

**Traffic Engineering**  
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**Lecture 26**

**Analysis of Multi Lane Highways (As per Indo HCM, 2017)**

Welcome to Module D, Lecture 11. In this lecture we shall discuss about analysis of Multi lane highways as per Indo Highway Capacity Manual., 2017.

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### Recap of Lecture D.10

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- Introduction to Indo HCM (2017)
- Capacity and LOS estimation of single lane, intermediate lane and two lane roads
  - ✓ Stream equivalency factor
  - ✓ Base capacity estimation
  - ✓ Adjustment factors
  - ✓ LOS estimation
  - ✓ Applications



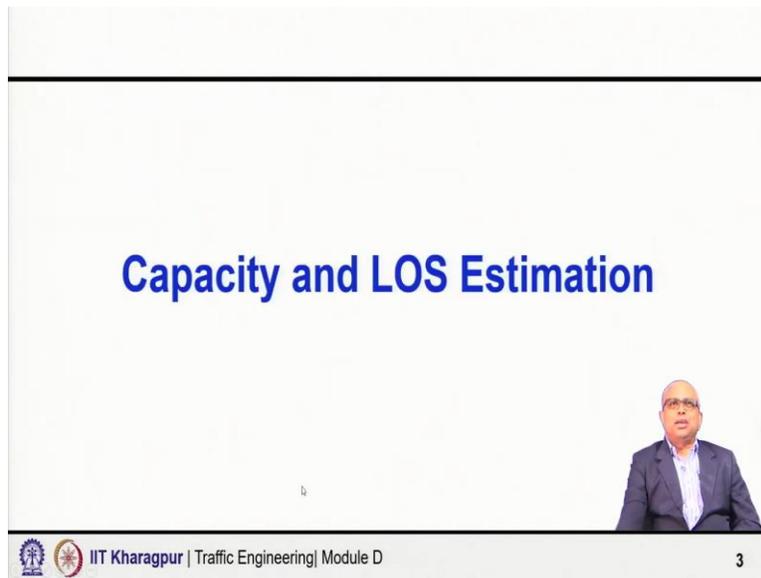
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In lecture 10, I introduced to you to Indo HCM. Why, what was the context for development of Indo HCM, and mainly discussed about the capacity and LOS estimation of undivided interurban roads, namely single lane, intermediate lane and two land roads. All these are undivided roads.

Then various key concepts, for example, the concept of stream equivalency factor, which is newly introduced in Indo HCM, then base conditions, how we estimate the capacity under base condition, relating it to operating speed for cars, standard cars.

Then whatever base capacity we estimate, how various adjustment factors are applied on that to account for the capacity under prevailing conditions, and then how we are estimating the LOS for undivided interurban facilities, and then took some example problems to explain you how for undivided road segments, we can calculate the level of service.

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Now with this background, today, we shall discuss about multi lane highways, how the multi lane highway segments can be analyzed as per, again, Indo HCM 2017.

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## Capacity and LOS Estimation

- **Uninterrupted flow segments** of multilane divided interurban highways operating under mixed traffic conditions
- Segments with no fixed causes of delay or interruption external to the traffic stream
  - ✓ Median openings spaced at least 1 (one) km apart
  - ✓ No major access roads connecting to the highways in those segments
  - ✓ Minor access roads joining such highway segments are catering to a substantially low volume of traffic throughout the day



In Indo HCM, multi lane highway segments for divided interurban highways operating under mixed traffic conditions prevailing in Indian condition, this is analyzed or this multi lane segments are analyzed considering uninterrupted flow facilities, considering them as uninterrupted flow facilities. That means these are the segments where there is no fixed causes of delay or interruption, external to traffic stream. That is as per the definition of uninterrupted flow facilities.

Considering a realistic situation, which can be considered as uninterrupted flow segments, there are certain aspects which are highlighted. For example, median openings spaced at least 1 kilometer apart, because often there are median openings which are placed on multi lane highways which are not really expressway category, but these are general multi lane highways so there are median openings, and what we are saying that if you are analyzing a segment as uninterrupted flow segment, then median openings at least should be 1 kilometer apart.

Similarly there should not be any major access roads connecting to the highway in those segments. There could be minor roads which are joining such highway segments but in all those minor roads, the traffic volume is substantially low throughout the day. So that means the volume of traffic is so negligible, which is entering or exiting highway, practically the operation on the facility is not interrupted to that extent by external

factors. So we can eventually consider it as uninterrupted flow facility. (Refer Slide Time: 04:42)

### Capacity and LOS Estimation

- Capacity and LOS analysis for four lane and six lane divided interurban highways in **plain and rolling terrains** (not in mountainous and steep terrains)
- Capacity values and LOS criteria estimated for multilane divided highways are not applicable for the expressways in India: Both are divided facilities but the major difference is in **nature of traffic and access control**



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So with this now, one more or two more things which are very important before I proceed further, one is that the capacity and LOS for four lane and six lane divided interurban Highways which are included in the manual, Indo HCM, all those roads are considered to be in plane and rolling terrain because such kind of four lane, six lane road in mountainous and steep terrain is very rare.

So the analysis capacity and LOS analysis which is presented, it is presented for four lane and six lane divided interurban roads only in plane and rolling terrain, not in mountainous or steep terrains. Second, the capacity values and LOS estimated for multilane divided highways as per the methodology what we are going to discuss are not applicable for the expressways in India.

Interurban expressways are also there, at least those categories of road are considered as a category, a separate category. And why the capacity values and LOS criteria are not applicable? Because although both are divided facilities, expressways are also divided facilities. But the major difference is in the nature of traffic and access control.

The kind of access control what we consider in multilane highways, there are multiple connections. Maybe the minor connections are there, traffic volume is not significant, so we consider them to be, like in a uninterrupted facility, facility but the level of access control on multi lane highways and level of access control on expressway, interurban expressway is not comparable, because in, interurban expressways are completely access controlled facilities.

The second thing the nature of traffic is also very different. Highway, multi lane highway also cater to long distance traffic, so mobility is very important. But often, because of too many connections, presence of junctions, at great junctions, and so, and also the land use, the kind of there is no fencing or barricading normally along these highways, dense development, roadside development in Indian condition.

So you will also find for some segments there may be completely, local traffic is segregated, but for some segments maybe part of the local traffic is also using the highway getting mixed up with the long distance traffic. So the type of vehicles are quite wide, in a quite wide range, little slow moving to fast moving, everything is there, size to nature of the acceleration, deceleration, speed capability, everything is different.

So the, the nature of traffic and also the nature of access control, both things are not comparable in these two types of facilities, that is, interurban multilane highways and interurban expressway. So the methodology what we are going to discuss now, that methodology for capacity estimation and LOS or the values also, right, particularly the values.

Methodology, many cases the steps, some steps might be similar, many of the steps also could be similar, but the values what we are going to see these are applicable only for multi lane highways, which segments, which can be considered to operate under or considered operating under uninterrupted flow facilities, as uninterrupted flow facilities, and these are not applicable for expressways in India. That, we must understand clearly.

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## Capacity and LOS Estimation

### Base Conditions

- Plain and level terrain
- No horizontal curve or vertical gradient
- Traffic lanes 3.5 m wide
- Paved shoulders of minimum 1.5 m followed by unpaved shoulders
- Minimum median width is 2.5 m
- IRI less than 2.7 m/km
- No direct access points
- No side friction
- No accidents at the time of investigation



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Like the undivided roads, here also the base conditions are defined. For example, like what are the base conditions, again? Nearly idealized situations. For example, the road is passing through plane and level terrain, no horizontal curve, no vertical gradient, traffic lanes exactly 3.5 meter wide, not less than that, paved shoulders of minimum, paved shoulders of minimum 1.5 meter followed by unpaved shoulder, minimum median width is 2.5 meter.

IRI roughness, indicating the surface condition, IRI less than 2.7 meter per kilometer, no direct access point, no side friction, no accident at the time of investigations. So all these describe the base condition or nearly idealized scenario. And as usual, we first focus on base condition, and then try to apply necessary corrections to reflect the prevailing condition or to represent the prevailing condition.

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## Capacity and LOS Estimation

### Methodology

- Analysis of **existing** facility or **new** facility
  - ✓ **Existing facility:** For determination of performance of an existing segment under existing or projected traffic demand. The effect of several other design features on capacity and LOS can be assessed.
  - ✓ **New facility:** For planning and designing a new facility for an estimated Average Daily Traffic (ADT). The details of geometry and other inputs can either be assumed or taken as recommended default values.
- Estimation of stream speed (**SMS**) for the development of speed-flow relationship of the section



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So the methodology for multi lane highways, which, which has been prescribed or described in the manual, this can be used for analysis of existing facility and also for new facility. When we are applying the analysis for existing facility, the focus is primarily on determination of performance of an existing segment, under existing or the projected traffic demand in the future, how the segment is operating now or the existing segment is expected to operate under projected traffic demand.

And since the road is existing already, the effect of several other design features, the effect of several design features on capacity and LOS can be assessed. That provides an opportunity. This provides an opportunity to actually assess the effect of several design features on capacity and LOS.

On the other hand, when we are applying the methodology on new facility, the basic purpose is planning and design of a new facility for a given or estimated ADT, Average Daily Traffic. This is a new facility we want to develop, which we know the, what is going to be the ADT. That, what ADT it has to handle, and therefore we want to assess, and basically try to see how many lanes we require, and such kind of questions we try to answer.

So the details of geometry and various other inputs we cannot go and measure from the field. It is not possible, the data available is limited. And most such data, we can either assume, that okay we want it to be like this, or we can take as recommended default values, that okay, whatever is the standard, we try to provide that. So many things are actually assumption.

Once we have decided the, what kind of, whether we want to apply this methodology for existing facility or a new facility, then the next step, general steps I am telling, is the estimation of stream speed. And here, what we mean by stream speed? Because it is actually SMS, Space Mean Speed, so I have written here as SMS. And why we need that?

Because generally for, what was done actually, how it was developed, because the data was collected at different traffic volume level and also the corresponding speed, because the speed-flow relationship was actually developed. Now once the speed-flow relationship is developed, we may simply use that later but when if you are trying to develop it obviously you need the speed, SMS at different volume levels.

Even otherwise also, if you want to analyze an existing road for a peak hour you need the, what is the speed and what is the flow. You need to calculate or measure the SMS, that is also required. And in this, all these cases these are uninterrupted facilities so flow equal to density into speed, and that speed is space mean speed. So that relationship is assumed, many cases the, the, it is also assumed that they follow this Greenshields model in terms of speed flow, flow density and speed density relationships.

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### Capacity and LOS Estimation

- Estimation of operating speed ( $V_{0.9}$ ): 85<sup>th</sup> percentile speed of standard cars under low volume conditions (i.e. time headway 8 seconds or more)
- Estimation of Passenger car unit i.e. **dynamic PCU values** or **stream equivalency factor** ( $S_e$ )
- Estimation of traffic flows: Collection of classified traffic volume data and estimating hourly flow in PCU/h using dynamic PCU values or  $S_e$
- Estimation of **base capacity**
- Estimation of **adjusted capacity**: Factors due to departure from base conditions e.g. horizontal curvature, gradient, road roughness, shoulder type and width, and median width



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Then the next step is estimation of operating speed, because you know the base capacity, as I have mentioned in earlier case also, undivided roads, for this divided multi lane highway segments also, the base capacity is related with the operating speed, which is 85th percentile speed of standard cars, that is, small cars, under low flow condition.

And as I have mentioned earlier, I want to repeat it again, that low volume condition means we are saying the time headway 8 seconds or more. So that in a way, represents the low flow condition. So we need to calculate the 85th percentile speed of standard curves and that we can take as operating speed.

Then, the next step is estimation of passenger car unit, because whether you want to develop speed-flow curve, or whether you want to assess the LOS for a given volume level, you have measured traffic in terms of the number of vehicles, under different categories. So we need to convert them into equivalent homogeneous streams using, in terms of want to express it in terms of PCU.

So there are two ways, as we have again discussed earlier, one is use dynamic PCU values. So many such similar segments multi lane, four lane, six lane divided roads were taken in different parts of the country, lot of data were collected, so composition was also

changing. So for a given or observed range of compositions, you take a vehicle type, it says what is the minimum share to what is the maximum share that is observed in the whole database, in different parts.

And then accordingly, what are the PCU values? So dynamic PCU values are given, say for a particular vehicle type, say for bus or bigger cars, the PCU value is from  $x_1$  to  $y_1$  or  $x_1$  to  $x_2$  for the composition of that particular volume, traffic time, vehicle time, varying from  $y_1$  to  $y_2$ .

So for a observed composition range, what is the PCU range, that is given. So one can use the dynamic PCU value or directly use stream equivalency factor, as I said, last class I discussed, in lecture 10, I discussed about this concept of stream equivalency factor. So you can directly use the stream equivalency factor to convert vehicles in terms of number to directly in terms of PCU.

So again, for four lane divided, six lane divided roads, so, how the stream equivalency kept factor can be modeled, those are also given. So you have a choice, either to use dynamic PCU value, use, values, or directly use the stream equivalency factor, use the equation, calculate the stream equivalency factor for a given situation, and use it. Then the next step is estimation of traffic flow.

Now, you have the, collected, classified traffic volume data, and also the stream equivalency factor or dynamic PCU value, so you are able to now express the traffic flow in terms of PCU per hour. Then the next step is with the  $V_{os}$  and the type of road and everything, you estimate the base capacity.

So the equations are also given, you use the base capacity, equation, appropriate equation you use, and calculate the base factor, based capacity then estimation of adjusted capacity. Adjusted capacity means, under prevailing condition, so we have to apply multiple factors to convert base capacity to adjusted capacity, for conditions such as horizontal curve, gradient, road roughness shoulder type and width, and median width, et cetera.

See normally, the carriageway width is not taken because, or lane width is not taken, because lane widths are for multi lane facility, not, is not, not really, non-standard. Everywhere you will find multi lane roads, 3.5 meter per lane. There, there is not much variation, so that is not included here.

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## Capacity and LOS Estimation

- Estimation of level of service
  - ✓ The service measures used for defining LOS for multilane divided highway are **density** and **volume-to-capacity (v/c) ratio**
  - ✓ Measure or estimate volume and SMS
  - ✓ Compute traffic density by dividing the equivalent **hourly flow** (PCU/h/direction) corresponding to peak hour with the **space mean speed** (km/h) of the traffic for the same duration
  - ✓ Estimate LOS using thresholds of **density** used for defining LOS boundaries (may also check using v/c ratio)



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So then the next step is actually estimation of level of surface. So what we did need to do that? Here, in this case the measure which is used is actually density, but like, as I discussed in two lane road, undivided road case, undivided segments, particularly two lane to a movement and intermediate lane also, that here the, although for multi lane highways, the measure is actually density but the v by c, corresponding v by c thresholds are also given.

It is again based on the data, based on the data and some further analysis, you are assuming this relationship in, in the, in the background that flow equal to speed into density, assuming Greenshields relationship, also you have so much data so you could also do, you could also carry out cluster analysis to see what are the corresponding threshold value. So as the density thresholds are also given, along with that volume to capacity thresholds are also mentioned, right.

So table will have the LOS A, B, C, D, E, and so, and then what are the density thresholds, what are the corresponding v by c threshold. v by c is, I say, is always very helpful for the practitioners. But remember that, the underlying basic measure that is considered for defining the level of surface, is the density. But you can also get the corresponding v by c thresholds because it is very easy for the practitioners if you are directly getting a v by c threshold value.

And for that also, of course, we need measure, to measure or estimate volume and SMS because once the volume and SMS only, you can measure. You cannot measure directly, the density. So density is measured indirectly from volume and specimen speed. And once you have done that, you have calculated the density, calculated volume to capacity ratio, then you compute the traffic density, as I said, and you just compare it with the threshold density values, and may also check using the v by c ratio. So one value you can take it as, for getting the LOS and another you can use for checking it.

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### Capacity and LOS Estimation

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#### Stream Equivalency Factor ( $S_e$ )

Four lane divided highway segments

$$S_e = 1 + 0.6 \cdot P_{BC} - 1.5 \cdot P_{2W} + 1.2 \cdot P_{AUTO} + 2.6 \cdot P_{LCV} + 4.8 \cdot P_{BUS} + 3.6 \cdot P_{TAT} + 59.8/N + 6.4 \cdot P_{MAT} \dots\dots(4.47)$$

Six lane divided highway segments

$$S_e = 1 + 0.7 \cdot P_{BC} - 2.1 \cdot P_{2W} + 1.2 \cdot P_{AUTO} + 3.3 \cdot P_{LCV} + 5.0 \cdot P_{BUS} + 4.8 \cdot P_{TAT} + 64.7/N + 7.5 \cdot P_{MAT} \dots\dots(4.48)$$

where,  $P_{BC}$  = proportion of big cars in traffic stream

$P_{2W}$  = Proportion of two wheelers

$P_{AUTO}$  = Proportion of auto rickshaws





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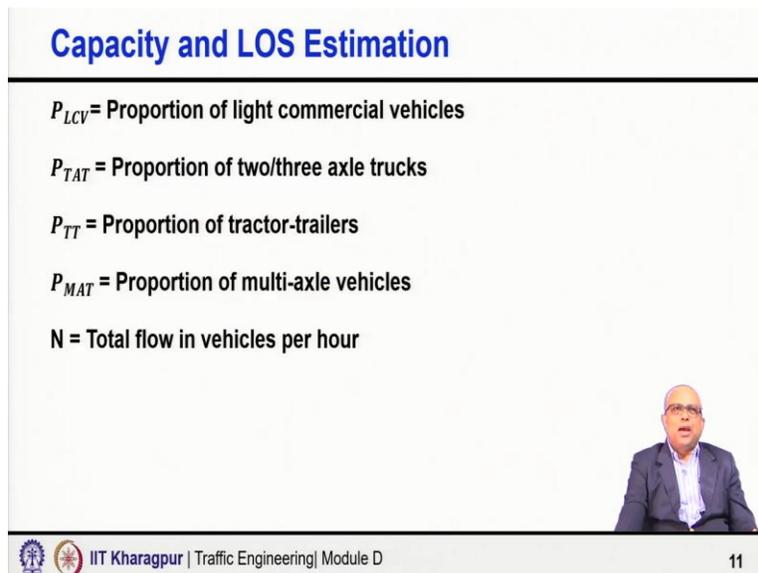
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So now, let us go back. So what are the key aspects? The stream equivalency factor, you already know what is stream equivalency, factor now these four lanes divided highway segments and six lane divided highway segment, these are the models which are, or

equations which are given for calculating the stream equivalency factor, for four lane and six lane divided highways, respectively, as I have shown in Equation 4.47 and 4.48.

So the proportion of different vehicles types and total number of vehicles and how they are getting related to explain the  $S_e$ , that is given. So directly, if I know, what is the total volume and number of vehicles, and if I know the proportion of different volume and the total volume, then I can simply use this proportion, number of total vehicle in this equations as appropriate, whether it is four lane or six lane divided highway, I can directly get the stream equivalency factor.

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**Capacity and LOS Estimation**

$P_{LCV}$  = Proportion of light commercial vehicles

$P_{TAT}$  = Proportion of two/three axle trucks

$P_{TT}$  = Proportion of tractor-trailers

$P_{MAT}$  = Proportion of multi-axle vehicles

$N$  = Total flow in vehicles per hour

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## Capacity and LOS Estimation

### Base Capacity Estimation

Four lane divided highway segments

$$C = 30 \times V_{os} + 1540 \dots\dots(4.49)$$

Six lane divided highway segments

$$C = 43 \times V_{os} + 2490 \dots\dots(4.50)$$

Base Capacity Values for Varying Operating Speed

Operating Speed (Km/h)	Capacity (PCU/h/direction) Divided Segments	
	Four Lane Highway	Six Lane Highway
70	3640	5500
80	3940	5930
90	4240	6360
100	4540	6790

Source: Table 3.6, Indo HCM, 2017



Then the base capacity estimation, like in previous case, and also as I explained just now, the base capacity for four lane and six lane divided highway segment is expressed in terms of the operating speed. So once the operating speed, for full lane divided highway use equation 4.49, or six lane Highway, use equation 4.50.

These equations are, for my Module D, so it is 4 point, and then I am continuously using the number. If you actually go to Indo HCM, the number may be, equation number may be different. And obviously, it will be different, not maybe but it will be different. So you can use these equations, once you know the operating speed, you can calculate the base capacity.

Now to, so that you get a feel, I have also reproduced the value from table 3.6, Indo HCM, 2017, for Indo HCM, 2017, for various operating speed like 70 kilometer per hour, 80 kilometer per hour, 90 kilometer per hour, 100 kilometer per hour, then what is the base capacity for four lane highway and six lane highway, and these values are actually capacity PCU, per hour per direction.

So if we are considering four lane highway, that means the total capacity in one direction which includes two traffic lane is given here. Similarly, six lane in one direction mean this

is the total capacity in PCU in one direction which includes three lanes. So you can see how the, get a feel about the capacity values.

And in between, suppose I want to get something between 70 and 80 for four length highway, I can interpolate the values and get it. Or, if it is four lane, I can directly use this Equation 4.49 to calculate my values, both options are there.

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## Capacity and LOS Estimation

### Adjustment Factors

Gradient, Curvature and Roughness

Four lane divided highway segments

$$V_{OS_{adj}} = V_{OS_{base}} - 4.7 \times IRI - 0.6 \times GR - 0.03 \times CU \dots\dots(4.51)$$

Six lane divided highway segments

$$V_{OS_{adj}} = V_{OS_{base}} - 1.2 \times IRI - 0.4 \times GR - 0.06 \times CU \dots\dots(4.52)$$

Where, IRI = International Roughness Index in m/km  
(no adjustment required for IRI  $\leq$  2.7 m/km)

GR = Gradient in %

CU = Curvature in degree/km



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Then, as I said, we need to apply lot of adjustment factor, what is observed from the data the gradient curvature and roughness, these have got direct impact on the operating speed. And operating speed also influence the capacity. So the corrections are actually applied on operating speed, so that you use that adjusted operating speed in the previous equation, as I have said, and you get the actual capacity.

So these connections are, as I said, two different equations are given as shown here, one for four length divided highway, another for six lane divided highway, and the connections with respect to IRI International Roughness Index, with respect to gradient and with respect to curvature. Now, curvature is expressed in degree per kilometer, gradient in percentage, and IRI, no adjustment is required for IRI if it is less than 2.7 meter per kilometer, otherwise you need adjustment.

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### Capacity and LOS Estimation

- In case of a new highway facility, operating speed of base section can be assumed as the operating speed obtained from a similar highway facility

**Shoulder Width and Median Width**

**Four lane divided highways**

$C_{adj} = C + 188 \times PSW + 170 \times UPSW + 74$  .....(4.53) When median width  $\geq 2.5$  m

$C_{adj} = C + 188 \times PSW + 170 \times UPSW$  .....(4.54) When median width  $< 2.5$  m

**Six lane divided highway**

$C_{adj} = C + 153 \times PSW + 64 \times UPSW$  .....(4.55)

Where, C = base capacity, PSW = Difference between actual and base width for paved shoulder (m) (**Actual Width - 1.5 m**); UPSW = width of unpaved shoulder in m



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So in case of new highway facility, if it is an existing, you know the operating speed, you can go and measure, and then actually say what is the operating speed. If it is a new facility, then operating speed for base condition can be assumed as the operating speed as you are obtaining or as you observed in similar highway facility.

Now, coming to the capacity adjustment. Capacity adjustment also need to be done, not for the, directly for the gradient curvature and roughness. Here, you adjust actually the operating speed, and then operating speed is going as input for base capacity estimation so that way the effect is taken. Separately, directly on capacity, the influence is PSW and UPSW.

PSW is basically the shoulder width, paved shoulder, paved should width, PSU, and the UPSW is the unpaved shoulder width. And these, are for four lane highways, different equations are given for different median width. If the median width is greater than 2.5 meter, then you use equation 4.53, if it is less than 2.5 meter, you use 4.54, and one equation is given on six lane divided highway. When you are making six lane, normally there is no such issue with the median, largely. There is no such issue with the median.

Now, as I said that in, all these equations C is the base capacity, then PSW is the difference between actual and the base width for pavement shoulder, for example, base width for pavement shoulder what we assume 1.5 meter paved shoulder, so what is the actual paved shoulder width in meter? Minus 1.5, that in meter will go as input for all these equations, 4.53, 4.54 and 4.55. And UPSW is the width of the unpaved shoulder in meter.

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## Capacity and LOS Estimation

### LOS Estimation

#### Four lane divided highways

LOS	Density (PCU/km/direction)	V/C Ratio	Service Volumes (PCUs/day)	Recommended DSV Value for Upgradation (PCU/day)
A	≤ 18	0.00-0.20	≤18000	22500 PCU/day @ LOS-B: Suggested threshold flow for conversion from four lane to six lane divided road to ensure enhanced safety in traffic operations
B	19-27	0.21-0.30	18001-27000	
C	28-45	0.31-0.50	27001-45000	
D	46-64	0.51-0.70	45001-63000	
E	65-90	0.71-1.00	63001-90000	
F	>90	>1.00	>90000	

Source: Table 3.8, Indo HCM, 2017




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Now, once you have done that, all, what you need to know little bit what I have not mentioned is the LOS threshold, that I am showing here. LOS A, B, C, D, E, V by C is always very important because V by C greater than 1 means it is LOS safe. So that way, straightaway you can say that it is LOS safe.

So here, the density, PCU per kilometer per direction, these thresholds values are given for A, B, C, D, E and also for F, and the corresponding V by C ratio, as I said that for practitioners you will always, for nearly all different types of segments, which are analyzed and included in Indo Highway Capacity Manual, they try to give the corresponding V by C ratio values because it is, the professionals, it is very easy.

Because finally whatever maybe you take, you take the density, but how the density gets related? So because the flow is something, traffic volume measurements and converting

to PCU, that is something which is very easy. So if there is a corresponding V by C thresholds are also there, it is very easy. So here, the limiting service volumes are also given, as show.

And the recommended design service volume is mentioned here, I have reproduced, this is taken as LOS-B, so that is the threshold which is taken for further improvement or upgradation of the road. And it is take expressed normally as per Indian convention, expressed per day, but as you know, the capacity is normally expressed in PCU per hour, but there is a relation between the ADT and the peak hour traffic or the design hourly volume, and this, all these relations are inbuilt.

So this is again expressed so that you calculate the AADT or ADT and then directly you can compare. So, what is my daily traffic volume and what is the DSB that is recommended, and then accordingly, you can decide what upgradation is necessary, if, if it is required.

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### Capacity and LOS Estimation

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**Six lane divided highways**

LOS	Density (PCU/km/direction)	V/C Ratio	Service Volumes (PCUs/day)	Recommended DSV Value for Upgradation (PCU/day)
A	≤ 27	0.00-0.20	≤ 27000	34000 PCU/day @ LOS-B: Suggested threshold flow for conversion from six lane to eight lane divided road to ensure enhanced safety in traffic operations
B	28-41	0.21-0.30	27001-41000	
C	42-68	0.31-0.50	41001-68000	
D	69-95	0.51-0.70	68001-95000	
E	96-136	0.71-1.00	95001-136000	
F	>136	>1.00	>136000	

Source: Table 3.9, Indo HCM, 2017




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So similarly, this is the table for six lane divided highways, only the threshold values are different, but nothing much to explain.

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### Capacity and LOS Estimation

**Example 1:** Determine capacity and level of service for a four-lane divided highway in plain terrain with the following characteristics:

- $V_{os} = 100$  km/h (Base section)
- Lane width = 3.5m
- Gradient=1.4%
- Total vol=1250 vehicles/hour/dir
- SMS=40km/h
- Traffic composition (Veh/h/dir): SC=431, BC=256, TW=282, LCV=49, TAT=24, MAT=61, AUTO=86, BUS=61
- Paved shoulder width=0.5m
- Median width=1.5m
- Curvature=172.5 degree/km
- IRI = 3.6m/km



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Now coming to an application part, let us take an example first. Determine capacity and level of service of a four lane divided highway in plain terrain, obviously all are in plane terrain, with the following characteristics. Operating speed under base condition is given, lane width standard, 3.5 kilometer gradient is given, total volume is given in vehicle per hour per direction, SMS is given, space mean speed, it will be required.

For this volume, we want to calculate LOS, so what is the SMS, that will be required. Paved shoulder width is given, median width is given, curvature is given, IRI is given and traffic composition, traffics are in actual number, these are given. But when it, you know the actual number and you know the total number of vehicles 1250 vehicles per hour per direction. So you can actually calculate the proportions, which are required as input for the equation.

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### Capacity and LOS Estimation

**Solution:**

- $S_e = 1 + 0.6 * P_{BC} - 1.5 * P_{2W} + 1.2 * P_{AUTO} + 2.6 * P_{LCV} + 4.8 * P_{BUS} + 3.6 * P_{TAT} + 59.8 / N + 6.4 * P_{MAT}$
- $S_e = 1.63$
- Traffic volume =  $1250 * 1.63 = 2038$  PCU/h/dir
- $V_{OS_{adj}} = V_{OS_{base}} - 4.7 * IRI - 0.6 * GR - 0.03 * CU = 100 - 4.7 * 3.6 - 0.6 * 1.4 - 0.03 * 172.5 = 77$  km/h
- $C = 30 * V_{OS_{adj}} + 1540 = 3850$  PCU/hr/direction



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So the stream equivalency can be calculated. Remember that these are all proportions. Here, numbers are given, but total and numbers are given so you can calculate the proportions and then accordingly you can fit the values to get the stream equivalency factor as 1.63. Once you have got the stream equivalency factor, your value is 1250 vehicle per hour per direction, so 1250 into 1.63.

Now, it will be not vehicle, but it will be now PCU per hour per direction. So 2038 is the volume. Now, what is the operating speed? Adjusted operating speed is the base operating speed. And on that, you have to apply correction with respect to IRI for grade and for curvature. So that operating speed is given as 100, that sort of thing is under base condition operating speed, and then gradient is 1.4 percent, so that is given.

GR is taken as 1.4, IRI is 3.6 meter per kilometer, so that you feed. And remember, these are the corrections we are doing on operating speed, not directly on capacity, on operating speed. So once you have calculated the adjusted speed, 77 per, kilometer per hour, then you use the appropriate equation what has been given there 30 into V operating speed plus 1540. So you get capacity is 3850 PCU per hour per direction.

So the volume also is known in PCU per hour part direction, capacity is also known. so we can directly get the volume to capacity ratio. And since the speed is, SMS is 40 kilometer per hour, so speed is also known. So speed is known, volume is known, so the density also can be calculated.

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**Capacity and LOS Estimation**

- $C_{adj} = C + 188 \times PSW + 170 \times UPSW$
- $PSW = 0.5 - 1.5 = -1m$ ;  $UPSW = 0$
- $C_{adj} = 3850 + 188(-1) + 170 \times 0 = 3662$  PCU/hr/direction

**Estimation of LOS:**

- $K = Q/V = 2038/40 = 51$  PCU/km/dir
- $\text{Volume/capacity} = 2038/3662 = 0.557$
- From **Table 3.8 of Indo HCM (2017)**, using density or V/C ratio, we get **LOS 'D'**



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So that is what, but before that, the, the capacity is adjusted further to take care of this PSW, paved shoulder width and unpaved shoulder width. So these are again adjusted. So PSW is calculated and then accordingly C adjusted is 3662. So this 3662 is actually the capacity which is to be compared with the traffic volume 2038. So you can do that and you can directly get the volume to capacity ratio.

Also 2038 is your actual volume, and 40 kilometer per hour is the speed, space mean speed. So you can also calculate the density which is 51. So you also have the value of density, you also have the value of volume to capacity ratio, now you refer to table 3.8 of Indo HCM, 2017, that is, this equation which is for four lane. So you know the density thresholds are given, V by C thresholds are also given, both you can check. So you checked both here, and both cases you found that it is indicating both, in terms of density value and in terms of V by C, it is indicating LOS D.

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## Capacity and LOS Estimation

**Example 2:** Determine the number of lanes required to maintain LOS B during peak hour for a new facility in a plain terrain with:

- AADT=20,000 veh/day
- Design speed for new facility= 100 km/h
- Proportion of AADT occurring during peak hour( $k$ )=0.08
- Proportion of peak hourly volume travelling in peak direction( $D$ )=0.60
- Traffic composition: SC=28%, BC=20%, TW=10%, LCV=12%, TAT=10%, MAT=7%, AUTO=3%, BUS=10%



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Now, the second example. Determine the number of lanes required to maintain LOS B during peak hour for a new facility in a plane terrain. So it is a new facility, so many of the values will not be known, except the ADT, the annual average daily traffic is known, 20,000 vehicle per day.

Design speed is assumed as 100 kilometer per hour, proportion of ADT during the peak hour is taken as 8 percent, normally, 8 to 10 percent. Proportion of peak hourly volume traveling in the peak direction, so, that is taken as 0.6, and traffic compositions are also given. All these are input.

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### Capacity and LOS Estimation

**Solution:**

- Directional design hourly volume ( $v$ ) =  $AADT \times K \times D = 20,000 \times 0.08 \times 0.6$   
= 960 veh/h/dir
- As this is a new facility, operating speed is not available. Assume operating speed as 100 km/h and facility to be **four-lane divided highway**
- $S_e = 1 + 0.6 * P_{BC} - 1.5 * P_{2W} + 1.2 * P_{AUTO} + 2.6 * P_{LCV} + 4.8 * P_{BUS} + 3.6 * P_{TAT} + 59.8 / N + 6.4 * P_{MAT}$
- $S_e = 2.67$
- Design hourly volume =  $960 * 2.67 = 2563$  PCU/h/dir



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So what we can do? We can get the directional design hourly volume. What is that? ADT. 20,000 into the proportion of ADT during the peak hour, so 0.08, and in the peak direction, multiplied by 0.6. So that is what is done, 20,000 into 0.08 into 0.6, so get peak hour traffic volume, and again, since this is not a new facility, so you do not know really how much what will be required, but let us assume that operating speed as 100 kilometer per hour, and the, we require actually a four lane divided highway.

And then we can test whether the four length divided Highway is adequate. Then, the proportions are known, numbers are known, so you calculate stream equivalency factor, which is come out to be 2.67. So the design directional hourly volume, 960 vehicle per hour, multiplied it by 2.67. So now you get the directional design hourly volume in PCU per hour, 2563 PCU per hour.

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### Capacity and LOS Estimation

- $C = 30 \times V_{os} + 1540 = 4540$  PCU/h/dir
- From **Table 3.8 of Indo HCM (2017)**, maximum  $v/c = 0.30$  for LOS-B
- Thus, service volume corresponding to LOS 'B' =  $4540 \times 0.3 = 1362$  PCU/h/dir
- Number of lanes required =  $2563/1362 = 1.88$
- Thus two-lanes are required for each direction i.e. **four lane divided highway** needs to be provided and **assumption is correct**



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Now, you calculate the capacity, which is using this operating speed. Now, from Table 3.8, you can get the maximum  $v$  by  $c$  threshold for this four lane divided road. If you want LOS B, the  $v$  by  $c$  threshold is 0.3. So if the capacity is 4540, and then with that operating speed and the threshold is 0.3  $v$  by  $c$ , so then that what is the threshold service volume. So service volume corresponding to LOS B is 1362.

Now, if it is 1362, then how many number of lanes are required to serve this 2563 PCU per hour per direction? 2563 divided by 1362, so you get 1.88. What we have assumed here? Four lane divided, so two lane in each direction. So we are able to maintain that LOS, once you provide two lanes in each side. So thus, two-lanes are required for each direction, and four lane divided highway needs to be provided, and also, our assumption is correct.

So this will be able to maintain, as we said, LOS B during the peak hour for a new facility in the peak terrain with all this, for this all input data.

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## Summary

- Capacity and LOS estimation of Multilane divided highways
  - ✓ Stream equivalency factor
  - ✓ Base capacity estimation
  - ✓ Adjustment factors
  - ✓ LOS estimation
  - ✓ Applications

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So with this, what we discussed actually in this lecture, the capacity and LOS estimation for multi lane divided highways. Again told you how you calculate stream equivalency factor, how you do the base capacity estimation, what all adjustments you do on operating speed, and then thereby, in the capacity, and what adjustment you do directly on capacity, then how you do the LOS estimation, and then took two small example problems to show you the applications. With this, I close this lecture. Thank you so much.