`Introduction to Multimodal Urban Transportation System

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Lecture – 32

Non-Motorized Transportation (NMT) Planning: HCM 2010 Methodology for PLOS

Welcome back friends in today's lecture, we are going to give you an understanding of how to develop pedestrian level of service for the various links, intersections, along us urban street.

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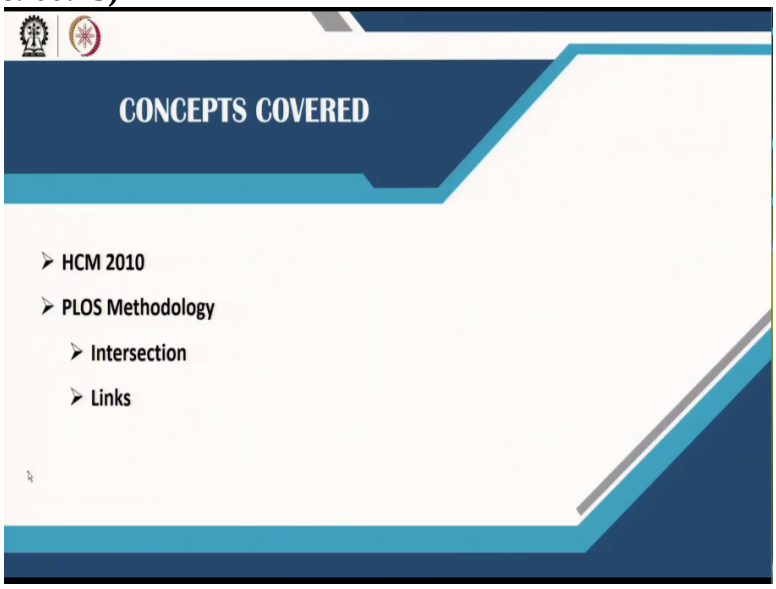

So, we are going to look at what are the functional elements in the urban street and then give you an idea about how to develop a pedestrian level of service for the intersection and the links. This is based on the highway capacity manual 2010 version developed in the United States. Such a methodology can also be adopted for the Indian situation. However, if you understand what is involved in the current methodology, you will be in a better place to adopt it.

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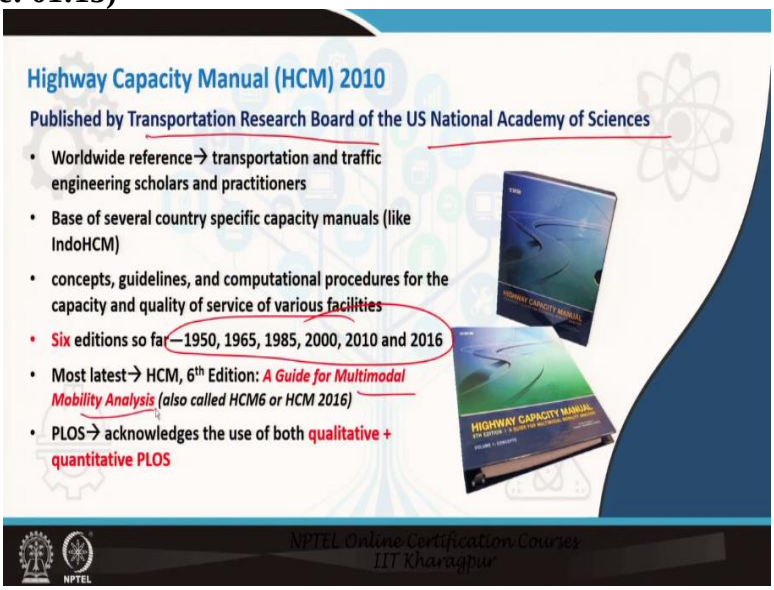

So, this is just a basic overview of the highway capacity manual which was published by the Transportation Research Board of the US National Academy of Sciences. It has had several versions so far and it has been very widely used in the field of vehicular transport. However, in the last couple of versions or editions, they have developed multimodal analysis, they have included pedestrian levels of service both qualitative and quantitative. So, this is what we are going to look at when we are looking at this lecture and also in some of the following lectures.

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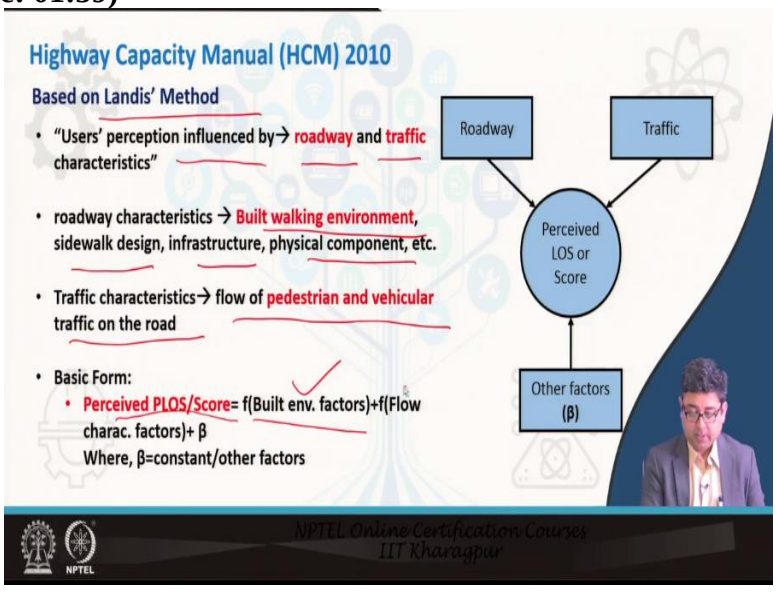

So, when we are talking about pedestrian level of service in the highway capacity manual, it is based on the Landis' method which we have already introduced to you. It says that the users'

perception is influenced by both the roadway and the traffic characteristics. Your roadway characteristics include the built walking environment, sidewalk design, infrastructure and the physical components. Whereas the traffic characteristics include the flow of pedestrians and vehicular traffic on the road. So overall if you look at form of the equation, if you think about it in that terms, how do you determine pedestrian level of service or score? It is a function of the built environment factors plus another function of flow characteristics and then you have a constant or the unexplained part of the equation. So, at gross level, it is a summation of the functions of built environment factors and the flow characteristic factors and this is essentially what the diagram is also telling.

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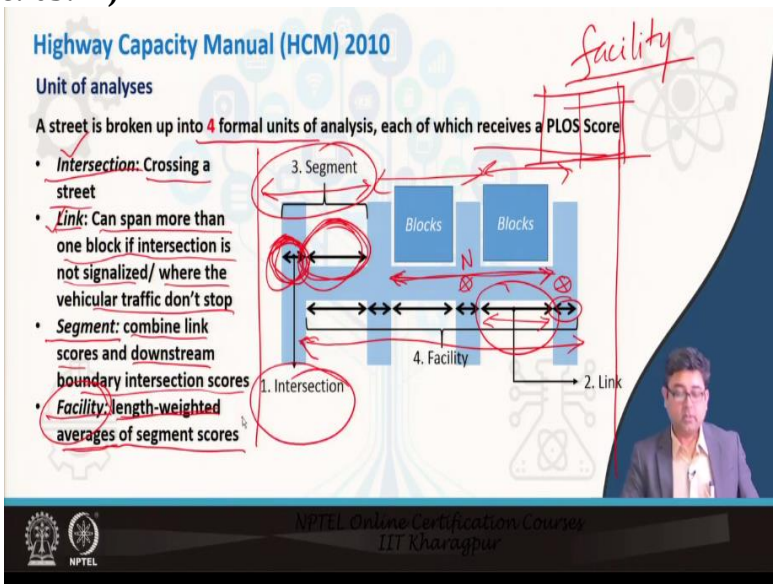

In this analysis, what is done is the entire analysis segment is divided up into separate units. There are formally 4 units of analysis, each of which receives a PLOS score. So, each of which receives a score and then that score is converted into a scale of A, B, C, D, or E to give you the pedestrian level of service. So, what are these 4 formal units? The first unit is the intersection. The intersection is a crossing of any street. So, if you look at this, this is will be the intersection. That is the first unit. The second is a link. A link is nothing but the distance, this one. So link can span more than one block if the intersection is not signalized or where the vehicular traffic does not stop. So here the link is the distance between these 2 streets. So that indicates that there must be a signal at these two junctions and that is why this is being considered as a link. If there was no signal at this junction, the link would then be the entire distance between these two. So that is essentially the understanding of the link. Just remember again the link does not

include the intersection if it is signalized however, if it is not signalized if it is non-signalized then it will also include the intersection as well. So that is how intersection and link is described. The next unit of analysis is what is called the segment. Now, what is a segment? Segment combines a link's course and the downstream boundary of the intersection's course. Now the segment is a combination of a link and an intersection. So, this entire thing is called a segment. When we are developing a pedestrian level of service score for a segment it will include the pedestrian level of service score for the intersection as well as a pedestrian level of service score of the link. So, that is what essentially a segment means. Then the final unit of analysis is the facility in itself. When we talk about the facility, we talk about the entire stretch now, okay. So, we are talking about the entire stretch, the length weighted averages of the segment scores. When we are developing a pedestrian level of service PLOS score for a facility, so, when we are developing this for a facility, what we are doing is we are doing a summation of a length weighted averages of the segment scores. Now we know the segment scores which consist of the scores of an intersection as well as a link. Now the facility will have the length weighted averages of each of these segments, okay. So that essentially is how a PLOS score for facility is developed. So, now let us start one by one with showing all different 4 formats of units of analysis and start with the smallest unit of analysis which is the intersection.

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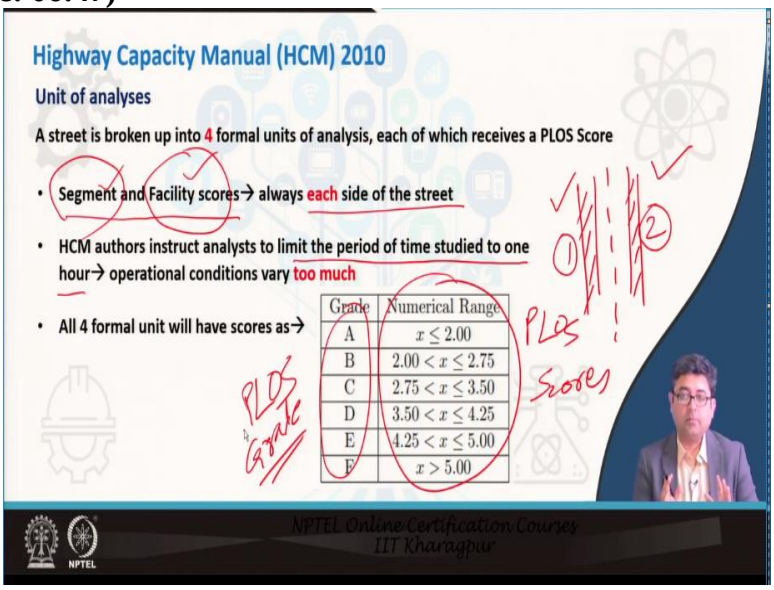

Before we do that, let us just tell you that the segment and facilities scores are always on each side of the street. Remember if there are walking facilities on both sides of the street then the segment and facility scores are different for different sites. So, that means that there may be one

road which has two pedestrian facilities, up and downstream or up and down, however it is not just enough to develop the level of service for only one side. So, this is one footpath and this is the other footpath, so, then each of these will have the PLOS score that has to be developed differently when you are looking at a segment PLOS score and the facility PLOS score, okay. And the time of study is limited to one hour. So, when we are looking for the flow, speed and density of how people are walking, we limit to one-hour time periods because it has been observed that the pedestrian flows vary greatly from hour to hour. So, we just keep it keep it down to one hour and then what usually happens, like we said, is you get a score for each either the intersection or the link or the segment or the facility. You will get different scores and those scores are then scaled into different grades, which gives you the pedestrian level of service. So, these are the pedestrian level of service scores, which are converted into a pedestrian level of service grade, okay. That is how you know how well your facility or your intersection is working. Remember, level of service or Pedestrian level of service is a performance measure which allows you to gauge or understand how well your facility is performing as per the stated objectives or functions. If the function of the facility is to provide mobility, to be a route to pedestrians, then how well is it providing mobility, or if the function is to provide safe crossing of pedestrians, how well is the pedestrian crossing providing it. So, that is what any level of service, in this case pedestrian level of service, measures.

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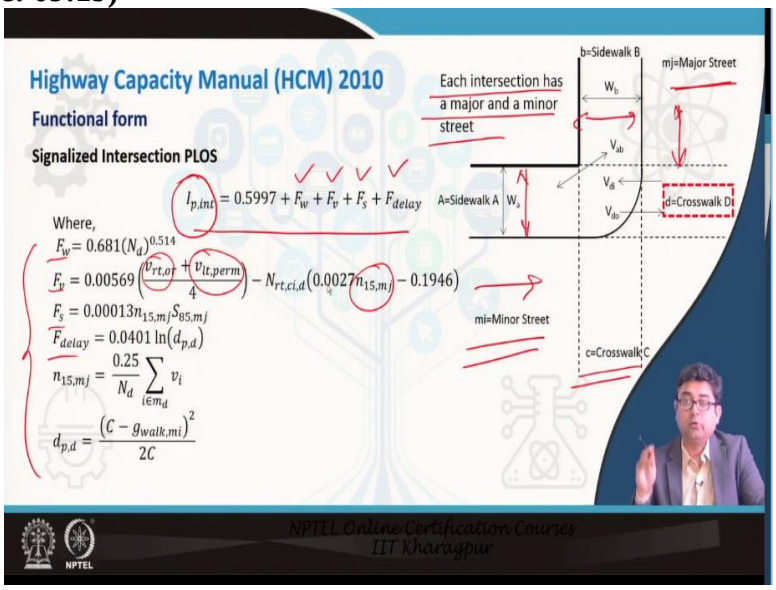

If you start looking at the intersection, all of this may seem very daunting, these equations and further equations, but they are very simple and we look at it one by one.

$$I_{p,int} = 0.5997 + F_w + F_v + F_s + F_{delay}$$

Where,

$$F_w = 0.681(N_d)^{0.514}$$

$$F_v = 0.00569\left(\frac{v_{rt,or} + v_{lt,perm}}{4}\right) - N_{rt,ci,d}\left(0.0027 n_{15,mj} - 0.1946\right)$$

$$F_s = 0.00013 n_{15,mj} S_{85,mj}$$

$$F_{delay} = 0.0401 \ln\left(d_{p,d}\right)$$

$$n_{15,mj} = \frac{0.25}{N_d} \sum_{i \in m_d} v_i$$

$$d_{p,d} = \frac{\left(C - g_{walk,mi}\right)^2}{2C}$$

If you look at a snapshot of an intersection, so you would always have an intersection where, a major street crosses a minor street. So, this is a major street and this is the minor street and they are intersecting, and both of them have sidewalks. So you know what is the width of the crosswalk, how much you have, or what is the width of the sidewalk, all of these are measurable. So, what this highway capacity manual tells you that at the intersection pedestrian level of service score is a given by a formula or a model or a linear regression equation, which is a function of these 4 different elements. Now, when we look at these 4 different elements, they are again further given by certain standard formulas. And these all formulas, the input to these formulas have to be collected on the street. So, for the particular intersection for which you want to develop a pedestrian level of service, you have to always capture certain amount of data, which if you put it in this equation or in this model, it will give you a pedestrian level of service score for that particular intersection, Okay. Now let us look into what individually all of these 4 elements are.

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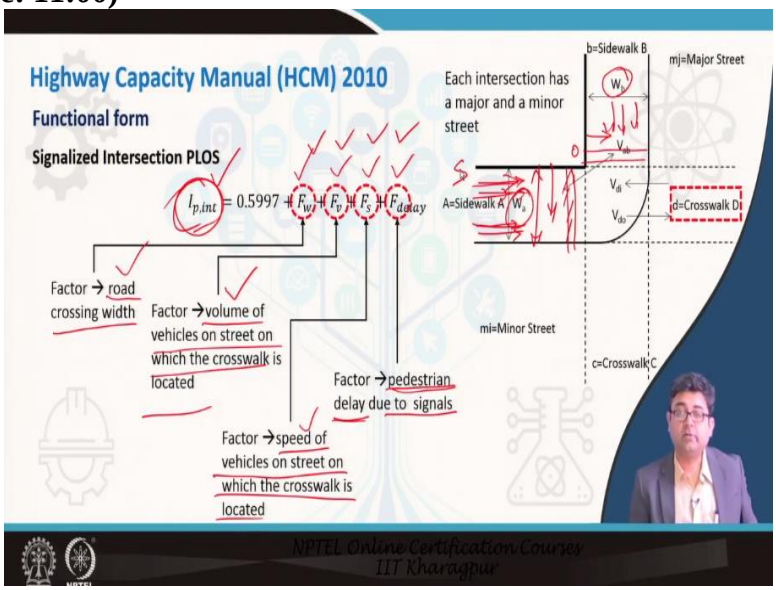

So, the first element which is F_w, is the factor the denotes the road crossing width. So, the width of the road that you will be crossing, okay you may have crosswalks on both sides. If you are here, you may be, want to cross either this street or this street, so the width of the road you are crossing is known. If you are crossing this road, what is the width, and if you are crossing this road, what is the width, so that is a factor. So, if the width is small, your pedestrian level of service score will be different whereas if the width is large, the pedestrian level of service score may be different. So that is a factor that controls the pedestrian level of service score. The next one is the volume of the vehicles on the street on which the crosswalk is located. So, this is a factor that governs the volume of the streets. Now, if you are trying to cross this way, what is the volume? If you are trying to cross this way, what is the volume of the traffic on this road? Versus if you are trying to cross this way, what is the volume of the traffic on this road? Right. So, that governs what the additional level of service score of the intersections. The third one is the speed of the vehicles on the street on which the crosswalk is located. So, you have to not only calculate the width of that road, the volume of vehicles on that road, but you also have to know your speed of vehicles on that road, and then finally, the fourth one is if there is a pedestrian signal. In case there is a pedestrian signal, so what is the delay of the pedestrians due to these signals? I mean, if not only pedestrian signal, if it is a signalized intersection, so if the pedestrians have to wait there, due to the presence of a signal, then how what is the delay that the pedestrians face?

Again, this delay is due to signal at the intersection not only a pedestrian signal but regular vehicular signal as well. So, what is the delay that is incurred or faced by the pedestrians at that intersection? So, the pedestrian level of score depends upon 4 factors. The first factor is the width to the sidewalk or width to the crosswalk or the width of the road which you are trying to cross. Second factor is the volume of vehicles that are on the road that you are trying to cross. Third factor the speed of the vehicles along that road that you are trying to cross and finally the last factor is if it is a signalized intersection. If there is a signal at that intersection then the delay faced by the pedestrians because of the signal. So those are the four factors that determine the pedestrian level of service score at a signalized intersection.

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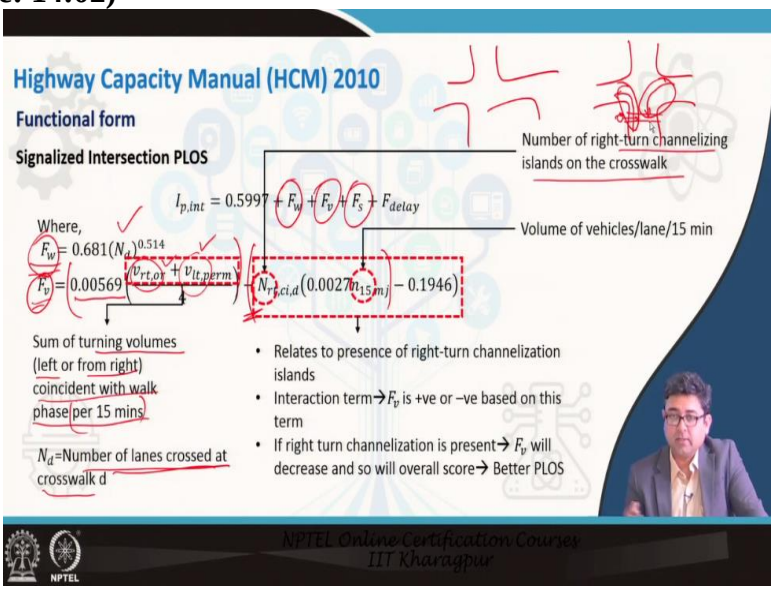

Now furthermore, if you break it down for each of these factors, you will see that the width factor only depends upon the number of lanes crossed at the crosswalk. So, it is 0.681 times N_d raised to the power 0.514, where this empirical formula it is only dependent upon the number of lanes you crossed. If you know the number of lanes, you just plug in the number of lanes here and you get the factor of F_w. If you want to know the volume of the vehicles that are crossing that are on that road, what you have to do is, you have to measure two terms. The sum of the turning volumes left or from right coincident with the walk phase per 15 minutes. You always have signals where the vehicles are also moving and you also have a green for pedestrians. So, for example, if I draw an intersection and you are waiting here, you are wanting to cross this road. So, what happens is you have left turning vehicles, and also you will have some right turning vehicles which are coming here. So, the volume of these right turning vehicles plus the

volume of these left turning vehicles will affect how you will cross, right? So, that is essentially the volume that you have to calculate in order to determine F_v. So, if you know the volume, you just add it divided by 4, multiply it by that factor and you will get the first element in F_v. The other elements in F_v are N, which is the number of right turn channelized islands in the crosswalk. Now, if there are any channelized islands, you just have to count the number of channelized islands. There are never more than 1 or 2 channelized lanes and that gives you the volume of the vehicles per lane per 15 minutes. So, if you know the volume of the vehicles per lane per 15 minutes, you just multiply that factor by the number of channelized lanes. This entire thing will now give you the F_v, the factor which determines the volume of vehicles that are on the road that you are trying to cross, okay. So now you know, Fw and you know Fv.

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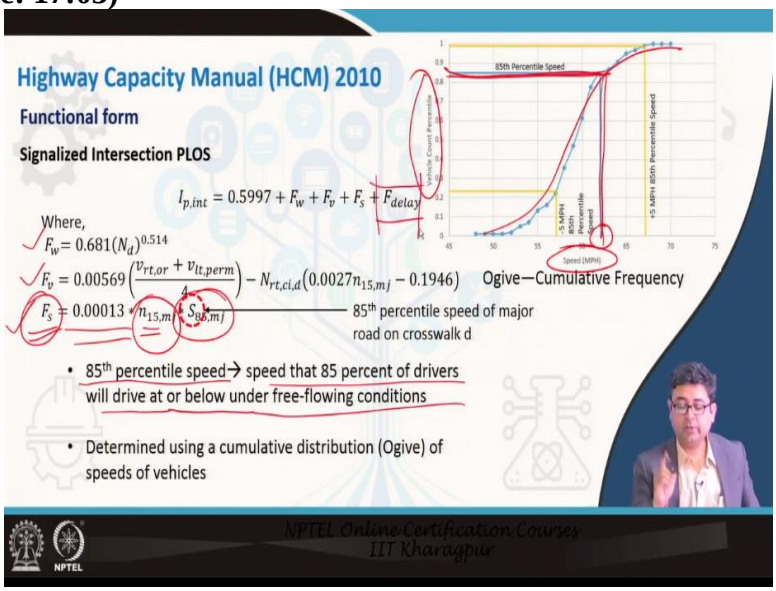

Finally, you also have to calculate F_s. You want to know the speed of the vehicles on the road that you are trying to cross. So, when you want to know the speed of the vehicles you have to know the volume. Which have already calculated for the 15-minute period and along with that you have to calculate what is called the 85th percentile speed. In order to just calculate the 85th percentile speed, it is nothing but the speed that 85% of the drivers will drive at or below under free-flow conditions. You just develop a cumulative frequency curve of the vehicle count and the speed. If you extend the 85th percentile speed and look at the X axis you will know what the speed of the vehicles are at which 85% of the vehicles are moving. That is the speed we want to know. Usually, we do not calculate the mean speed because it has been found out that above 85th percentile speed is a safe speed to assume, as not many vehicles are moving above

that speed. Once you know the 85th percentile speed of the vehicles on that street, you just multiply that with the volume. Now you know F_w F_v F_s and the final thing to know is F_{delay}.

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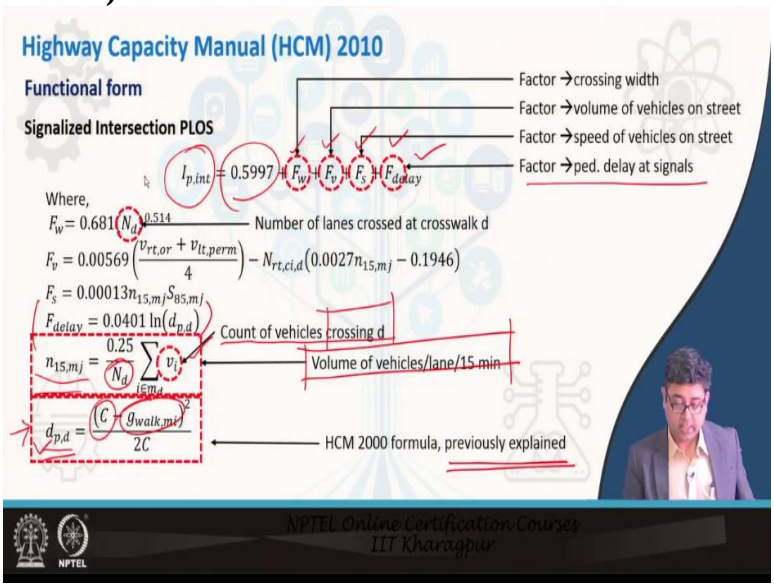

If there is a signalized intersection, pedestrian delay occurs at signals, we already know how to calculate the delay at signalized intersections. This is the cycle length minus the effective green time square by twice the cycle length. We have already explained it to you previously. In addition to that, if you want to calculate the count of the vehicles crossing the crosswalk, and the volume of the vehicles per lane per minute that is crossing the crosswalk, okay. So, that is crosswalk if you calculate that you already know the number of number of lanes. So, you can then determine the delay which is given by this formula. Here you will determine the count and then determine the delay and if you use this formula, you will get what is called the F_{delay} factor. So, now you know all of the 4 factors, you just plug it in in this formula added to this constant and you will know the intersection level of service score. We will give you an example problem. So, you can then relate back to these individual formulas and that will make you understand it much better.

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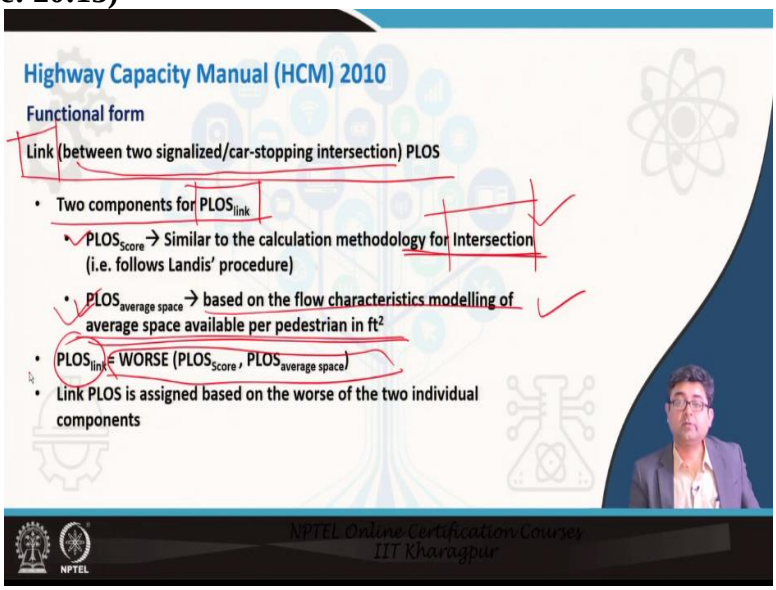

Before we do that, let us also give you an example of how to determine the pedestrian level of service score for the link. Remember again link is between 2 signalized intersections. If it is 2 signalized intersections the distance between that is called a link. If there is no signalized intersection, then you start from one signalized intersection till you reach another signalized intersection, that entire length is called the link. So, the pedestrian level of service score of the link depends upon 2 things that is the pedestrian level of service score for the intersection which we have already looked at and now then it is also depending on the flow characteristic; modelling of the average space. So, the average space available for the people to walk that also determines the pedestrian level of service score for the link. So, two elements in this a pedestrian level of service score similar to the intersection calculation. That we looked at and the other one is the pedestrian level of service for the average space. So, based on those two the worst of that will give you the pedestrian level of service link.

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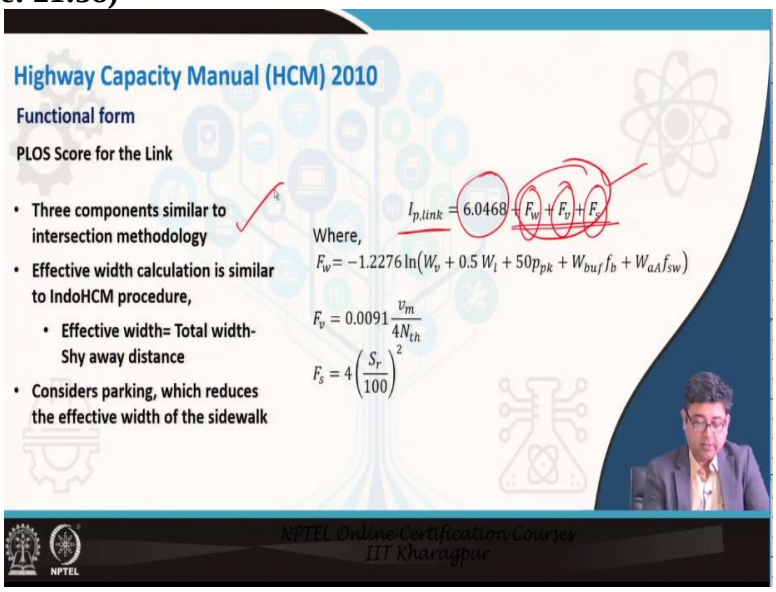

Similarly, just as for the intersection you had four factors to determine the pedestrian level of service, here you have only 3 factors, you have a constant term as well which is different in this case, but again let us quickly look at how do you calculate these three factors.

$$I_{p,link} = 6.0468 + F_w + F_v + F_s$$

Where,

$$F_w = -1.2276 \ln(W_v + 0.5\,W_l + 50p_{pk} + W_{buf} f_b + W_{aA} f_{sw})$$

$$F_v = 0.0091 \frac{v_m}{4N_{th}}$$

$$F_s = 4\left(\frac{S_r}{100}\right)^2$$

This is the width, this is the vehicle volume of vehicles, and this is the speed of vehicles along that. So, these 3 components are included and then for the score, you know that for the average space, you know that we are always have to calculate the effective width. The effective width is reduced if you consider parking. Right. You already know how to calculate effective width.

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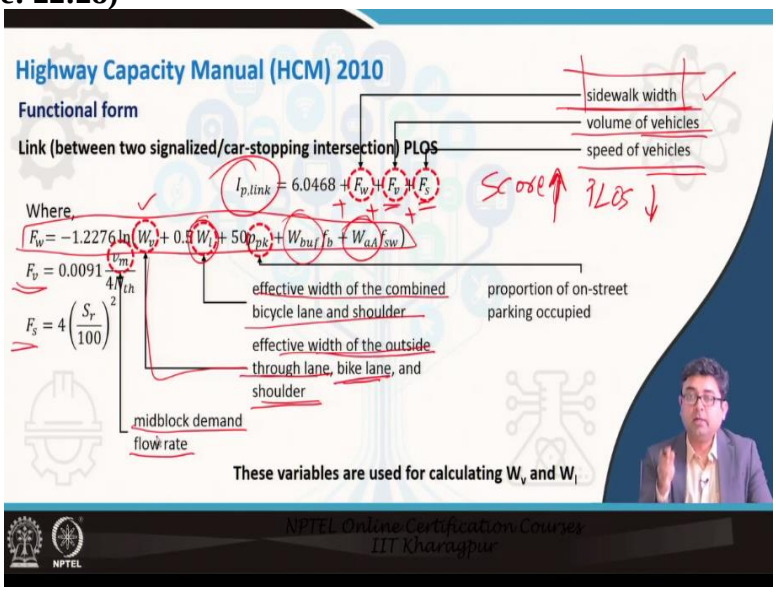

So, if you start looking at each of these factors again, F_w his time is the sidewalk width, remember last time when we were calculating the intersection but as a level of service score, that F_w was the crosswalk or the width of the road that you are trying to cross. In this case it is the width of the sidewalk because you are talking about a link. F_v remains the volume of the vehicles and F_s the speed of the vehicle. So, what this tells you is that the link on which you are walking, the pedestrian level of service even though you are walking on a segregated pedestrian facility, it depends upon the volume of vehicles that is plying on the adjacent street and also the speed of the vehicles. So, you should not always think that putting a sidewalk on a high speed road will entice more people to walk on it because the pedestrian level of service score usually goes down. So, if you have high speed vehicles along alongside footpath usually the score will be high because you know these are all additive functions and the score being high usually means the PLOS is low, okay, that is how score and PLOS are related to each other. We look again, one by one, if you calculate the factor that influences the sidewalk width, you have to know first the effective width. The effective width of the outside through lane, bike lane and the shoulder. So, will tell you in a diagram in the coming slides what we mean by the outside through lane, bike lane and shoulder. But we are calculating the effective width based on the outside traffic lane, okay, not the ones inside. Inside meaning the traffic lanes that is closer to the median. Outside meaning the traffic lane that is closer to the footpath. Then you have to have the effective width of the combined bicycle lane and shoulder. So, this is the effective

combined width, the bicycle lane and shoulder, whereas this is the effective width of the outside through lane, bicycle lane and shoulder. The other component is the width of the buffer that is available, if there are any plantations or anything between the vehicles and the pedestrians. Then finally for the other 2 factors, i.e. the vehicle volume factor or the vehicle speed factor. For the volume factor again V_m you have to determine the midblock flow rate. You know already how to calculate flow rates, so you are to determine the midblock flow rate. So, at the middle of the link it will determine the flow rate and for speed they are given by these 3 formulas.

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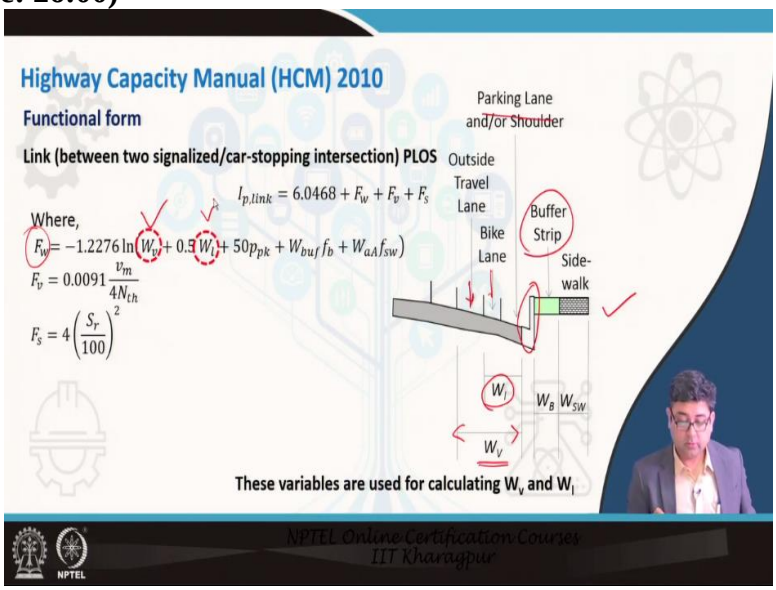

So here it is while calculating F_w, when we say W_v or the outside lane this is what we are meaning you have the sidewalk here and then you have a buffer, some kind of plantation and then you have curb and gutter here. So, then the first one may be just the shoulder of the parking lane, then you may have a bicycle lane and then maybe your outside travel lane is starting. So, this the entire distance is called your W_v. If you want to only know the W_l effective width of the bicycle lane and the shoulder that is your W_l. This P_{pk} factor is the proportion of the length that is covered by parking.

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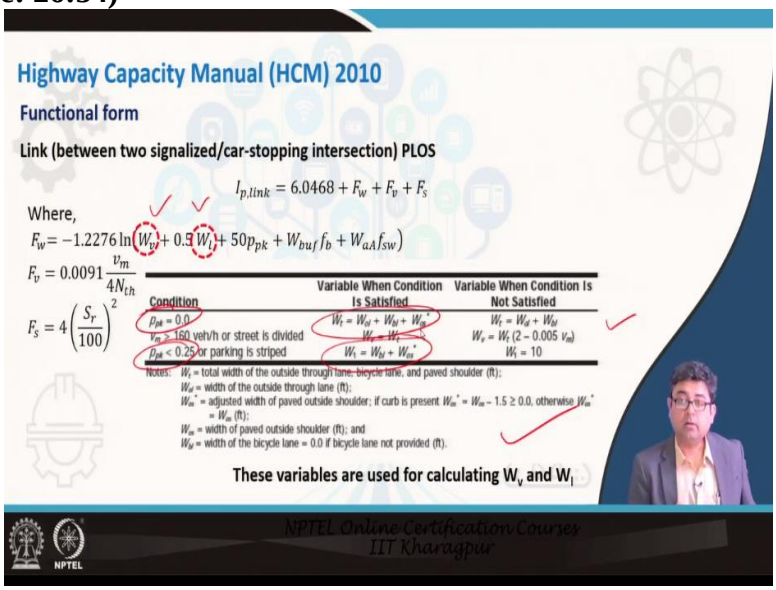

Now, there are some certain conditions that you have to take into account while you are developing these width factors and these are standard conditions that have been again developed based on certain urban conditions in the United States. Because we do not have specific for our country or for our Asian environment, we will still go with these. But this is for your understanding, maybe when you are conducting field experiments in your city or in any different parts of India, these factors may change. But you have to at least have an understanding of how do you determine this. If for example, the proposal there is no parking; versus if at least 25% of it is covered by parking. Then how do you determine those effective widths? They are given by this condition or they are given in this table and it is just plug and play. You just have to pick which condition you are dealing with or you just have to determine simple widths.

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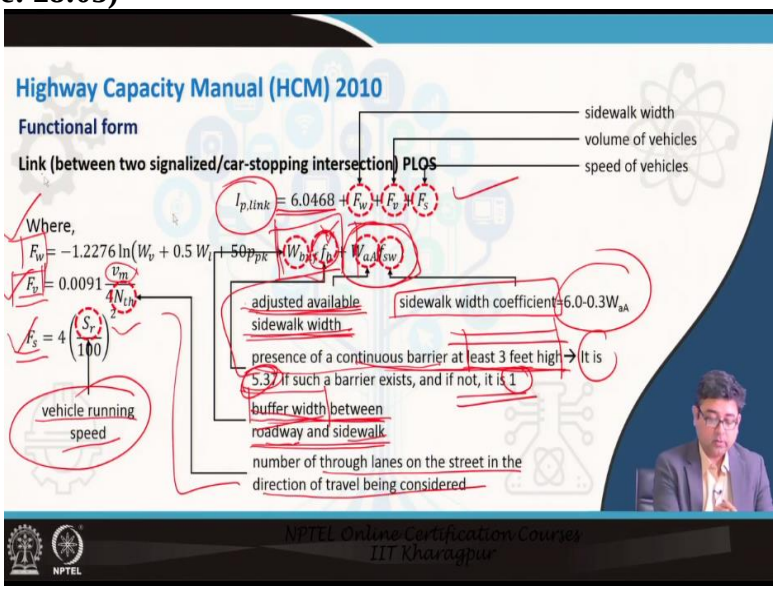

For F_s again in this case we are just determining the vehicle running speed, we are not determining the 85th percentile speed. You just have to calculate the regular running speed and may conduct certain spot speed studies. In order to understand what the regular running speed is for volume, all you have to know is the number of through lanes on the street in the direction of the travel being considered. If you know the number of true lanes, you are already calculating the volume of vehicles per 15 minutes per lane, if you plug in those you will get the factor of volume. Now that the other two things that were included in the F_w term, one was the adjusted available sidewalk width. So, you have to there is a factor that you have to multiply the buffer width. W_b is the buffer width if there is a plantation width is called the buffer width between the roadway and the sidewalk. With that buffer width you have to multiply that with the factor which tells you the available sidewalk width. That factor multiplied gives you this element. Similarly, for this factor is the presence of the continuous barrier for at least 3 feet high. So, let us make it again clear you first have to for this term, you have to understand what the width between the roadway and the sidewalk that is the buffer width. Once you know the buffer width, if you feel or if you see the presence of that continuous buffer and that buffer is at least 3 feet high, then f_b factor is 5.37, if it is not then the f_b factor is 1. So, that is very empirical so you can understand it is a very empirical way of doing things, these were done in 2 or 3 locations in the United States and based on those sites specific locations this formula was developed. okay. So, if the buffer exists and it exists continuously and the buffer and the width the height is at least 3 feet, then this factor is 5.37 otherwise, the factor is considered as 1.

Finally, the last term is the adjusted available sidewalk width, along with that you have a sidewalk width coefficient that you have to multiply this with, which is given by the simple formula for this. So once you calculate F_w, once you calculate F_v and once you calculate F_s you just plug it in in this formula, add to the constant and you will get the PLOS of the link. Remember we are talking about the PLOS score of the link.

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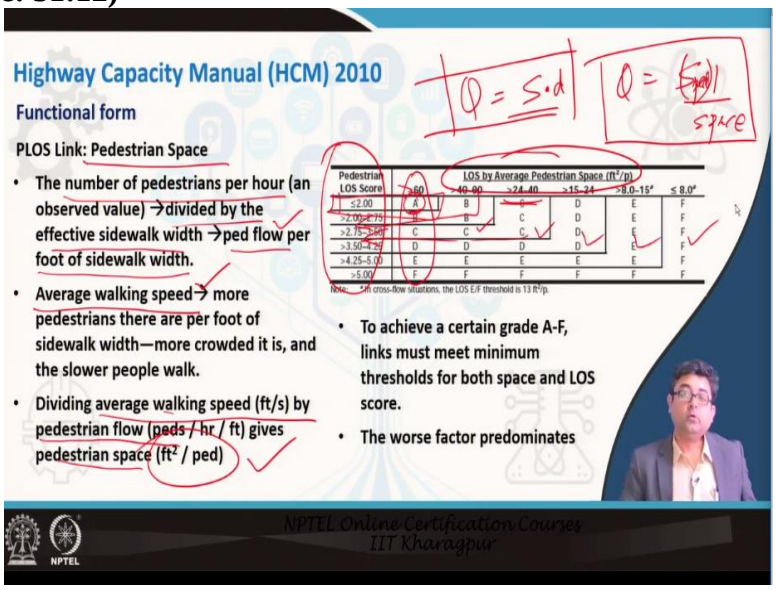

Now again going back you remember that for the link you have to have 2 different PLOS calculations, whereas that we have just calculated the other one is based on the pedestrian space. You already know how to calculate the pedestrian space for the number of pedestrians per hour divided by the effective sidewalk which will give you the pedestrian flow per foot per sidewalk with average walking speed. More pedestrians are there, more crowded, so you know the average pedestrian speed, you know the original pedestrian flow rate, divide the average pedestrian speed by the pedestrian flow rate which gives you the pedestrians space. Pedestrian spaces given by square foot per pedestrian; how much space individual pedestrians need, i.e., square foot per pedestrian, they were in the average walking speed by the pedestrian flow. Remember the basic equation flow is equal to speed by space. So, that is the basic relationship. So, based on that relationship you are calculating the pedestrian space now, if you know the pedestrian space and if you know your pedestrian level of service score that you have calculated for the links, you will then, for each given pedestrian space, you will have a corresponding pedestrian level of service score, right. So, you see that it is very difficult to achieve a pedestrian level of service A because that is only available in this condition when the score is

less than 2 and when the space is greater than 60. Otherwise in any of these you would not have a level of service A, so usually we do not design for level of service A.

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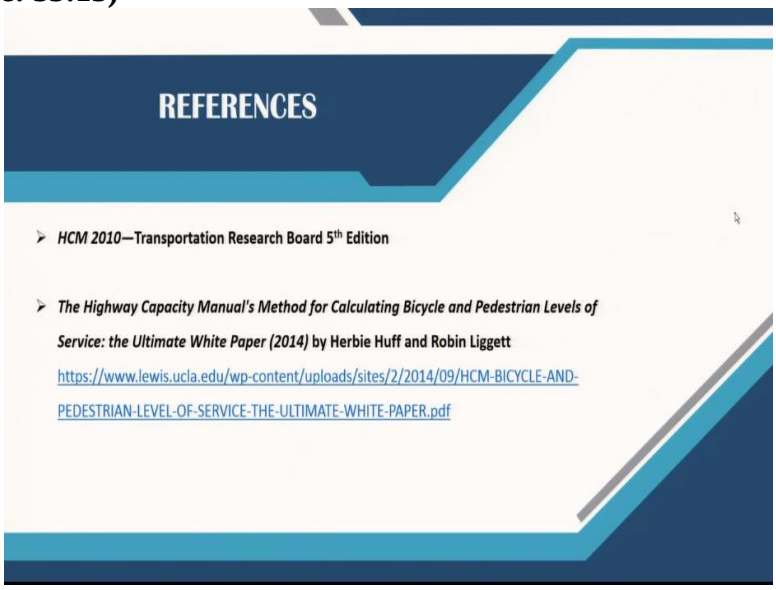

That brings us to the end of this lecture. However, we will continue this lecture in the next half hour, we will continue this same series because we have only looked at the intersection and the link. Next, we will look at the segment and the facility and we will give you some examples of this, so that you are thorough with the understanding these are the references.

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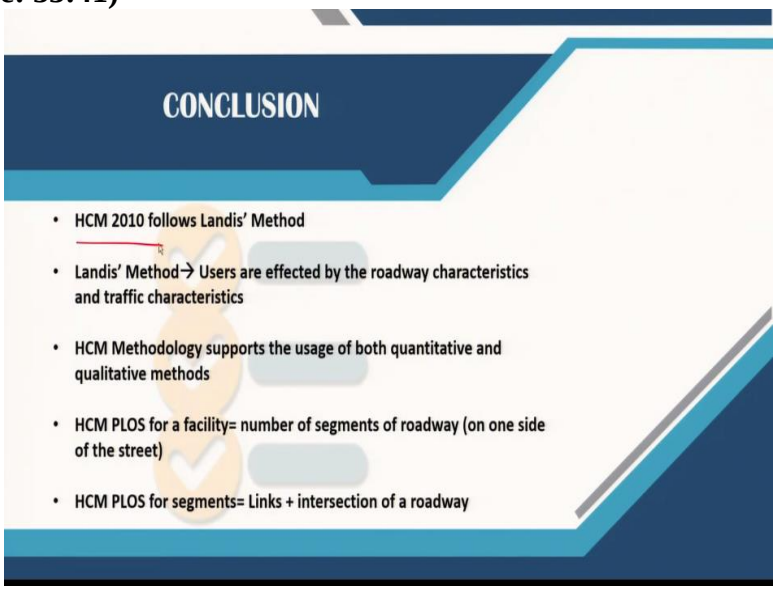

So, in this lecture, we have looked at the highway capacity manual 2010 version of how to develop a pedestrian level of service score for an intersection as well as for a link. Thank you for your attention.