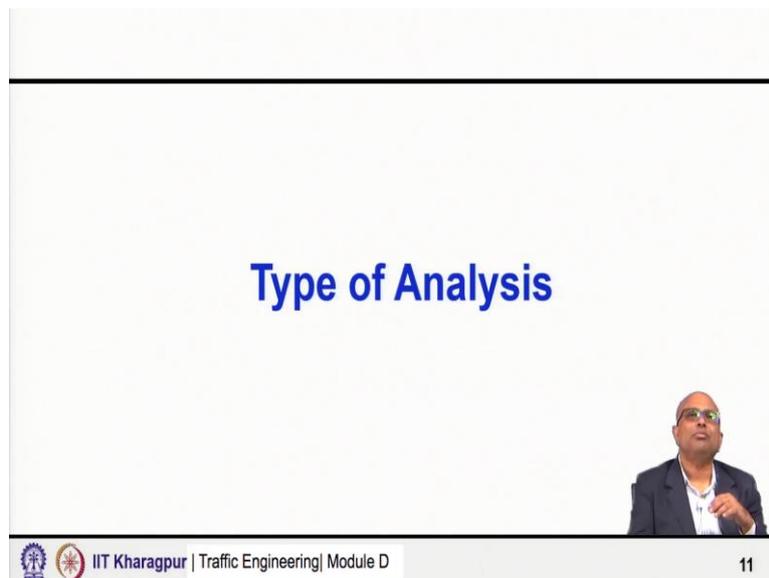
If the subject segment is within a coordinated signal system, then the following rules apply when the signal boundaries are identified, how we identify the segment boundary? So, if we are taking a segment within a coordinated signal system, then these rules may be applied. One a signalized intersection is always used to define the segment boundary. So, there has to be a signalized intersection in the segment boundary.

And second, only intersections at which the segment through movement we are taking a segment and we are talking about segment through movement is uncontrolled. For example, maybe to a stock control can exist along the segment between the boundaries. So, talking about to take a segment 2 boundaries are there.

So, we are saying only intersections at which the segment through movement is uncontrolled that kind of intersections can exist along the segment between the boundaries. When the segment is not within the coordinated signal system, then also certain rules may be applied to identify the segment boundaries. First and intersection having a control that can impose on the segment through movement illegal requirement to Stop or yield must always be used to define a segment boundary.

So, they are the segment boundary what kind of intersections will be there? Having a type of control that can impose on the segment through movement a legal requirement to stop or yield. It has to stop control or yield control. Another an intersection and which segment through movement at intersections and intersection at which the segment through movement is uncontrolled. That means, again to a stock control intersection example, may be used to define a segment boundary, but it is typically not done the first case is more common.

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Type of Control and System of Operation

- If the subject **segment is not within a coordinated signal system**, the following rules apply when the segment boundaries are identified:
 - ✓ An intersection having a type of control that can impose on the segment through movement a legal requirement to stop or yield must always be used to define a segment boundary
 - ✓ An intersection at which the segment through movement is uncontrolled (e.g., a two-way STOP-controlled intersection) may be used to define a segment boundary, but it is typically not done



Now, going to the type of analysis, what kind of analysis we want. So, what we discussed so far the background and then type of control and system of operation coordinated, non-coordinated and so, on.

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Type of Analysis



Type of Analysis

- The phrase 'analysis type' is used to describe the **purpose** for which a methodology is used.
- Each purpose is associated with a different level of detail, since it relates to the **precision** of the input data, the **number** of default values used, and the **desired accuracy** of the results
- Three analysis types are recognized:
 - ✓ Operational
 - ✓ Design and
 - ✓ Planning and preliminary engineering



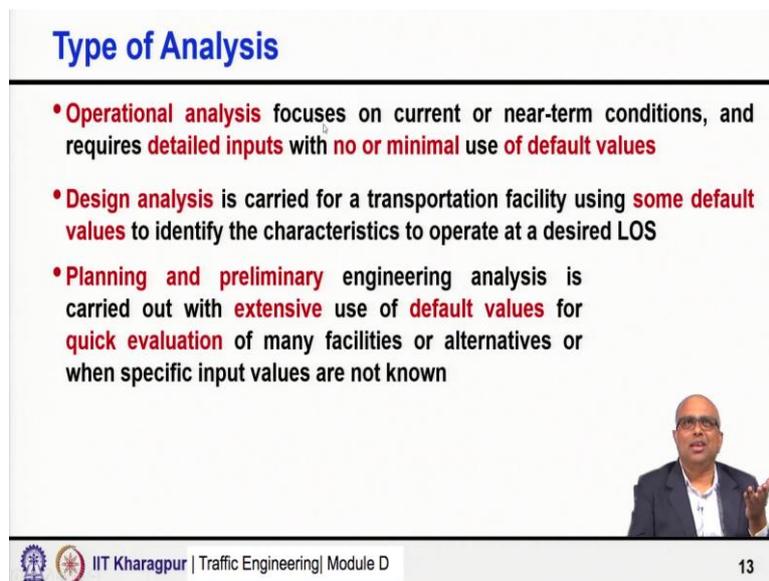
The type of analysis, the phrase analysis type is used to describe the purpose for which the methodology is for what purpose we are doing this analysis. So, the purpose will determine what kind of analysis is required and each purpose is associated with a different level of detail. The purpose will determine or influence or control what level of detail is required.

Since it relates the precision of the input data also will dictate how much precision data is required. How many default values can be assumed for analysis or I have to go on to the field and everything context specific data I have to get and how much accuracy I require for better analysis. It depends on the level of detail.

It is all included developed detail or the purpose, some purposes maybe a more detailed analysis is required, a more much more accuracy, higher accuracy is expected, but for certain other kinds of purposes, the required accuracy may not be that high. So, there are 3 analysis types that recognized. Operational, the most detailed ones obviously, practically everything you want to collect from the field because there is operational level analysis, then design level analysis and planning and preliminary engineering analysis.

Now, when it is planning and preliminary engineering, many things are not even known, we may have certain forecast, certain specifications, certain ideas, so, many things we can assume. Simpler analysis we can do, because my purpose is to do a planning and preliminary engineering level analysis. But, if I want to do operational level analysis, then I have to go for a more rigorous database I cannot assume much and the methodology also has to be different for different types of analysis.

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Type of Analysis

- **Operational analysis** focuses on current or near-term conditions, and requires **detailed inputs** with **no or minimal use of default values**
- **Design analysis** is carried for a transportation facility using **some default values** to identify the characteristics to operate at a desired LOS
- **Planning and preliminary** engineering analysis is carried out with **extensive use of default values** for **quick evaluation** of many facilities or alternatives or when specific input values are not known

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Operational analysis focuses on current or near-term conditions and requires detailed inputs as I said, we practically no or minimal use of default values, it will not work that I will assume many things. We cannot assume because it is operational level analysis, you go to the field and get the data. So, data collection effort and more rigorous data more rigorous analysis also needs to be done.

Design analysis is typically carried out for a facility using some default values, not like operational analysis, where we practically do not use any default value or make a minimum. But here some default values to use and it is used to identify the characteristics of the facility which are expected to operate at a desired level of service. Characteristics of facilities, which are expected to operate at a desired LOS.

That is the desired level of analysis. Planning and preliminary engineering level analysis is carried out with extensive use of default values here we use extensive default values because it is at the planning stage. So, many things are not available, you may not go to be able to go to the field and measure it and some of the things you might have decided also, some decisions have been made. So, largely or extensively we are using default values.

And the basic aim is to do a quick evaluation of many facilities or alternatives. That is what is done planning level always we do that, we want to evaluate alternatives, not we are going for a detailing. So, the purpose is quick evaluation of many facilities or alternatives or when specific input values are not known.

So, it is a quick kind of analysis, simple analysis and without using extensive field data, because field data may not be available also. So, a lot of default values for use.

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LOS Criteria

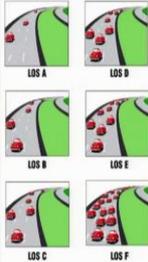


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LOS Criteria

Motorized Vehicle Mode

- Two performance measures are used to characterize vehicular LOS for a given direction of travel along an urban street segment
 - ✓ **Travel speed** for through (TH) vehicles: Reflects the **factors** that influence **running time** along the link and **the delay incurred** by TH vehicles at the boundary intersection
 - ✓ **Volume to capacity ratio (v/c)** for TH movement at the downstream boundary intersection to reflect the **degree of mobility** for the segment



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Type of Control and System of Operation

- The methodology focuses on evaluation of motorized vehicle performance for a street segment bounded by intersections that can have a variety of **control types and systems of operation**
- **Types of control** used at the intersections: signalized, two-way STOP-controlled, all-way STOP controlled, or a roundabout
- **Systems of operation:** Coordinated and non-coordinated
 - ✓ Analysis of coordinated systems **recognizes the influence of an upstream signalized intersection on the performance** of the street segment
 - ✓ Analysis of non-coordinated systems considers that **arrivals to a boundary intersection are random**



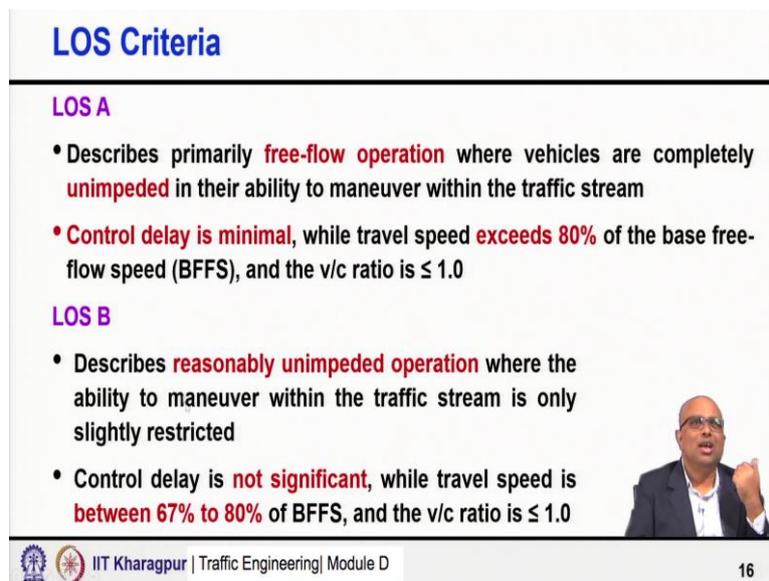
Now, going to deal with LOS criteria. As I said, our focus is on the street segments. And also as I said that our focus is basically the street segments and also the motorized vehicle. So, the LOA is also based on that. Now, 2 performance measures are used to characterize vehicular LOS for a given direction of travel along an urban street segment.

If we know how to calculate the or decide the LOS, 2 predominant performance measures, others are also there we will discuss later. A few other things also where we can see that as possible methods and are considered also but for here, say what is then the LOS, we are using 2 specific performance measures. One is travel speed for through vehicle because it is the segment and the through vehicle is the primary objective or our focus.

So, through vehicle travel speed while you are interested because it reflects the factors that influence the running time along the link and the delay incurred by through vehicles at the boundary intersections. Second, volume to capacity ratio for through movement at the downstream boundary intersection to reflect the degree of mobility for the segment, how much that it is loaded. Is it loaded more than the capacity or it is within the capacity?

Because the effects are going to be very different. So, considering travel speed and volume to capacity the issue. Six levels of service are defined as follows.

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LOS Criteria

LOS A

- Describes primarily **free-flow operation** where vehicles are completely **unimpeded** in their ability to maneuver within the traffic stream
- **Control delay is minimal**, while travel speed **exceeds 80%** of the base free-flow speed (BFFS), and the v/c ratio is ≤ 1.0

LOS B

- Describes **reasonably unimpeded operation** where the ability to maneuver within the traffic stream is only slightly restricted
- Control delay is **not significant**, while travel speed is **between 67% to 80%** of BFFS, and the v/c ratio is ≤ 1.0

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LOS a primarily free flow operations vehicles are completely unimpeded in their ability to maneuver within the traffic stream. Control delay, it is one type of delay, we will discuss what is exactly control delay in some other lecture, when we talk about the intersections and signalized intersections particularly in Module-E.

And the travel speed exceed 80 percent of the basic base free flow speed, you are you already know what is BFFS base free flow speeds, we discussed earlier about various other segments. So, here also there is a value for BFFS. So, the travel speed is more than 80 percent of the BFFS. And obviously, all cases from LOS A to E, v by c ratio is less than 1 less than equal to 1. So, A, B, C, D all cases it has to be less than 1 and E maybe near capacity.

LOS reasonably impeded operation reasonably unimpeded operations and for the ability to manage our traffic stream is only slightly restricted here it was like free flow, slight deterioration has happened, but still reasonably unimpeded operation and control delay again is not so significant, lower site. Travel speed is between 67 percent to 80 percent, here it was more than 80 percent, here it is in the range of 67 to 80 percent and v by c ratio as you see a less than 1.

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LOS Criteria

LOS C

- Describes **stable operation** where the ability to maneuver and change lanes at mid-segment locations may be more restricted than at LOS B
- Longer queues at boundary intersection may contribute to lower travel speeds; travel speed is between **50% to 67% of BFFS**, and v/c ratio is ≤ 1.0

LOS D

- Indicates a **less stable condition** in which small increases in flow may cause substantial increases in delay and decreases in travel speed
- Due to adverse signal progression, high volume, or inappropriate signal timing, travel speed is between **40% to 50% of BFFS**, and v/c ratio is ≤ 1.0



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C, stable operation, where the ability to maneuver and change lane at mid-segment location may be more restricted than what was there under LOS B and share the travel speed is somewhere between 50 to 67 percent of BFFS and v by c ratio still less than 1.

LOS D is relatively less stable condition in which the small increase in flow may cause substantial increase in delay and have a larger impact on the travel speed, travel speed will come down and due to adverse signal progression, high volume or inappropriate signal timing travels speed is somewhere between 40 to 50 percent. Further going down, but still the volume to capacity the issue is not more than 1.

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LOS Criteria

LOS E

- Characterized by **unstable operation** and **significant delay**
- Due to some combination of adverse progression, high volume, and inappropriate signal timing at the boundary intersection, travel speed is between **30% to 40% of BFFS**, and v/c ratio is ≤ 1.0

LOS F

- Characterized by **flow at extremely low speed** and **congestion** likely occurs at the boundary intersection, which is indicated by **high delay** and extensive **queuing**
- The travel speed is **30% or less of BFFS**, or and v/c ratio is > 1.0



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E, characterized by unstable operation almost near capacity and therefore significant delay will be there. And due to some combination of adverse progression, high volume and inappropriate signal timing in the boundary intersection travel speed is only in the range of 30 to 40 percent of the BFFS just come down to (29:33).

And F for flow. Here, first take the v by c the ratio is greater than 1. So, it is characterized by flow at extremely low speed and condition likely occurs at the extreme at the bounded intersection, which is indicated by high delay and it extensive queuing. So, overall speed is below 30 percent of the BFFS. That is the way the whole LOS different levels of service are defined and described.

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LOS Criteria

LOS Thresholds Established for the Motorized Vehicle Mode on Urban Streets

LOS	Travel Speed Threshold By Base Free Flow Speed (mi/h)							v/c ratio*
	55	50	45	40	35	30	25	
A	> 44	> 40	> 36	> 32	> 28	> 24	> 20	≤ 1.0
B	> 37	> 34	> 30	> 27	> 23	> 20	> 17	
C	> 28	> 25	> 23	> 20	> 18	> 15	> 13	
D	> 22	> 20	> 18	> 16	> 14	> 12	> 10	
E	> 17	> 15	> 14	> 12	> 11	> 9	> 8	
F	≤ 17	≤ 15	≤ 14	≤ 12	≤ 11	≤ 9	≤ 8	
F	Any							> 1.0

Note: *v/c ratio of through movement at downstream boundary intersection
Source: Exhibit 18-3, HCM 2016



So, these are the threshold value as given in exhibit 18-3 Highway Capacity Manual 2016. You can say A, B, C, D, E, F, except for F all within 1 v by c ratio, v by c ratio greater than 1 means straight way LOS F. So, within 1, 5 levels of service threshold speed are given different BFFS value base free flow speed 55, 50, 45, 40, 35, 30 up to 25 mile per hour then, what is the threshold value for different levels of service?

Say for example, if the base free flow speed is 50 mile per hour, then anything greater than 40 mile per hour average speed is actually always a, a greater than 34 less than 40 somewhat deep and so on.

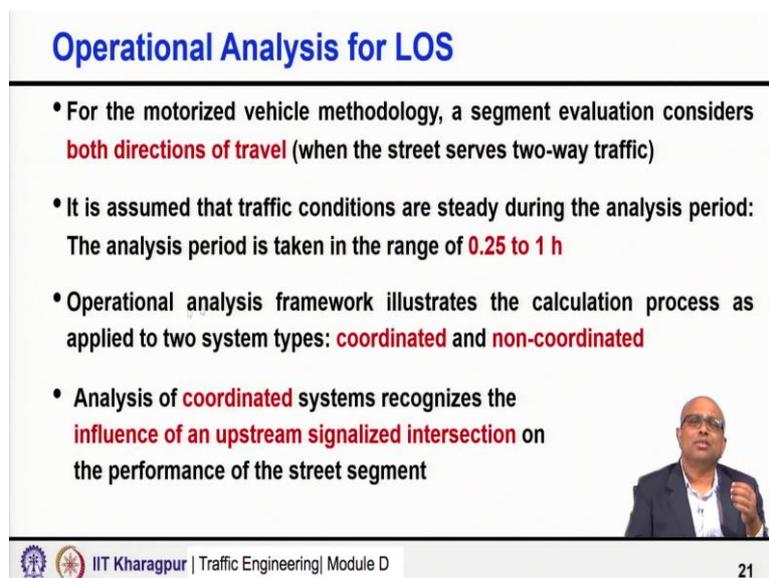
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Operational Analysis for LOS

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Operational Analysis for LOS

- For the motorized vehicle methodology, a segment evaluation considers **both directions of travel** (when the street serves two-way traffic)
- It is assumed that traffic conditions are steady during the analysis period: The analysis period is taken in the range of **0.25 to 1 h**
- Operational analysis framework illustrates the calculation process as applied to two system types: **coordinated** and **non-coordinated**
- Analysis of **coordinated** systems recognizes the **influence of an upstream signalized intersection** on the performance of the street segment

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A small inset image of a man in a suit and glasses is visible in the bottom right corner of the slide.

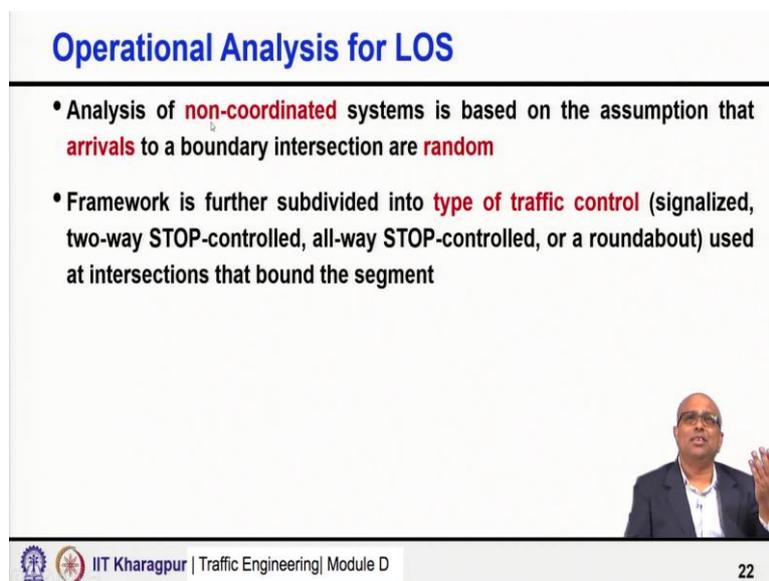
Now, going to operational analysis of level of service as I said earlier the analysis could be operational level analysis or it could be planning level analysis. First the operational level analysis. For motorized vehicle methodology, we are focused is motorized vehicle and segments. A segment evaluation considered both directions of travel when the street serves two-way traffic. Earlier this is a change in this highway capacity manual 2016 as compared to the previous version.

So, when we are two-way streets, two-way traffic then for motorized vehicle methodology we consider both directions of travel because there are interdependence. Also it is assumed that traffic conditions are steady during the analysis period, no systematic change happens during that analysis period, stochastic variations that anyhow will be there.

So, it is assumed that the traffic conditions are steady and typically analysis period is taken as 15 minutes to 1 hour most cases we take even 15 minutes, but range is actually 15 minutes to 1 hour. And as I said the operational analysis framework what we are going to discuss. In that the calculation process whatever we are going to say is applicable for both systems, both coordinated and non-coordinated systems.

Analysis of coordinated system recognizes the influence of upstream signalized intersection on the performance of street segments I mentioned this earlier also.

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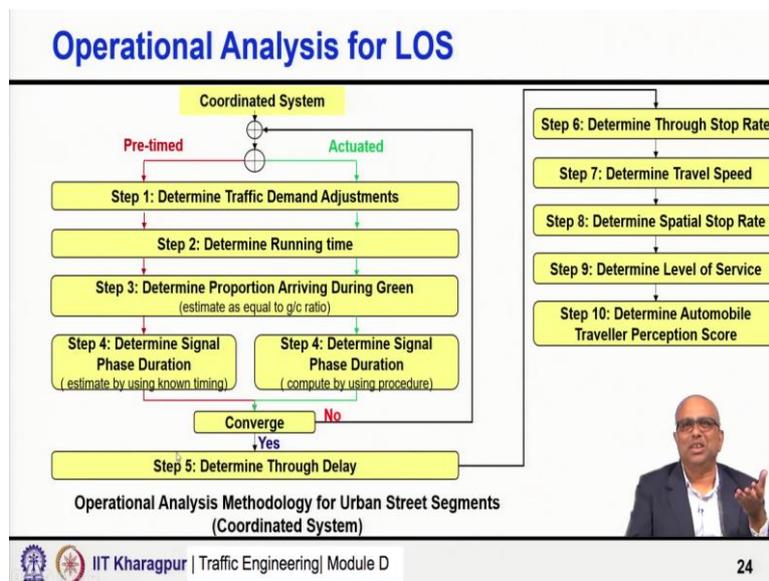
Operational Analysis for LOS

- Analysis of **non-coordinated** systems is based on the assumption that **arrivals** to a boundary intersection are **random**
- Framework is further subdivided into **type of traffic control** (signalized, two-way STOP-controlled, all-way STOP-controlled, or a roundabout) used at intersections that bound the segment

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And when we are analyzing non-coordinated system, the basic assumption is that arrival to boundary intersections are random because the signals are not correlated. So, always by default for non-coordinated operations that is the basic assumption. So, here also we make that same assumption. Framework is further subdivided into type of control could be signalized two-way control, all-way stop control like that used at intersections that bound that segment.

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Operational Analysis for LOS

- The methodology is iterative within Steps 1 to 4, with convergence achieved when the predicted discharge volume, phase duration, and capacity from successive iterations are effectively in agreement
- **Several iterations** are typically needed for **coordinated** systems
- Only **one iteration** is needed for **non-coordinated** systems unless there is a downstream lane closure
- In case of downstream lane closure, multiple iterations are needed to ensure that the vehicle discharge upstream of the lane closure do not exceed the lane closure capacity

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Now, here I am going to discuss briefly what you can see this is the non-coordinated system again it could be pre-timed or actuated pre-time teams taking the average suppose you are doing it for the peak hour. So, what is the average peak hour flow from different approaches in a signal and for the typical peak hour flow, you actually design it and operate everyday with that or during that entire time with the same signal setting.

But actually there will be stochasticity volume may change, so many reasons also. So, every green time whatever giving every cycle may not require that much green time. Sometimes every cycle may not even the green time what you were getting may not be adequate for every cycle also, some cases the demand may go up, some cycle the demand may go down.

So, if you can make it actuated that means, as from sensory we are getting the inputs accordingly the whole system is getting optimized based on real time data. Now, actuate it could be in so many ways actuation may occur partly actuated, fully actuated operations, we shall again discuss things in details in Module-E.

But here I just wanted to mention pre-time means fixed inputs we are assuming during that entire period say peak hour means the entire peak hour every day same. So, same signal setting we are operating. Actuated means, it could be as we are getting the inputs on a real time basis from sensors accordingly the whole control is happening the cycle length or and maybe the green time, fizing everything will change detailing will be changed accordingly.

So, for both cases we can do step one is determined traffic demand analysis, traffic demand adjustment, what of adjustment we need to do in the traffic demand considering capacity considering other factor, then determine the running time. Step three, determine proportion arriving during green that is very important for signal control.

And then step four includes determine signal phase duration here also the same, then we check for that the convergence has happened. If no then we are again going back doing again necessary adjustment in the traffic demand and keep on repeating this procedure unless the whole thing is stabilized. And once convergence has happened, then we calculate the through delay and if it is also since it is non coordinated system the intersection could be stopped controlled, yield controlled or even uncontrolled.

So, in that case, this signal part determine the proportion arriving during green phase determination all these need not be done. So, directly we can come from the step 2 to step 5 to determine the through delay. And then once the delay is known, then we want to determine the through stop rates then, the travel speed is determined. Also the special stop rate and then accordingly determine the level of service.

Then also as I said that LOS definitely is important, but traveler's perception may depend on not only the travel speed, but many other factors, the special stop rate all these that is why we have calculated. So, we can also calculate the automobile travel app, overall perception score how good or bad they think, we can express it not only in terms of level of service, but also based on perception score.

Now, the methodology for coordinated signal system is the steps are more or less same. Except the fact that since it is coordinated system, there cannot be stopped yield or uncontrolled intersections. So, what we consider here is that link is omitted otherwise the steps are same. Now, the methodology as you can see is iterative up to step 1 from step 1 to step 4 and then we are checking this convergence, if not then we are going back, if no we are going back, if no we are going back.

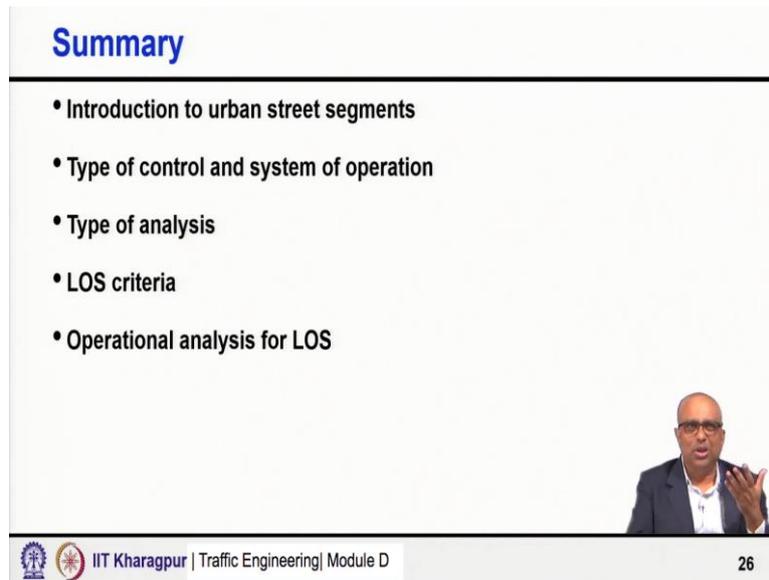
Only we are coming out when the answer is yes, the convergence has happened to step 1 to step 4 therefore, is clearly iterative in nature. With convergence achieved the same convergence yes or no what we mean by convergence? Convergence mean when the predicted discharge volume, phase duration and capacity, discharge volume, how much is the discharge volume, hat is the phase duration, and what is the capacity that we are calculating at different steps.

When from successive iterations, the calculations do not change then we say that it is effectively in agreement. So, then it is yes otherwise do further adjustment. Normally several iterations are typically needed for coordinated system to stabilize the process stabilize this values as I say, the predicted discharge volume phase duration and capacity, but generally only one iteration is needed for non-coordinated system unless there is a downstream closer, downstream closer that means, what happens LN may be closed downstream.

So, in that case we may require multiple iterations to ensure that the vehicle discharged upstream of the lane closer do not because their capacity will be more but there is a bottleneck. So, the vehicle discharged upstream of the lane closer we have to check so, that that do not exceed the lane closer capacity. Ultimately, what can get discharged is only the lane closer capacity.

So, the upstream vehicle discharged upstream of lane closer do not exceed that lane closer capacity that has to be maintained. So, he may require multiple iterations.

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Summary

- Introduction to urban street segments
- Type of control and system of operation
- Type of analysis
- LOS criteria
- Operational analysis for LOS

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So, altogether what we discussed in today's lecture is that it gave you introduction to urban streets segment, discussed about various types of control and various systems of operations, systems mean coordinated, uncoordinated both. Then we talked about types of analysis, planning level analysis, design level analysis and operational level analysis mentioned about the LOS criteria and how the LOS is defined or described and then just indicated to you the operational analysis framework.

Now, in the next lecture, I am going to discuss a little bit more about each of these 10 steps. I only mentioned to you the flowchart today and just mentioned to you about the steps. Further description discussion we shall make in the next class. Thank you so much.