Welcome to Module D, Lecture 10. In this lecture, we shall discuss about Analysis of Single, Intermediate and Two-Lane Roads as per Indo Highway Capacity Manual 2017.

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Till lecture 9, we discussed mostly based on Highway Capacity Manual 2016 US Highway Capacity Manual and specifically in lecture 9 we discussed about planning level analysis for urban road segments, calculation of running time then proportion of vehicles arriving during green control delay stop trade and also travel time speed spatial stop rate.

And finally, calculation of LOS and we took a simple example problem to explain you, how you can calculate planning carry out planning level analysis to understand the level of service. Now, today, we are actually starting a new part in the sense that we will discuss about Indo Highway Capacity Manual.

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Now, as you know the Manual like US Highway Capacity Manual 2016. We have referred to this manual extensively in our several lectures in this module also similarly, there is a Chinese manual Indonesian Highway Capacity Manual all these were developed based on traffic condition present in respective countries and it may not be just one country.

But also sometimes like US Highway Capacity Manual multiple countries several countries will have similar kind of traffic state and where HCM can be applied Highway Capacity Manual 2016 can be applicable, but traffic on Indian roads is composed of slow and fast moving vehicles highly heterogeneous.

So, many varieties strive and with substantial differences in their both static and dynamic characteristics including the size engine power everything there is quite a lot variation and also wide range of motorized and non-motorized traffic sometimes use the same road space resulting in highly heterogeneous traffic environment.

So, therefore, many of the provisions methodology wise may be quite advanced quite detailed, but, many of the assumptions may not be really valid for Indian heterogeneous traffic condition not only the traffic environment, but the roadway control environment, the abutting land use the kind of side friction what we get. So, the real behavior of the traffic even speed flow relationship also might be very different for uninterrupted flow facilities.

So, there was a need and an attempt was made to develop a Indo Highway Capacity Manual in 2000, which came out in 2017. And you may consider it as this is the first version first version one of this manual. So, obviously, a lot of things have been done, but a lot of things are also yet to be done. So, I want to give you a little bit quick understanding of some of the features of this Indo HCM in today's lecture and the next lecture. So, lecture 10 and lecture 11 will be primarily on Indo HCM.

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In Indo HCM or in as per Indian conditions we have both urban and rural as we have done in the case of Highway Capacity Manual 2016 rural is specifically calling here as interurban highways and they include sometimes single lane road, sometimes intermediate lane road, two-lane road also multi-lane highways and even expressway.

These are not urban expressway but interurban connectivity with access control routes. Multi-lane highways are not access control. And that is a real big challenge in our Indian context. Now, out of all these roads, different categories, different accessibility mobility functions, single lane intermediate and two-lane roads are undivided and facilitating two way traffic movements.

Multi-lane highways and expressways are divided carriageways. So, upstream, downstream moving in different using different distinctly different and physically segregated carriageways with

two or more lanes in each direction. Now, obviously, the traffic operations on undivided and divided highways are largely different.

And therefore, the capacity and LOS analysis are also presented separately for divided multi-lane highways and undivided routes in the indo highway capacity manual, we will not have opportunities to go for urban routes, because of the time limitation, but we shall focus how the capacity and LOS at least the key aspects in today's lecture and next lecture, lecture 11. Today we shall focus on undivided roads.

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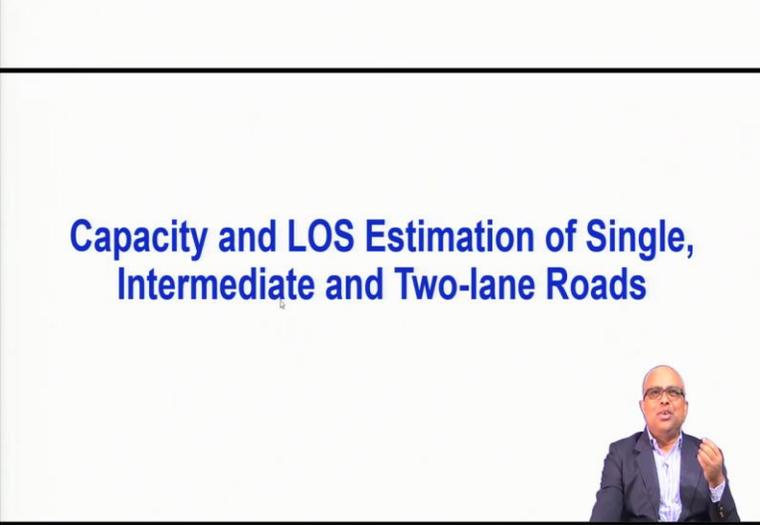
Capacity and LOS Estimation of Single, Intermediate and Two-lane Roads

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Capacity and LOS Estimation

- Inter-urban undivided roads have two-way traffic movement which influences the capacity of the road

- Two-lane carriageway width is generally considered as 7.0 m, intermediate carriageway width as 5.5 m, and single lane carriageway width as 3.75 m

Base Conditions

- In addition to the prescribed carriageway width, minimum of 1.0 m soft shoulder on both sides should be present

- Section should be straight and level

- No influence by interruptions such as intersections

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So, now capacity and LOS estimation for single intermediate and two-lane roads inter-urban undivided roadways have to a movement, which influence the capacity of the road. So, basic concept basic understanding is always same irrespective of which manual we are referring to.

I have told you that the passing opportunity greatly influenced by the opposing flow level flow in the other direction, higher the flow less will be the opportunity and higher the flow in the direction of the movement there will be higher demand also for doing the passing. So, the passing opportunity is a major, major consideration here also two-lane carriageways.

As per Indian provision generally have the carriageways width of 7 meter, 3.5 meter per lane, assuming that there is no curb most of the rural sections you do not expect curb. So, 7 meter intermediate carriageway width of 5.5 meter intermediate carriageway is not very common, but in Indian condition it is there because single lane you have 3.75 meter carriageway.

Sometimes single lane the passing opportunities is extremely difficult both vehicles have to go and use part of the shoulder part of the carriageway to do it to do the main over passing or even crossing both. So, an intermediate carriageway is something in between a compromise two-lane in a sense with carriageway width a 5.5 meter often it could range also up to 6 meter or so.

And this at least limited way provide passing and crossing opportunity if two cars want to cross or one car wants to pass another car, they will be able to manage probably within 5.5 meter, but if two trucks or heavy vehicles are trying to pass or cross each other, then they have to use part of the shoulder and part of the carriageway.

Now, like the highway capacity manual, here also the base conditions are defined. And in addition to this prescribed carriageway width as I have just said for single lane and intermediate lane and two-lane un-divided roads, they also have additional assumptions like the shoulder must be present on both side at least minimum of 1 meter shoulder. Then, section should be straight and level. So, if there are gradients then gradient effect has to be accounted for separately. No influenced by interruptions such as intersections.

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Then, steep gradients and curvature. So, if there is that is again level ground. So, if it is no effect of steep gradient or curvature as well as any other adjoining roads, no physical barrier on at least 500 meters section means physical barrier in the sense the most common physical barrier is the speed breakers if the speed breaker rumble strips speed humps.

So, on Indian roads, often we find that because the abutting land is something very different, the intended and actual use of road is very different. A road may intended use maybe to serve mobility, but actual use maybe very much higher performance on higher requirements to serve really accessibility.

So, the actual and intended so, the speed limit and safety speed, it is all a more complex issue and complex problem. So, it is assumed that there is no physical barrier for at least 500 meter section; section should be free from any other roadside friction activities. That is again, an important consideration section should be free from any work activity for at least 1 kilometer on either side.

Nothing like some part of the road is blocked and work is in progress. So, that will again disturb the traffic stream and also no incident or crashes at the time of observation for at least 1 kilometer on either side. So, that all these are assumptions to define the base condition. So, base condition is almost as you already know it, it is almost like nearly idealized situation.

So, and then we apply again as usual several correction factors may not be exactly the same way as it is done in Indo highway capacity manual 2016 US Highway Capacity Manual, here the considerations are much simpler, and I will show you some of those.

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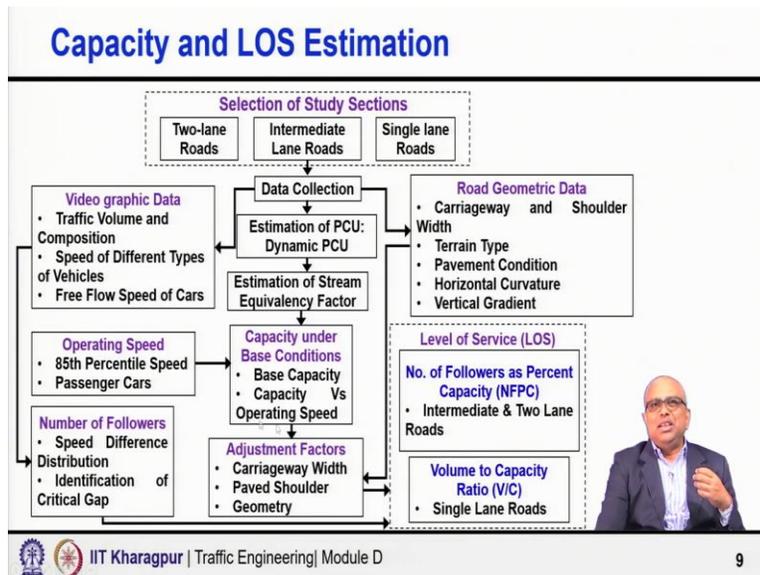
So, here is the framework how you can decide capacity and level of service very quick look, selection of study locations. So, you it is maybe either a two-lane road or intermediate lane road or a single lane road, then you go for the data collection two types of data you collect one is the traffic related data. The other is geometric related data; traffic data mostly as per Highway Capacity Manual Indo Highway Capacity Manual are Indo HCM we are saying that use videography as far as possible for collecting the traffic data.

So, traffic volume compositions speed free flow for speed of cars, standard cars what we take, so, all these are can be collected using videography data and the geometric data may include carriageway and shoulder width, terrain type pavement condition, horizontal curb or curvature, vertical gradient, all such kind of inputs, then the estimation of PCU as the Indian traffic condition is highly heterogeneous.

So, as most of the cases the Highway Capacity Manual we consider only heavy vehicle or sometimes even just another category recreational vehicles. But here the range of mix is quite, vast. So, we have to how to use the PCU value is also a challenge and as the passenger car passenger carry equivalency and passenger carry unit they mean the same thing we call it passenger carry unit.

But while in most other countries many other countries probably they call it passenger car equivalency. So, PC or PCU they are again dynamic not static. So, use of different values depending on composition presence of other vehicles different other factors the influence the PCU value.

So, the dynamic PCU value range, it suggests the range observed composition is so much percentage so much percentage for a vehicle and the PCU also may vary from this range to that range. So, accordingly for every vehicle type it is given a new concept which is introduced in Indo Highway Capacity Manual.

Is the stream equivalency factor instead of using an individual vehicle type dynamic PCU and getting the equivalent PCU directly the stream equivalence effecter can be multiplied with by the number of vehicle to get the flow in PCU this one value directly can be multiplied based on the composition of the traffic steam and other things.

Again the development formulas are developed then capacity under base condition is calculated taking the operating speed at 85 percentile speed and for passenger cars. And then several adjustments are done on that because the capacities under base conditions. So, adjustment may include carriageway width pavement shoulder, the road geometry. And then the finally, the number of followers also may be counted for calibration purpose for understanding purpose. And then

finally, the level of services decided, and here two things I have indicated in blue font, they show that, that is what is the measure, which is used to define the level of service.

So, for example, for intermediate and two-lane roads number of followers as percent capacity what is the capacity and what is the number of followers as percent capacity. So, NFPC that is used as a measure for defining the level of service, so, we calculate this end of the day, when we are using this framework and for single lane road, it is the volume to capacity ratio. So, in that case the V by C is calculated. So, capacity you have calculated we know the volume from the video graphic data. So, for the given volume, what is the V by C ratio?

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Now, with this background, let us see some of the key concept as I say, the stream equivalency factor is a new concept that is introduced to Indo Highway Capacity Manual. As I said the PCU value of a vehicle type is found to be sensitive to traffic and roadway condition. So, is single PCU value cannot be used for all types of traffic condition?

So, what is done here in this manual it presents that in multiple locations in different parts of the country, so many roads are taken and the observed range of composition for each vehicle type, what is the range, because different section different percentage different composition was observed? So, it presents a range and then presents a range of PCU value.
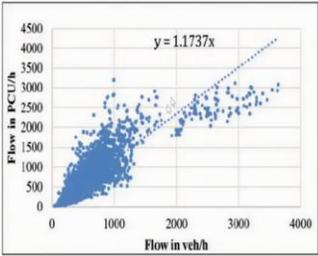
So, depending on the context, the manual also can be used to pick up a particular value of PCU which is actually suitable for the context it is dynamic PCU. And, what is always found as I told that a small change in the traffic volume or composition may change PCU factors substantially, especially for large sized vehicles which have got bigger impact which get actually influenced by this parameter.

So, therefore, the stream equivalency factor this concept is introduced that let us not try to use dynamic PCU values based on the condition pick up a value observed composition and so on. We can have a single value which can be just simply multiplied by the number of vehicles to get the flow in PCUs per hour. So, SEF stream equivalency factor is defined as the ratio of flow in PCUs per hour to the flow in vehicle per hour.

So, what is the flow in PCUs per hour divided by what is the flow in vehicle per hour. So, you use one factor which duly considers the composition the volume effect as I said here, the traffic volume or composition may change PCU. So, this volume effect is considered composition is effect is considered and can help you to directly translate total traffic volume in vehicle per hour into PCUs per hour equivalent stream of homogeneous traffic.

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Now, what is also found that the flow in PCUs per hour when you estimate and flow is also effectors? As you can see that as the flow increases the PCU also increases, the flow in PCU increase and these are there is some kind of correlation and this is shown for flow in PCU vehicle per hour and the corresponding flow in PCU.

Here also the flow in vehicle per hour and flow in PCU this is for two-lane and intermediate lane road and this is for single lane road. So, based on that all such kind of observations and understanding as Se, represents the overall equivalency factor of the, entire traffic stream. So, stream equivalency depends on volume and composition, as I have said earlier also small changes in volume and composition may change PCU factor. So, here also the Se is made sensitive two composition, and traffic volume.

Capacity and LOS Estimation

Single Lane Roads

$$S_e = 1 + 0.01 \times P_{BC} - 0.38 \times P_{2W} - 0.29 \times P_{AUTO} + 0.231 \times P_{LCV} + 1.18 \times P_{BUS} + 0.770 \times P_{TAT} + 2.26 \times P_{TT} - \frac{7.72}{N}$$

Intermediate and Two Lane Roads

........(4.33)

$$S_e = 1 + 0.150 \times P_{BC} - 0.702 \times P_{2W} + 0.204 \times P_{AUTO} + 1.770 \times P_{LCV} + 5.075 \times P_{BUS} + 3.550 \times P_{TAT} + 4.598 \times P_{TT} + 5.414 \times P_{MAT} - \frac{1.239}{N}$$

........(4.34)

- where, P_{BC} =proportion of big cars (capacity more than 1400 cc) in traffic stream

P_{2W} = Proportion of two wheelers

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Capacity and LOS Estimation

P_{AUTO} = Proportion of auto rickshaws

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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So, based on extensive data collection for each category of road, different range of, traffic composition, overall traffic volume. So, extensive works are done to develop such kind of equation which you can use. So, you can use see that this is for single lane road this is for intermediate and two-lane road how one can use the stream equivalency values.

So, it is 1 plus it is taking percentage of big cars big cars means two types of car what we are taking a standard car is up to engine capacity of 1400 cc and big cars means which is bigger than our capacity more than 1400 cc. So, percentage a big car percentage of two wheeler percentage of auto rickshaws auto rickshaws are the three wheeler typically that is what it is called, then proportion

of light commercial vehicle proportion of two or three axle trucks, proportion of tractor trailer, proportion of multi axle trucks. And also as I said the PCU or PC or equivalency stream equivalency also depends on total flow. So, that total flow is also used as a variable here you can see and very logically the two wheeler percentage the coefficient comes with negative sign and the number of vehicles.

Where this is used this again comes very logically with the negative side they all are generally positive, because these are bigger vehicles bigger than what is considered a standard car. So, this stream equivalency equations, as I have shown here, in this module as 4.33 and 4.34 can be used directly to get the stream equivalency for a given composition and number of vehicles.

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Capacity and LOS Estimation

Intermediate Lane Roads
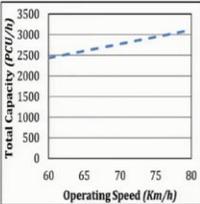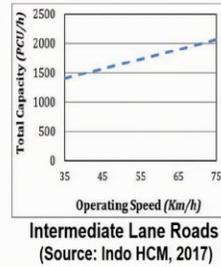
$$\text{Base Capacity} = 830 + 16.4 \times V_{os} \quad \text{........(4.36)}$$

Single Lane Roads

$$\text{Base Capacity} = 187 + 12.4 \times V_{os} \quad \text{........(4.37)}$$

Where, V_{os} = operating speed on road (in km/h)

- Operating speed is taken as the **85th percentile** of free-flow speeds of standard cars in field

Intermediate Lane Roads
(Source: Indo HCM, 2017)

So, then the Base Capacity Estimation this was again done extensive field data collections was done to try what are how the relationships come up here you can see the total capacity, it is found to have a some kind of relationship with the operating speed. So, the operating speed of cars this is the operating speed is taken as 85th percentile of free flow speed of standard cars in field.

So, as operating speed increases, so the capacity also is found to increase. So, the one equation is developed for two-lane roads, the base capacity under ideal condition is taken as 394 +34×Vos where Vos is operating speed on road that is operating speed means it is the 85th percentile free flow speed of standard cars in the field.

So, this equation can be used once you know the speed these are all calibrated at the backend the Green Shield secretion, the speed flow density relationship is also considered to be valid. So, a lot of other assumptions other works extensive fieldwork observations are all made to suggest this, similarly the intermediate lane road and single lane road two other equations very similar to this equation what is shown here for two-lane roads very similar equation is suggested.

And here also the Vos is the operating speed as taken as 85th percentile of the free flow speed of standard car and here as I have shown it for two-lane road, it is also shown for intermediate lane road that speed has got an impact on capacity. So, that operating speed has got an impact on capacity. So, that is actually captured here.

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Capacity and LOS Estimation

Adjustment Factors

- Capacity of a road is affected by various factors: Carriageway width, shoulder width and condition, directional split, road geometry (curvature and gradient), and pavement condition (roughness)

Carriageway Width

Two Lane	Carriageway Width (in m)	6.50	6.80	7.0	7.20	7.50
	Adjustment Factor (f_w)	0.86	0.95	1.0	1.05	1.14
Intermediate Lane	Carriageway Width (in m)	5.50		5.60	5.80	6.00
	Adjustment Factor (f_w)	1.00		1.03	1.09	1.15
Single Lane	Carriageway Width (in m)	3.50		3.75	4.00	4.20
	Adjustment Factor (f_w)	0.76		1.00	1.24	1.43

Source: Table 2.6, Indo HCM, 2017

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Then as I said that under base conditions or things are different. So, now the prevailing condition will expect it to be very different from the base conditions a lot of corrections are to be applied. So, here capacity of road is found to get affected by various factors, say for example, carriageway width, shoulder width and condition, then the directional split it is undivided road.

So, the directional split is again very important the road geometry particularly the curvature and gradient and also the pavement condition, which we can express in terms of the roughness IRI values international roughness index, first coming to the carriageway width such kind of correction factors are suggested by the manual.

And again I am saying these are based on extensive research field observations data collection number of roads under the same category with different carriageway width and then trying to capture the relationship and then trying to suggest what under based on that understanding that what kind of correction factors may be appropriate.

So, you can see for Two- lane for Intermediate lane, Single lane, Two-lane the carriageway supposed to be 7 meters ideally. So, it could be less than that it could be more than that, then what multiplier we can use Intermediate lane roads supposed to be 5.5 meter cannot be lesser, because it is intermediate. So, we do not expect it to be when lesser than 5.5. So, it could be sometimes higher and go up to 6 meter.

So, the factors are calculated given Single lane road supposed to be 3.75 meter. Then it is 1, if it is lesser than less than 1 multiplier if it is more than 1 higher than 1, multiplier value is used as the factor. So, these are corrections related to carriageway width.

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Similar correction is applied based on the pavement shoulder you can see that pavement shoulder width in meter and then what is the correction factor then the directional split 50 50 is assumed and then capacity decreases as the directional split move away from even split of 50 50. So, 50 50 case it is 1, and then as it is becoming different the different values are used.

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Capacity and LOS Estimation

Road Geometry (Two-lane hill road)

- In case of **hill roads**, operating speed is found to get influenced by road geometry such as gradient and curvature
- As gradient or curvature **increases**, operating speed **decreases**
- Both capacity and operational speeds of different vehicle types are influenced by road geometry
- Operating speed of cars can be observed or estimated using the following equation

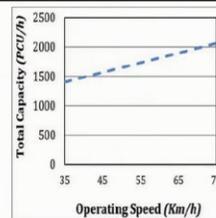$$\text{Operating Speed} = 70.6 - 1.84 \times \text{Gradient (\%)} - 0.026 \times \text{Curvature } (degrees/km) \quad \text{........(4.38)}$$

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Capacity and LOS Estimation

Intermediate Lane Roads

$$\text{Base Capacity} = 830 + 16.4 \times V_{os} \quad \text{........(4.36)}$$

Single Lane Roads

$$\text{Base Capacity} = 187 + 12.4 \times V_{os} \quad \text{........(4.37)}$$

Where, V_{os} = operating speed on road (in km/h)

- Operating speed is taken as the **85th percentile** of free-flow speeds of standard cars in field

Intermediate Lane Roads
(Source: Indo HCM, 2017)

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Then the road geometry influenced a lot and why do you expect such things to happen the curvature and gradient, curvature and gradient where we expect them to impact it is in hilly areas, difficult terrain conditions. And what is interestingly found that in hill roads operating speed is found to get influenced by root geometry such as gradient and curvature capacity definitely getting impacted.

But the operating speed itself is getting impacted by the, geometric Road geometry particularly say gradient and curvature and as gradient or curvature is increasing the operating speed is actually decreasing. So, what is done in the absence of the observation in the full range of flows starting

from free flow condition to capacity level or congested regime the entire range of observations. So, what again was considered take the free flow speed of cars estimate it considering the impact of the fit not the free flow speed, but the operating speed of car dually considering the effect of the gradient and curvature what is the and this operating speed is what it is the 85th percentile speed as I have told earlier considering standard car a small car.

So, operating speed is taken as the 85th percentile speed up free flow speed of standard car in field. So, observe it so, take the effect of gradient and curvature on operating speed and then relate as we have done other case relate this operating speed to the capacity as we have done in earlier case also, but this is specifically for Two-lane hill roads.

So, that is what was done operating speed of cars you can either observed in the field or estimate using this equation as given here. You can see here operating speed reduces once the gradient is steeper, gradient is more or the curvature that means degrees deviation per kilometer average change in degree per kilometer once that changes.

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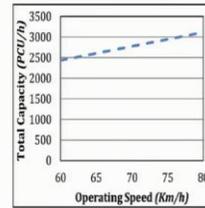## Capacity and LOS Estimation

Base Capacity Estimation

Two Lane Roads

- Capacity of a two-lane road is influenced by the road conditions and drivers' behaviour

  Base Capacity $= 394 + 34 \times V_{os}$ ....(4.35)

  Where, V_{os} = operating speed on road (in km/h)

- Operating speed is taken as the **85th percentile** of free-flow speeds of standard cars in field

Two Lane Roads
(Source: Indo HCM, 2017)

Capacity and LOS Estimation

Intermediate Lane Roads

Base Capacity $= 830 + 16.4 \times V_{os}$ ....(4.36)

Single Lane Roads

Base Capacity $= 187 + 12.4 \times V_{os}$ ....(4.37)

Where, V_{os} = operating speed on road (in km/h)

- Operating speed is taken as the **85th percentile** of free-flow speeds of standard cars in field
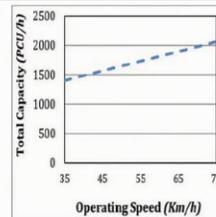
Intermediate Lane Roads
(Source: Indo HCM, 2017)

Then the relationship is established between capacity and operating speed of standard car as I said. So, the capacity is expressed like this very similar to what I have shown earlier for this two-lane road there then you have intermediate lane road and single lane road. But this is again specifically for Two-lane hill roads. Dually considering the effect of curvature and gradient on speed and therefore, on the capacity. Now, similarly the riding quality the effect of IRI international road roughness in is taken actually and then operating speed effect is considered here.

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Then, effect of roughness IRI on capacity was also directly captured based on the available data and relationships were developed. So, With Paved Shoulder, Without Paved Shoulder, then this is for two-lane road and then for intermediate and single lane road how the things change that was given. Coming to the LOS estimation in Indo-HCM.

LOS for intermediate and Two-lane road is defined based on the number of followers as percent of capacity we it was reviewed several measures which are used in different manuals all over the world for undivided facility in similar situation, these are all reviewed then in Indian conditions, what are the challenges, what are the problems, what could work better, if we want to apply then

what kind of practical difficulties we may face all such kind of things were considered and finally, these any NFPC number of followers as percentage of capacity, this was used to define the LOS for intermediate and Two-lane roads. So, this was taken as the service measure, for single lane road V by C volume to capacity ratio as prescribed.

So, a vehicle is considered to be the following state little bit about the NFPC a vehicle is considered to be in the following steps if it moves with a gap value equal or less than the critical gap. So, based on the critical gap, it was said and critical gap value obviously decreases with an increase in the traffic volume in roads vehicle move more closely.

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Capacity and LOS Estimation

- As **traffic volume** on the road increases, the **number of followers** also increases: number of followers on the road is related to traffic volume

$$NF = 1.1742 * Q^{0.9306} \quad ....(4.46)$$

where, NF = Number of followers, PCU/h

Q = Two-way traffic volume, PCU/h

- Different ranges of NFPC evolved for different LOS are given in a table for intermediate and two lane road
- The corresponding ranges of volume to capacity ratio (V/C) derived through cluster analysis are also presented for easy understanding of analysts

Capacity and LOS Estimation

LOS Estimation

- In Indo-HCM, LOS for intermediate and two-lane roads is defined based on **number of followers as percentage of capacity** (NFPC)
- For **single lane** roads, **volume/ capacity ratio** is sufficient to describe LOS
- A vehicle is considered to be in the **following state** if it moves with a gap value **equal or less than** critical gap
- Critical gap value **decreases** with the **increase** in traffic volume on the road

Capacity and LOS Estimation

Intermediate and Two Lane Roads

LOS	NFPC	V/C Ratio	Service Volume for Two Lane Roads (PCUs/day)	Recommended DSV Values for Upgradation (PCUs/day)	
A	≤ 0.15	≤ 0.25	<7500	10500 PCUs/day @ LOS-B: Suggested threshold value for conversion from two-lane bidirectional to Four Lane Divided Roads to ensure enhanced safety in traffic operations	Source: Table 2.9, Indo HCM, 2017
B	0.15-0.25	0.26-0.45	7500-13500		
C	0.26-0.40	0.46-0.60	13500-17500		
D	0.41-0.55	0.61-0.75	17500-23000		
E	0.56-0.70	0.76-1	23000-30000		
F	>0.71	>1	>30000		

Single Lane Roads

LOS	V/C Ratio	LOS	V/C Ratio	
A	≤ 0.15	D	0.51-0.80	
B	0.15-0.30	E	0.81-1.00	Source: Table 2.10, Indo HCM, 2017
C	0.31-0.50	F	>1.00	

So, there is a relation which was again developed and given in this manual switch you can use as shown here as equation 4.46. So, if we know the traffic volume, we can calculate the NF value number of followers. So, number of followers in PCU per hour can be expressed as a function of Two way total traffic volume in PCU per hour.

And obviously, as the traffic volume increases, the number of followers also will increase. So, this relationship was developed and one can use it and then using different ranges of any NFPC. Once the NF number of followers, we can also considering the capacity we can calculate number of followers as percentage of capacity, we can just translate NF into two out to express it in terms of NFPC.

So, we can do that. So, different ranges of NFPC for different LOS are given in the table. I am just going to show it here. And what I want to say the corresponding ranges of V by C ratio are also given you can see here it is for intermediate and Two-lane road where NFPC is the service measure to define the level of service.

So, the threshold values are all given, but also the corresponding V by C ratio are also given. Does it mean that directly we are saying that take the V by C ratio not directly in that sense, but what was done, the corresponding ranges of V by C ratio are also derived, because we had huge data that was available? So, the LOS was the NFPC values were also calculated known and also the V

by C was known. So, then using the cluster analysis, this corresponding V by C ratio thresholds were also worked out.

So, that is what I say the corresponding range of V by C ratio derived through cluster analysis are also presented and what we (34:23) because this is for easy understand of analyst whatever you do, although, internally we are actually considering NFPC. But giving these V by C ratio are very handy, because practitioners can easily get, you get the volume, what is the V by C ratio of light very simple, very simple rather than trying to calculate the NFPC.

So, both are given NFPC calculation is also not so, difficult one can easily do it, you have a formula directly which you can use, but corresponding V by C ratios were also given. So, that we generally get a field that how the volume as the volume is increasing how the NFPC and overall the LOS thresholds are happening.

Similarly, as I said before single lane road it is only the V by C ratio. So, the threshold value for A B C D E F as if is always greater than 1, here also anything V by C greater than 1, is a safe. And here the LOS-B thresholds are given because these are in rural or inter-urban facility. So, the PCU here is expressed as PCU the demand is expect design service volume the demand is expressed in PCU per day, but that internally this understanding is there, that capacity per hour and then the, what is the percentage of daily traffic two peak hour traffic. So, all those things are there internally to explain it.
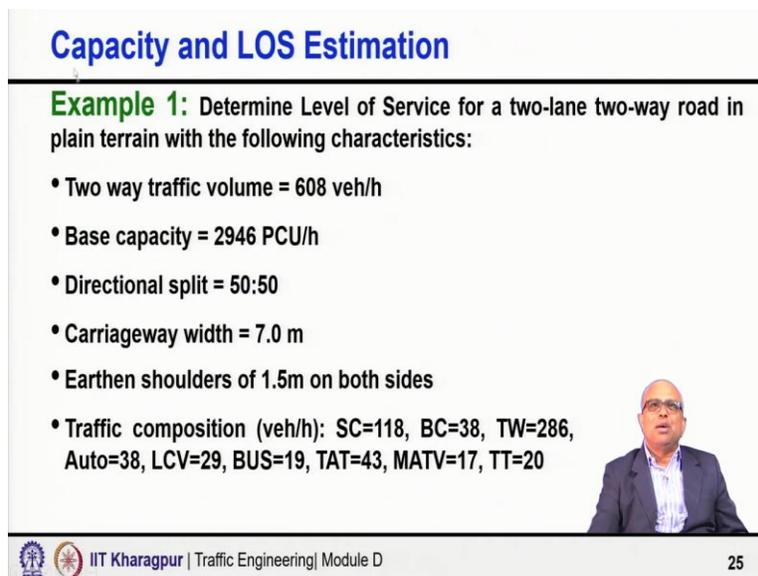
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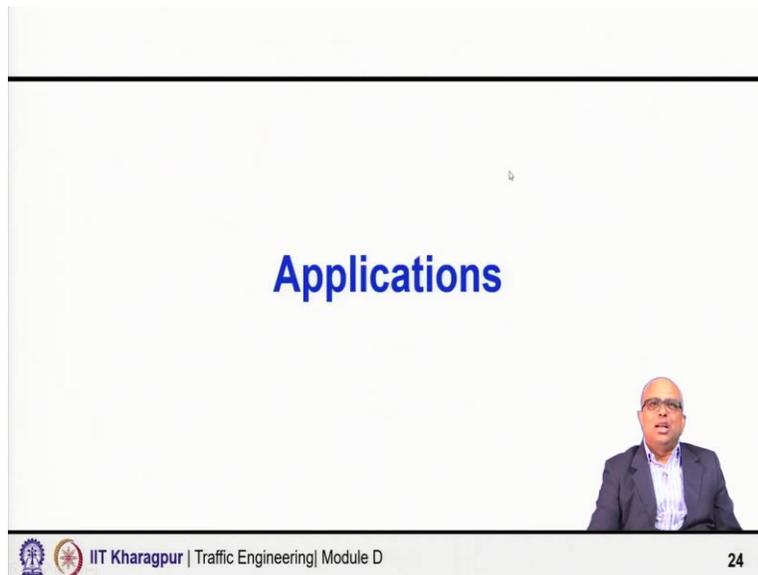
Applications

Capacity and LOS Estimation

Example 1: Determine Level of Service for a two-lane two-way road in plain terrain with the following characteristics:

- Two way traffic volume = 608 veh/h
- Base capacity = 2946 PCU/h
- Directional split = 50:50
- Carriageway width = 7.0 m
- Earthen shoulders of 1.5m on both sides
- Traffic composition (veh/h): SC=118, BC=38, TW=286, Auto=38, LCV=29, BUS=19, TAT=43, MATV=17, TT=20

Now, just take a small example determine LOS surface for a Two-lane road given this data Two way volume is given Base capacity in this case is given we could calculate based on the operating speed, Directional split ideal, Carriageway width ideal Earthen shoulder 1.5 meter on both sides. So, traffic compositions are also given.

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Capacity and LOS Estimation

Solution:

- $S_e = 1 + 0.150 \times P_{BC} - 0.702 \times P_{2W} + 0.204 \times P_{AUTO} + 1.770 \times P_{LCV} + 5.075 \times P_{BUS} + 3.550 \times P_{TAT} + 4.598 \times P_{TT} + 5.414 \times P_{MAT} - \frac{1.239}{N}$

- $S_e = 1 + 0.15 \times 0.063 - 0.702 \times 0.470 + 0.204 \times 0.063 + 1.770 \times 0.048 + 5.075 \times 0.031 + 3.550 \times 0.071 + 4.598 \times 0.033 + 5.414 \times 0.028 - \frac{1.239}{608} = $ **1.488**

- Flow in PCU/h = S_e x Flow in veh/h

  = 1.488 x 608 = **904 PCU/h**

- Number of followers, $NF = 1.1742 * Q^{0.9306} = 1.1742 * 904^{0.9306} = $ **662 PCU/h**

Capacity and LOS Estimation

- Capacity after adjustments = given base capacity = **2946 PCU/h** (Adjustment factors for directional split = 50:50, carriageway width = 7.0 m, earthen shoulders of 1.5m on both sides is 1.00)

- Number of Followers as Percentage of Capacity (NFPC) = NF/Capacity

  = 662/2946 = **0.225**

- From **Table 2.9 of Indo HCM (2017)**, LOS is found to be **LOS B**

- Alternatively, Volume/capacity=904/2946=0.307

- From **Table 2.9 of Indo HCM (2017)**, LOS is **B**

Capacity and LOS Estimation

Intermediate and Two Lane Roads

LOS	NFPC	V/C Ratio	Service Volume for Two Lane Roads (PCUs/day)	Recommended DSV Values for Upgradation (PCUs/day)	
A	≤ 0.15	≤ 0.25	<7500	10500 PCUs/day @ LOS-B: Suggested threshold value for conversion from two-lane bidirectional to Four Lane Divided Roads to ensure enhanced safety in traffic operations	Source: Table 2.9, Indo HCM, 2017
B	0.15-0.25	0.26-0.45	7500-13500		
C	0.26-0.40	0.46-0.60	13500-17500		
D	0.41-0.55	0.61-0.75	17500-23000		
E	0.56-0.70	0.76-1	23000-30000		
F	>0.71	>1	>30000		

Single Lane Roads

LOS	V/C Ratio	LOS	V/C Ratio	
A	≤ 0.15	D	0.51-0.80	
B	0.15-0.30	E	0.81-1.00	Source: Table 2.10, Indo HCM, 2017
C	0.31-0.50	F	>1.00	

So, what we could do solution as shown it here very simple directly you calculate the stream equivalency. So, use that equation what was given earlier for Two-lane road and then you can get the flow PCU taking the flow in vehicle per hour multiplying it by the stream equivalency, what is 1.488 in this case.

So, the number of followers then you can simply calculate using this equation Q is known. So, NF is known, NF is known and the capacity is also given. So, and everything is ideal, no further adjustment is necessary. So, number of followers as percentage of NFPC can be calculated varies, you calculate that and then refer back to this table what I have shown corresponding NFPC value and you can see the LOS is B alternatively if you use the V by C, V by C also you can take because the corresponding V by C as I said based on cluster analysis those who are also given. So, V by C also refer to the same table we will get LOS-B.

Capacity and LOS Estimation

Example 2: Determination of capacity using operating speed for hilly terrains

Road Section	Gradient (%)	Curvature (deg./km)
I	2.3	226
II	3.6	381
III	4.7	307
IV	5.1	256
V	6.8	421

Solution: We know, $Operating speed$
$=70.6-1.84\times Gradient(\%)-0.026\times Curvature(deg/km)$

• Operating speed for these sections are calculated and given in the table below

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Capacity and LOS Estimation

Road Section	Operating speed (km/h)
I	60.5
II	54
III	54
IV	54.6
V	47.1

• $Capacity=23.6\times operating\ speed(km/h)+167$

Road Section	Capacity(PCU/h)
I	1595
II	1441
III	1441
IV	1456
V	1279

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Going to another small example determination of capacity using the operating speed of hilly terrains, this is a hilly terrain so, 4-5 sections are given each case the gradient and curvature is given. So, straightway we can calculate the operating speed using this equation, knowing the gradient knowing the curvature we can calculate the operating speed. So, that is what is calculated then once operating speeds are known the capacity can be calculated again using this equation. So, straightaway you get the capacity for different section.
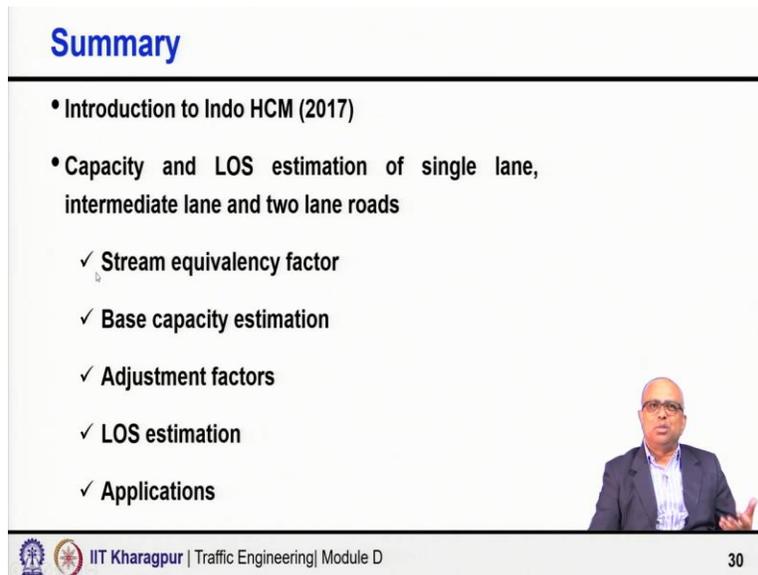
So, what we discussed here we introduced to you about the Indo highway capacity manual which was published in 2017. Then the capacity and LOS estimation what we use as measures of to define the LOS for single lane, intermediate lane and two-lane roads, the concept of Stream equivalency factor, Base capacity estimation, various adjustment factors, shoulder width, carriageway width, gradient curvature and the LOS estimation and took some small and very simple example problems to explain you the application. So, with this I close this lecture. Thank you so much.