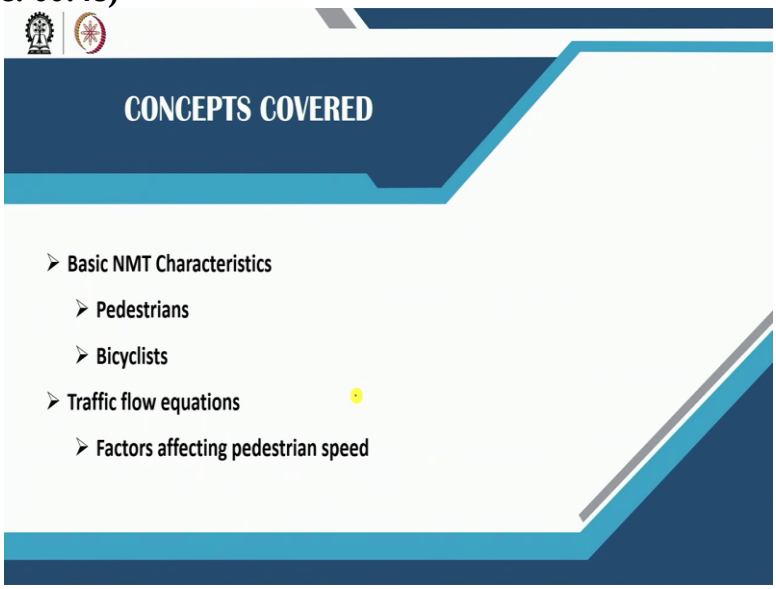
Introduction to Multimodal Urban Transportation System

Prof. Arkopal Kishore Goswami
Department of Ranbir and Chitra Gupta school of Infrastructure Design and Management
Indian Institute of Technology - Kharagpur

Lecture – 26
Non-motorized Transportation (NMT) Planning: Basic NMT Characteristics

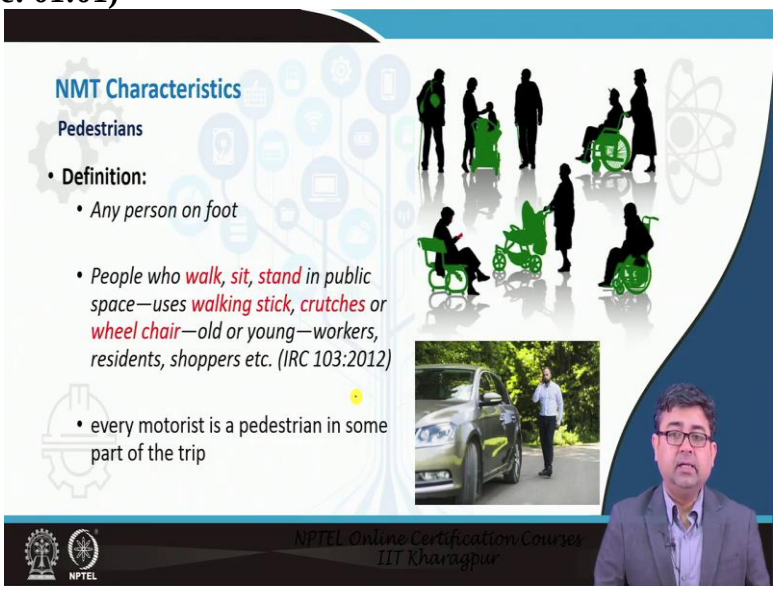
Welcome back friends, let us begin our next module which is on non-motorized transportation. We have looked so far at the five basic steps of planning for non-motorized transportation. Now we will get into the details of bicyclists and pedestrians one by one.

(Refer Slide Time: 00:48)



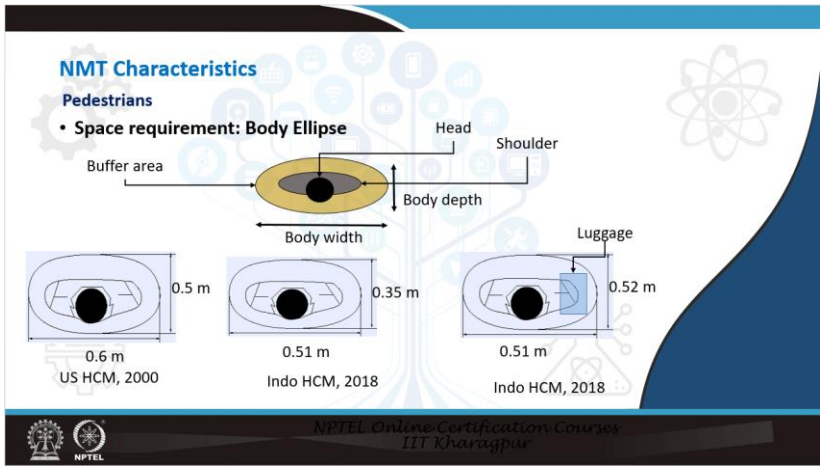
In this lecture, we will be looking at the characteristics of pedestrians and bicyclists and get into the traffic flow equations and the factors that affect the pedestrians speed.

(Refer Slide Time: 01:01)



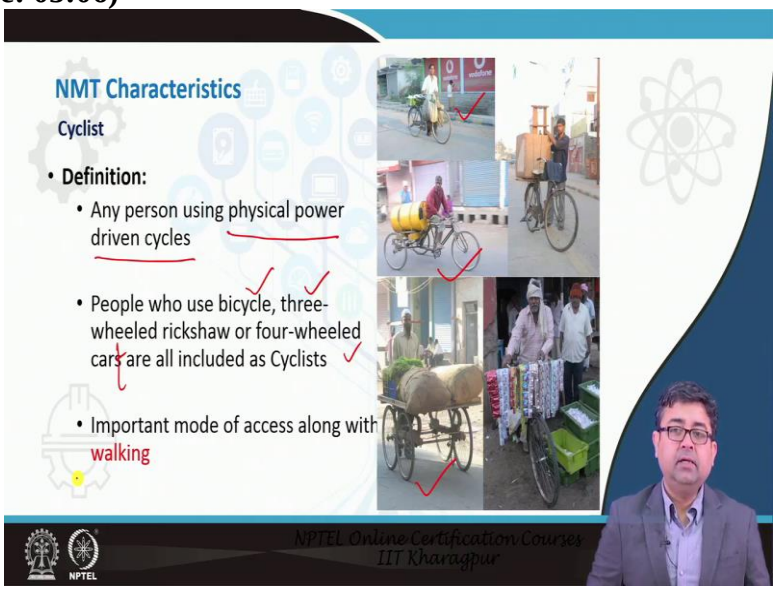
Now, when we are going to plan or design any facility, you have to understand who you are designing it for. So, at a broad level, pedestrians are defined as any person on foot, or anybody who is walking, is a pedestrian. However, while planning for pedestrians we also plan for people who not only walk, but also, sit or stand in public spaces, uses a walking stick, crutches or a wheelchair. We look at different types of people old or young workers; residents as well as shoppers who are shopping in the market area along the streets. This is a definition given in IRC codes. So it kind of encompasses everybody who is on foot, who is standing, who is running, playing around, a mother with a toddler in the stroller, a person on the wheel chair that is being pushed by another person, etc. When you are looking at designing any pedestrian facility we are looking at each and every one of them, and also remember, every motorist is a pedestrian in some part of the trip. Even if you are driving a car, you have to get to your car. So, while you are accessing your car, you are most likely walking to your car. So, facilities such as footpaths or sidewalks that lead up to a parking facility, they have to be designed in mind keeping in mind the accessibility needs of the motorized people as well.

(Refer Slide Time: 02:41)



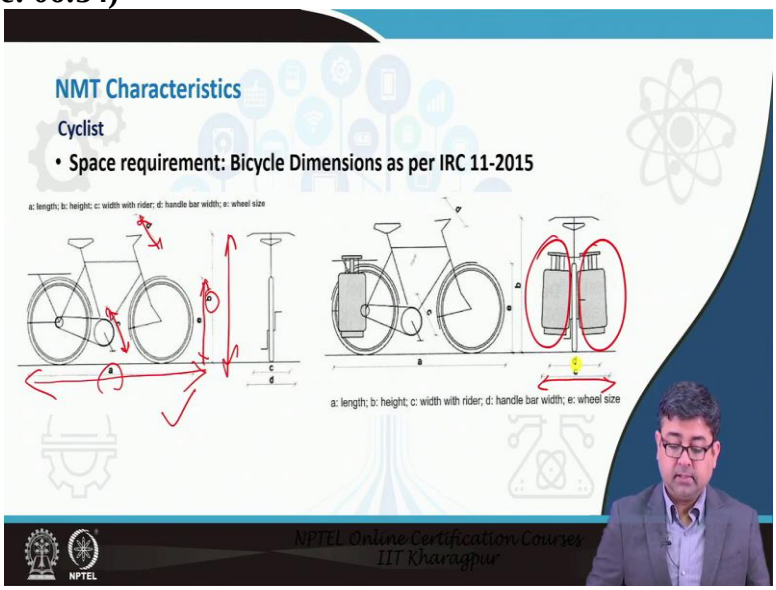
Now when we look at the space requirements for each pedestrian, they are usually determined by the ellipse that our body forms. If you look at our body, the top view of the body, then we will see our head which is in this black circle and the shoulders, the grey elliptical as well as the buffer area that is needed for free movement of your arms. When you walk, your arms swing. So, there is some free buffer area that is needed by each and every person in order to walk freely. These are the basic elements of the body which has to be taken into consideration while you design for pedestrians or design any facility for pedestrians. Now, there are different values that are used based on the average person in that country. So, in the highway capacity manual that was developed in the United States, they usually use the value of 0.6 meters for the body width and 0.5 meters for the body depth. Whereas the Indo highway capacity manual that was developed in India, we use a body width of 0.51 and a body depth of 0.35meters. In addition, the indo HCM also defines that, more often than not, we do carry a luggage on our shoulder. So, we have to give an extra body depth, 0.52 meters. So we have to give an extra body depth of about 0.15 meters, which, in addition to the 0.35, so that we can plan for any people, for an average person, who is actually walking on the street with something on his or her shoulder. So, these are the average values that can be used for designing any pedestrian facility.

(Refer Slide Time: 05:06)



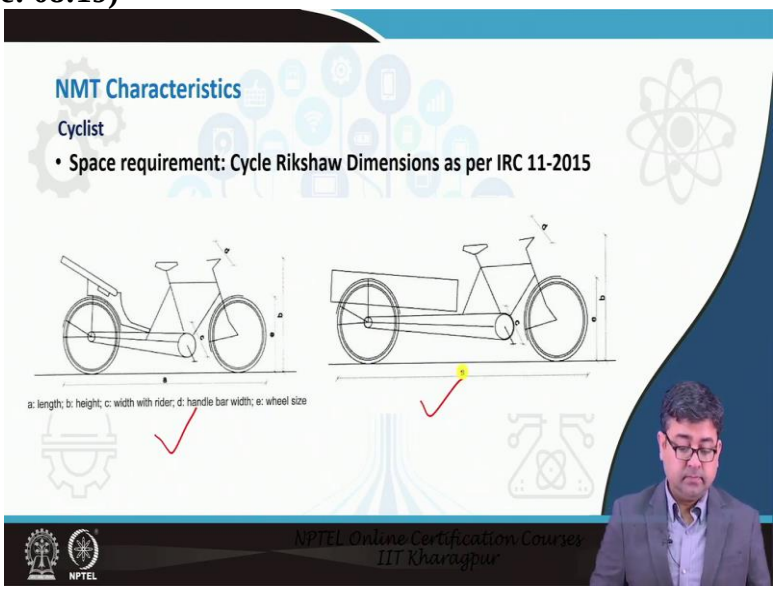
Next, how do we define a cyclist? A cyclist is any person using a physical-power driven cycle. Now there are electric cycles, electric bikes that are coming out, so those do not fall in this realm. In this realm, we only find bicycles, tricycles, and sometimes your vendor carts that have to be taken into consideration while you are designing for cycling, i.e. people who use cycles, three-wheeler rickshaws, or four wheeler carts. Sometimes it is noticed that walking, that does not get a lot of importance while we are looking at transportation, does get significant importance when we are looking at urban transportation. However, cycling is still not getting its due importance despite the high number of cyclists that are on our urban streets. So it is very, very important to take into consideration cyclists along with people who walk, while we design for an NMT infrastructure.

(Refer Slide Time: 06:34)



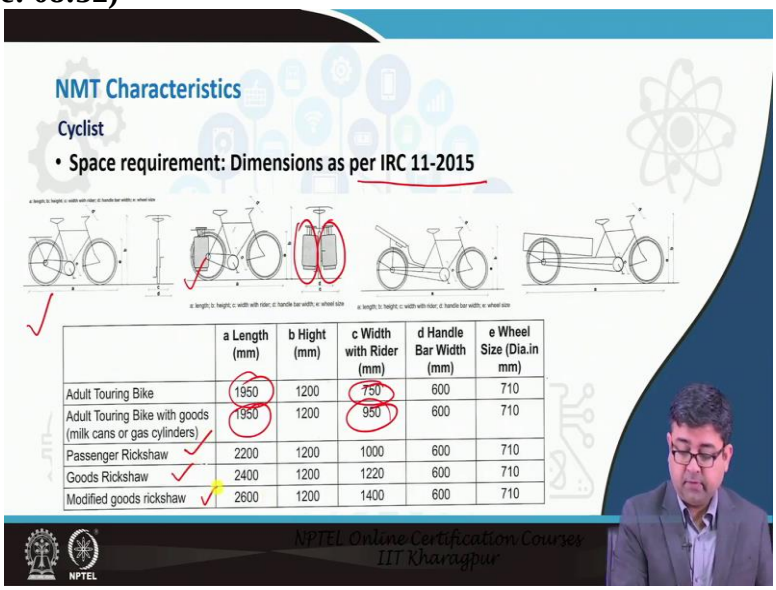
Now, similar to the body ellipse, with there are also standard dimensions for bicycles. Normal bicycle would be such, and we will give you the dimensions in the next couple of slides. But we are not only looking at the width or the length of the bicycle, we are also looking at the circumference or the diameter of the wheel, the entire height and also the length of the handles. So, it is important that we have to look at diameter along with the pedal length as well. These all play an important role while we are planning for bicycles because the handle is the one that will turn the bicycle in the direction. So, it has to have free manoeuvrability, it has to have space to manoeuvre. Dimension of the handle is also important. Now in the Indian context, we also consider goods that will be transported on a bicycle. So in order to consider the goods standards, look at either one piece of luggage or goods on each side of the cycle. So, in this case it is shown as a cylinder but it could be anything. However, it is restricted, i.e. we usually restrict them to a certain width, we do not encourage that very wide objects be carried on bicycles.

(Refer Slide Time: 08:19)



Similarly, there are standard dimensions for cycle rickshaws as well as carts that are used to ferry vegetables.

(Refer Slide Time: 08:32)

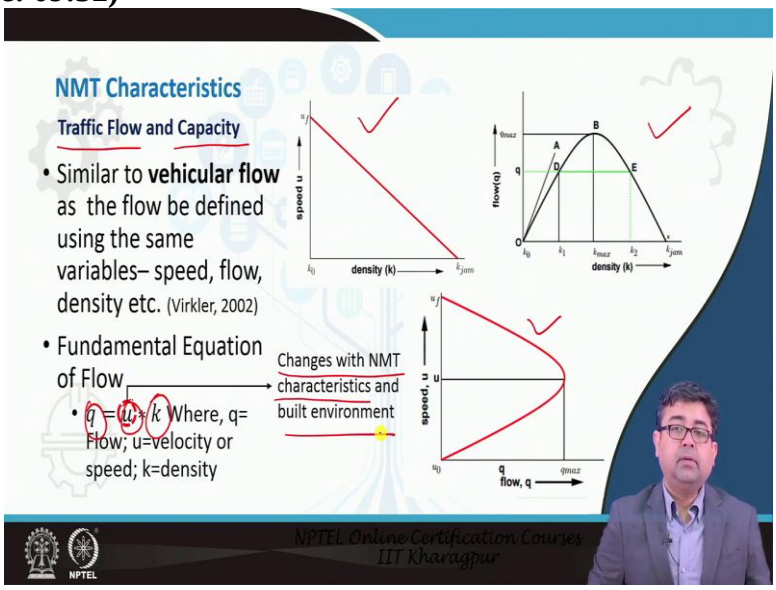


	a Length (mm)	b Hight (mm)	c Width with Rider (mm)	d Handle Bar Width (mm)	e Wheel Size (Dia.in mm)
Adult Touring Bike	1950	1200	750	600	710
Adult Touring Bike with goods (milk cans or gas cylinders)	1950	1200	950	600	710
Passenger Rickshaw	2200	1200	1000	600	710
Goods Rickshaw	2400	1200	1220	600	710
Modified goods rickshaw	2600	1200	1400	600	710

Now, here are all the dimensions given in one slide. These are as per IRC code 11-2015, you would see that an adult touring bike has a standard length of 1050 millimetres, whereas, an adult touring by bike with goods would still have the same length but it would have a different width with rider. So that is the only difference when you are carrying goods versus when you are riding alone. When you are riding alone, the width to be considered is 750 millimetres.

Similarly, different dimensions are given for passenger rickshaws and modified good rickshaws.

(Refer Slide Time: 09:32)

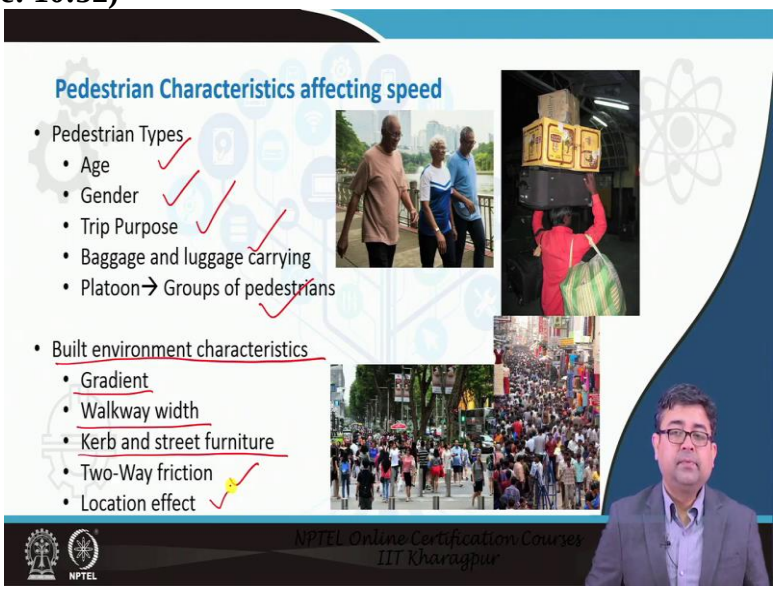


Now the next thing to consider when we are looking at NMT infrastructure, is the traffic flow and the capacity of the facility that you are trying to build. Now, the basic terminology is all borrowed from vehicular traffic or motorized traffic, but they also apply in case of Non-motorized transportation. So, the basic equation says that flow (q) is a product of speed (u) and density (k). So, that is the basic equation,

$$q = u * k$$

Now the speed will vary as per the NMT mode, its characteristics and the built environment. So, we will look now further into what are the elements that affect the speed of pedestrians specifically, before we get into bicycles, and then in the coming lecture, we will explain these three diagrams in much more detail.

(Refer Slide Time: 10:52)

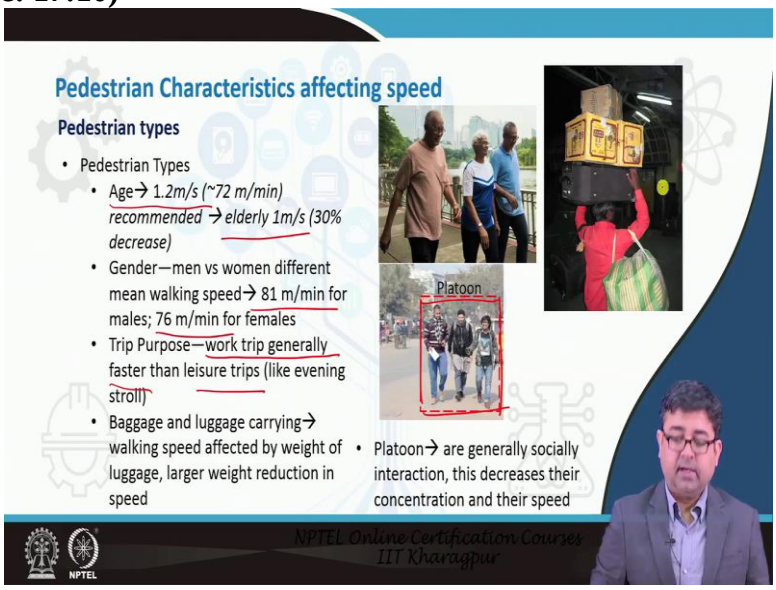


So, what are the characteristics of pedestrians that affect speed? First point is why you need to look into the speed of pedestrians while designing for pedestrian facilities, (a) because you need to understand how many people can be accommodated along any facility. So, for example, if you have a sidewalk, you need to know how many people a sidewalk will accommodate per unit time. So, people are constantly moving or some people are standing. So, you have to take into consideration them as well. Some people may be standing, some may be walking at a fast speed, some people may be walking at a slower speed. So, maybe on an average you can accommodate a certain number of people per unit time. So, that people per unit time will give you actually that capacity of the facility. So, given length of sidewalk, given width of sidewalk, you can accommodate 'n' number of people per unit time. So this 'n' per unit time depends upon how quickly people move across that facility. Even if it is a crosswalk, for example, if it is a zebra crossing, and people are trying to cross the road along the zebra crossing, you still need to know how fast the people can move across. What is the width of the road that they are crossing in order for you to give the traffic signal sufficient pedestrian walk time for them to cross the street? So that is the two basic primary reasons for which you need to know what are the factors that affect speed. The basic factors that affect speed are the age of the people that are on the facility; the gender, as women tend to walk slower than the men; the trip purpose, so if you are walking, to go to office, or walking to catch a train or walking for some urgent purpose, then you would walk faster. Well, if you are shopping and walking and looking at different kinds of stores, or you are walking with friends, you would be walking slowly. Speed also

depends on whether you are carrying any bags or not. And also, whether if you are walking with a group or with some group of people, or not. These are different types of just pedestrians, which are also factors that affect their speed. Now, if you look at the built environment characteristics. So, if you are walking on a road that has a steep gradient, or if the road is very up and down, then your speed will vary. Walkway width, now it is a very narrow sidewalk, then automatically you are aware of the fact that you are very close to the vehicles that are moving very fast on the road. So you tend to be walking a little bit away from the vehicles, and then tend to be very careful that you do not step on to the carriageway. So that automatically kind of reduces your speed. And on top of it, if there are a lot of people walking on that narrow footpath, then your speed gets reduced. The kerb and the street furniture, now if you have a lot of, trees in between the sidewalk, this is a very tricky situation. We do need trees for pedestrians to feel comfortable while they are walking because they provide shade and trees overall are a very essential part of the urban infrastructure, urban green infrastructure. But at the same time if they are right in between your walking path, in the middle of the sidewalk that causes some inconvenience to pedestrians because now they have to walk around the tree, they have to bypass the tree, which kind of again reduces the speed. So this this factor not only reduces the speed, but it also causes a minor inconvenience to the pedestrians who might be wanting to walk the shortest distance between the two points and not go on a winding path. Well, again, it depends on the purpose if you are leisurely walking, then you would enjoy walking on winding paths, but if you have some other purpose, some urgent purpose, you would not. You would prefer that you walk fast. So that is one of the things and there are other things such as benches and sometimes of course the footpath is encroached upon. Sometimes two wheelers that are parked on sidewalk or sometimes even four wheelers are parked on sidewalks or footpaths. So, all of these cause great deal of inconvenience and also reduces the speed of pedestrians. Now two-way friction is the other thing, if there is only sidewalk on one side of the road and no footpath on the other side of the road, then all the people usually tend to walk on the side of the road that has footpath. And so you have a two-way pedestrian traffic on one side of the road on the footpath. So that again causes a lot of friction between pedestrians walking in both directions, and that friction reduces the speed. Last but not least, of course location effect. So you are walking through an area that has many things to see, museums, good restaurants, good shops, then automatically your speed goes down because you want to slow

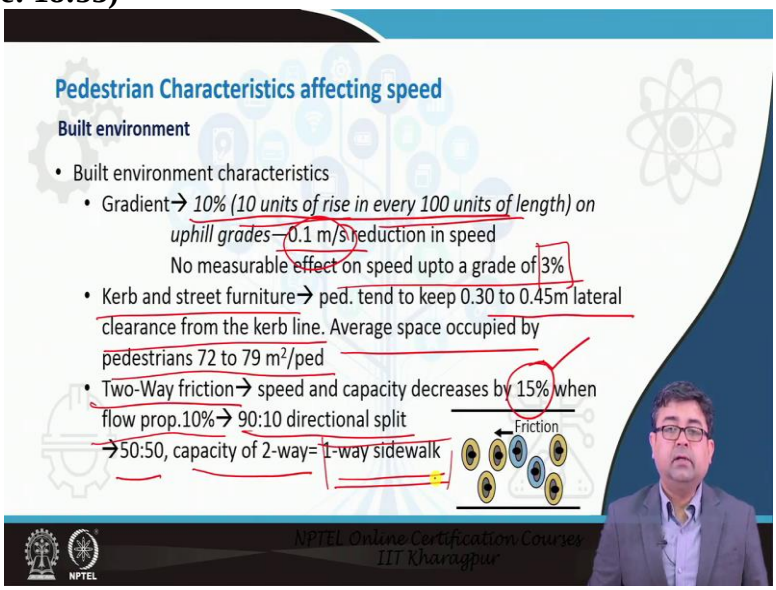
down and appreciate the environment through which you are walking and so the speed reduces. So this gives you an idea of what are the factors that the speed of a pedestrian depends upon.

(Refer Slide Time: 17:10)



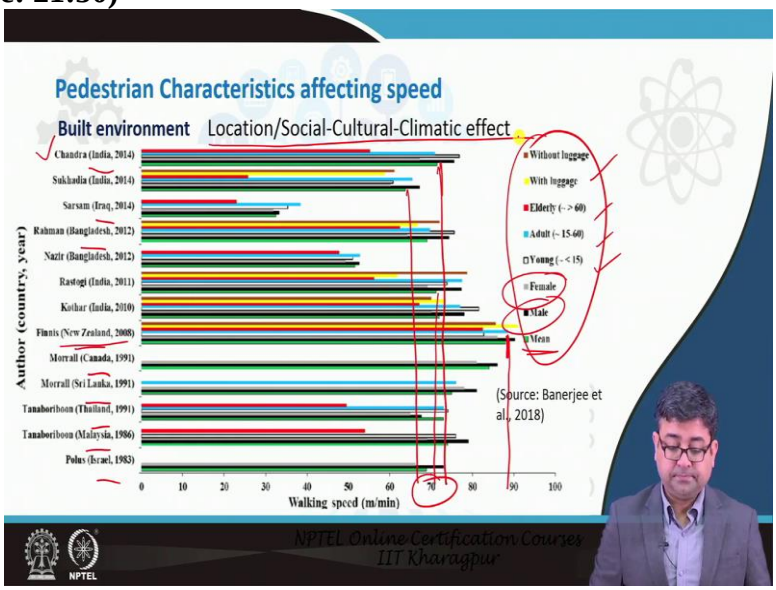
Now, based on the different types of pedestrians, there are some average values of speed that can be used. Based on age, you can say that the average speed at which people walk is usually 1.2 meters per second, the elderly walk a little bit slower, i.e. 1 meter per second. Now, when it comes to gender, men versus women, mean walking speed of men are about 81 meters per minute (or 1.35 m/s), whereas, women walk a little bit slower of 76 meters per minute (1.26 m/s). When it comes to trip purpose, work trips, like we discussed already, generally are faster than leisure trips. And of course if you have baggage, you are walking much slower than if you do not have a baggage. Similarly, platooning effect is when we walk two or three friends together and when we are walking together our speed usually decreases. So, I mean, remember we also should be planning for pedestrians with luggage. So this is a typical example. Say when you are planning for a pedestrian facility for example, platform on a railway station, you have to take into account the people who help us with the luggage and plan for them as well.

(Refer Slide Time: 18:53)



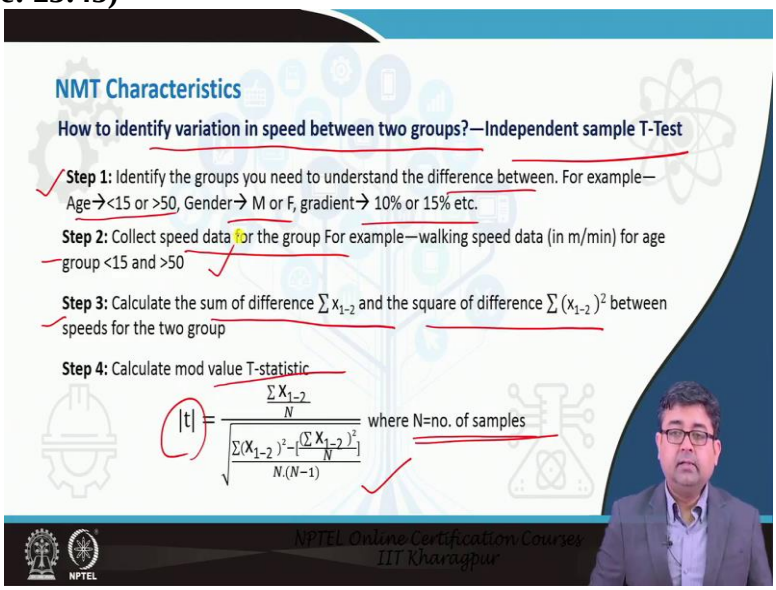
Now when it comes to the built environment and its effect on speed, it has been seen that when there are 10 units of rise in every 100 units of length on uphill grades, there is a 0.1 meter per second reduction in speed. So, when the gradient becomes steeper and steeper, for every 10 units of rise in every 100 units of length, your speed reduces by 0.1 per second. No measurable effect on speed up to grade of 3%. So, up to 3% grade you do not have much effect on speed but once the grade is steeper than three percent then you are kind of worried. When there is a lot of street furniture, or the kerb is too close to the motorized vehicles, pedestrians tend to keep 0.3 to 0.54 meter lateral clearance from the kerb line. So, we tend to walk a little bit away from the kerb line so that we are away from the motorized traffic. So, then the average space occupied by the pedestrians are 72 to 79 meter square. So, one person on average occupies 75 meter square on that footpath. So, given this lateral distance that we leave from the kerb line and the space that we actually need to travel, there is an impact on speed. In case of two-way friction, speed and capacity decreases by 15% when the flow proportion is 10%, so when there is a 90 to 10 directional split, i.e. 90% of the people are walking in one direction 10% is walking on the other direction, there is already a reduction of about 15% of the maximum speed at which they can walk on the sidewalk or footpath. At 50-50 split, capacity of a two-way facility is equal to a one-way sidewalk facility. So if you have 50% of the people walking one direction, and 50% of the people walking in the other direction, it is as good as having a one-way sidewalk, i.e. the capacity of a two-way sidewalk is as good as one wayside walk. So it reduces the speed causes a reduction in the capacity as well.

(Refer Slide Time: 21:50)



Now here are some examples from various researchers that have been done in different countries. So you would see research from India, Iraq, Bangladesh, New Zealand, Canada, Sri Lanka, Thailand and Malaysia as well as Israel. So, you would see that how the walking speeds differ based on weather based on all these different conditions. So, you would see that it seems like New Zealand, in New Zealand the mean speed is the highest (the green color), just a little bit less than 90 meters per minute. If you look at India, different studies say different things. One study has said that speed is anywhere just about 70 may be 75 meters per min. The other study says it is less than 70. So, I think under Indian conditions it is safe to say that the average speed of pedestrians is somewhere around 70 meters per minute. The speed varies based on whether you have luggage, whether you are older than sixty years, whether you are an adult or whether you are less than fifteen years old and whether you are male or female. So, this gives you an idea of the speed as a function of locations plus socio-cultural, climatic effect, because all these countries have different climatic effects different social-cultural environment. So, you can see how speed varies depending upon that.

(Refer Slide Time: 23:45)

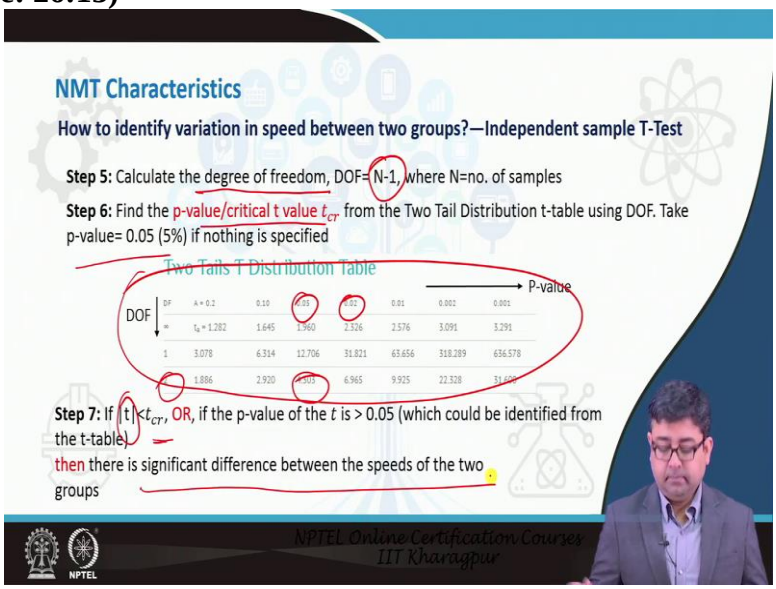


Now, so, a very important question is often asked that how do you identify this variation in speed among different groups? So, for example, if you want to know whether actually, the speed between men and women are different or not, or whether actually the speed between people who are carrying luggage versus people who are not, is different or not. Many times the speeds are so close to each other, that there does not seem to be any significant difference. But statistically, you are always required to see or check whether those speeds are different or not. Statistical test that we usually use is an independent sample T-test. So how do we do that? First, you need to identify the groups for which you are testing for the difference for example, are you testing for difference between the speeds of different ages of people, or gender, or gradient. So identify your groups. Next you have to collect speed data for that group, sample speed data for that group, you need to collect for the two groups for which you are trying to find the statistically significant difference. In step three, you need to calculate the sum of the differences as well as the square of the differences between the two groups. So, you will have, the speeds of one group, you will have the speeds of the other group, you have to calculate the sum of the differences, you have the difference of the speeds you have to sum it up. And similarly you have to find out the summation of the squares of the differences. Then the t-statistic which is given by this equation,

$$|t| = \frac{\frac{\sum x_{1-2}}{N}}{\sqrt{\frac{\sum (x_{1-2})^2 - [\frac{(\sum x_{1-2})^2}{N}]}{N.(N-1)}}}$$

Which I am sure very many of you would know if you are not aware. It is available in any of the common statistical text books. So you need to calculate what is called the t-statistic which is a modulus t. Does not matter of whether this is a positive or negative sign, so, it is a modulus and it will be based on the number of samples for which you have collected the data. So, how many samples you collect it depends upon that sample size.

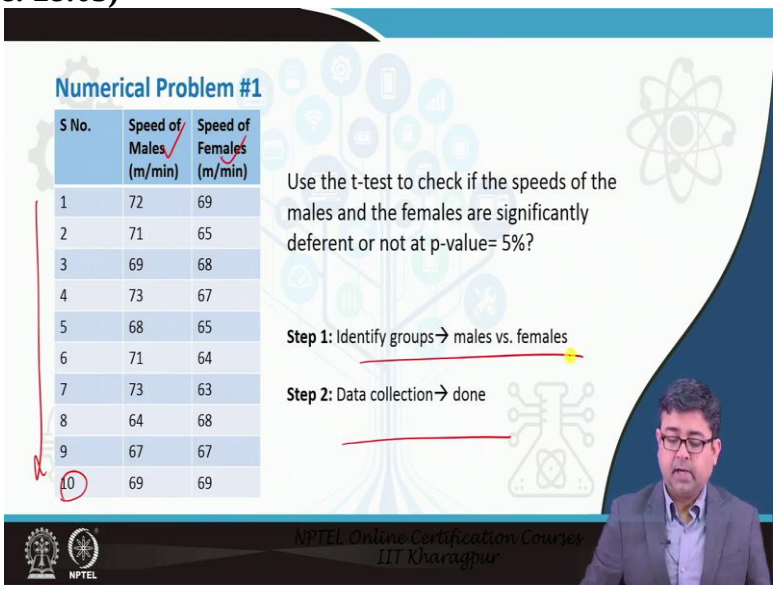
(Refer Slide Time: 26:13)



Then you calculate what is called the degrees of freedom, which is nothing but number of sample size minus one. And finally, you will have a table. A t-statistic table will tell you what is the critical t-value based on for standard p values, usually, the p value that we use is 0.05 that means, it is statistically significant at 95%. So, we usually look at 0.05 if nothing is specified. You will look at 0.05 and you will find some t-critical value for your degrees of freedom for example, if your degrees of freedom is two then your t-critical value will be 4.3. So, now the value that you have calculated in the previous step t-modulus, if that is less than your t-critical value then the inference would be that there is significant difference between the speeds of the two groups. So, that is how you find out whether there is significant difference between the two sets of groups which you are interested in finding out and then you would know that yes there is significant difference. And hence we need to take into cognizance, these significantly different speeds and design for them accordingly. If there is no significant difference then you can say that you have a pretty homogeneous group of people who are walking on that facility and you

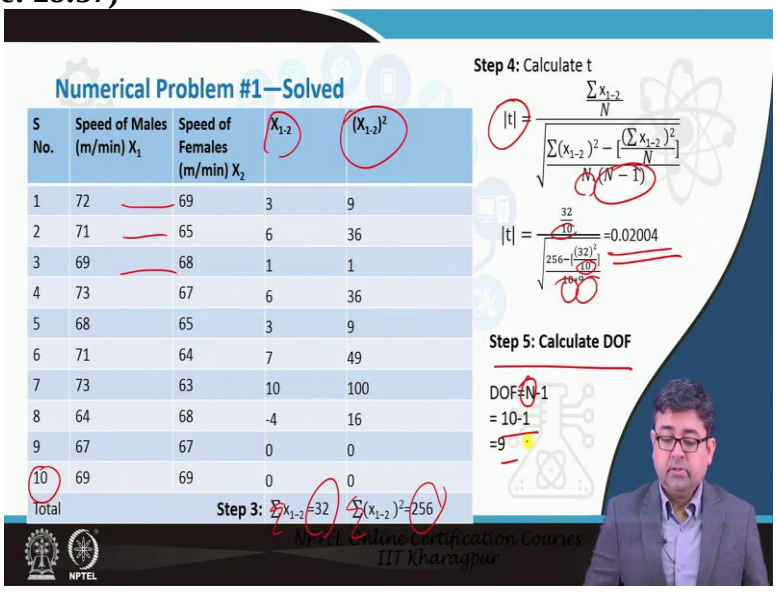
can design the facility for average means speed of the entire walking population along that facility.

(Refer Slide Time: 28:03)



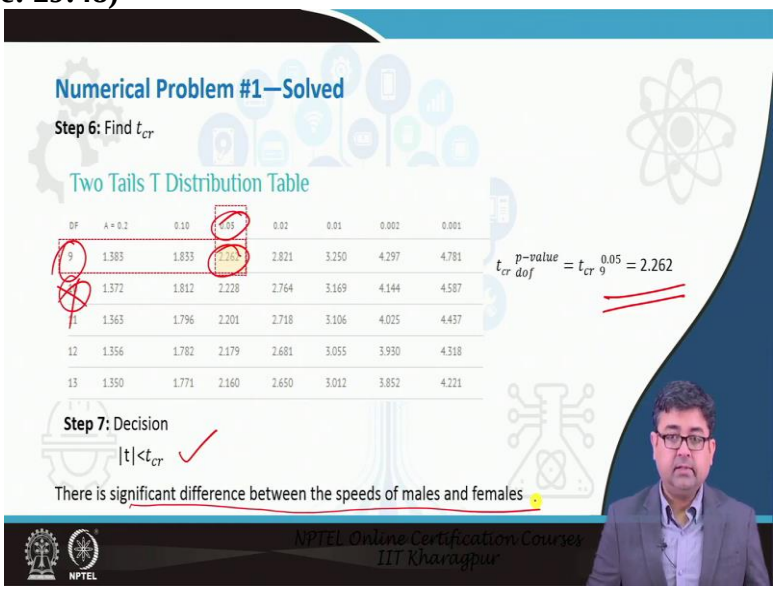
So, let us quickly look at a simple example that will allow you to understand all the calculations. Now, say that you have collected the speeds of ten different males and ten different females. So, you are your aim is to find out whether these speeds, or the mean speeds between these two groups, are statistically significantly different or not. So data collection was done, the groups were identified.

(Refer Slide Time: 28:37)



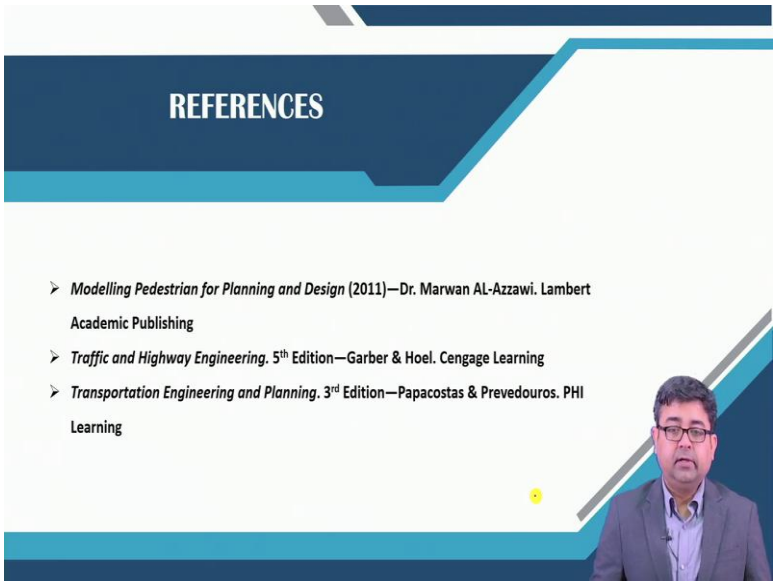
Now, you have to calculate the t-statistic. So, what you need to do first is to find out the differences between each, 72 minus 69 and so on and so forth. And then sum it up. Similarly, you need to find the squares of the differences and finally, sum it up. Then you can use these formulas are here and put up these values. So this is summation, summation of the differences by the sample size. So it is 32 by the sample size is 10. Then the whole square root of square of the summation, plus 256 minus thus the summation 32 to the power 2 by N this 10, and this is N into N minus 1, ten times nine. So the answer would be 0.02004. Now you need to know what is the T critical value for the degrees of freedom of 10-1= 9, N =10. So, 10 minus 1.

(Refer Slide Time: 29:48)



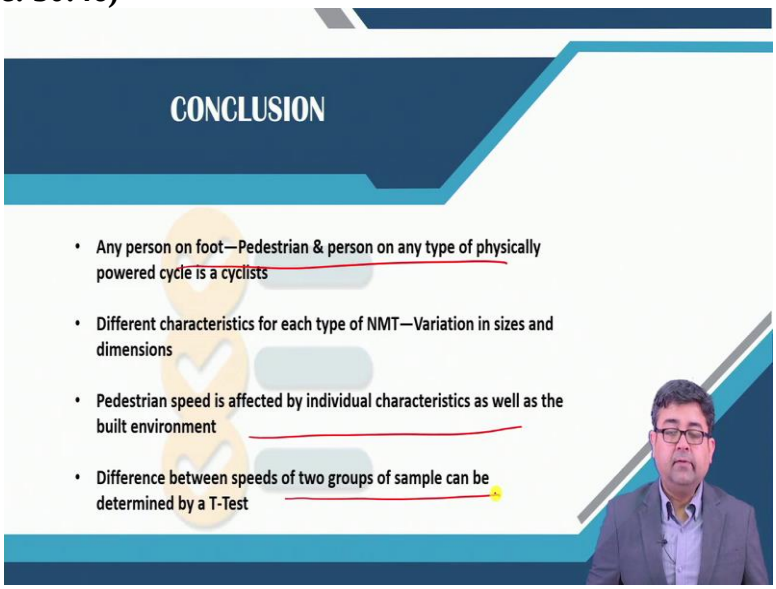
So if you look at the table, the standard table that you have for 0.05 and degrees of freedom nine, your t-critical value is 2.262. So, what that means is your t-value is less than your t-critical, which means there is a significant difference between the speeds of male and female. So that tells you that if you are trying to plan a facility at that location, or footpath or whatever it may be, that there are significant different speeds of all the females and the males that walk on that road. And hence, you have to take into account both of these groups when you are planning for this facility.

(Refer Slide Time: 30:34)



I hope that is clear. That ends this lecture. Again, the references are given from which all the different exercises and the matter is taken for, your further reading.

(Refer Slide Time: 30:46)



In conclusion, what we looked at is, what we look during this presentation or during this lecture, is the understanding of who the pedestrian is and who the bicyclist is for whom you are going to design the facility. So what are their characteristics? And then we started looking at what are the pedestrian speed related factors that are affected. What are the factors that affect the speed of pedestrians? We looked at built environment factors, we looked at age, gender, and then finally we looked at a statistical test that will allow you to understand whether there is a significant difference between the speeds of two groups that you are calculating for your site.

Hopefully, that will be a very useful tool for you. And we look forward to having you in the next lecture. Thank you.