Introduction to Multimodal Urban Transportation System
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Lecture – 27
Non-Motorized Transportation (NMT) Planning: Pedestrian Data Collection and Flow Characteristics

Welcome back friends, we will now begin the next lecture on non-motorized transportation, where we will look at pedestrian data collection and flow characteristics.

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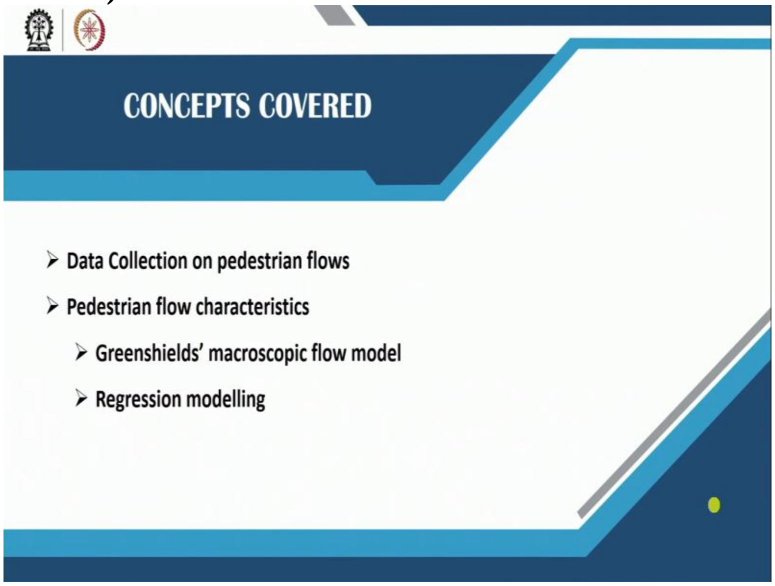

In this lecture, we will show you the different methods in which you can collect pedestrian data as well as give you a detailed understanding about the different flow models that can be used in modelling pedestrian data along different facilities. And we will also look at regression modelling and how you can use regression modelling in developing these flow models.

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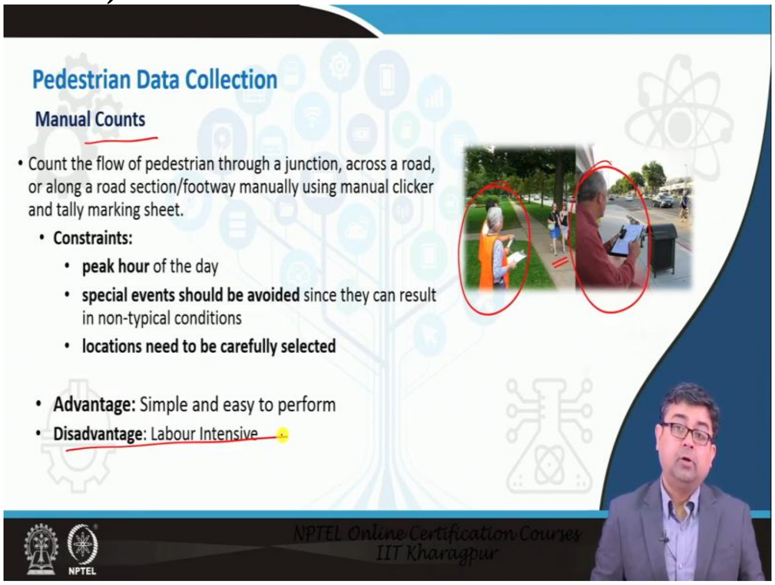

So, when it comes to collecting pedestrian data, you can do it in various ways. The first most common way of doing it is the manual counts. But this is effective only when you have a facility that has very few pedestrians that walk. If you want to collect data on a residential street or a street along which there are not many people that walk, then it is easier to have few data collectors, who will stand on the side of the road and just count how many pedestrians are walking. So, this count data, so we are not collecting data on the type of people who are walking, i.e., male, female, what is their age group, etc. neither are we going to hand out any survey questionnaires to them, we are just having data collectors stand on the side of the road and count the number of people that are walking by him or her. So that is a very basic method of counting pedestrians and you have to have all the count data, because you have to know the volume of people that walk along the street. So, once you know the count, then you can sum it up and say that per hour, there are 'n' number of people that walk on a day. Then you can figure out which is the most congested period along the sidewalk, which are the lighter periods of along the sidewalk. And maybe if that sidewalk is connected to a signalized intersection, then you can determine how much green time may be given for these pedestrians. Based on the volume of pedestrians on that approach the crosswalk or the intersection, how much signal timing should be given for them to cross across the streets. So, this is the basic requirement of designing any facility, which is to understand what the volume of people walking is, and hence this counts are done. It is very labour intensive. So, you have to hire a lot of people who will do these manual counts and stand on the roadside for a long period of time.

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However, now, there are a lot of automatic data collection methods or count collecting devices that are available. For example, the slab type device which can be buried under the walkway and it works on the principles of pressure. So, pressure is applied on it, it will automatically count as a vehicle. Then there is something called Pyro-box that can be mounted on a light pole. And it can count the number of people that are crossing the box. It has some infrared signals by which it can count the number of people walking and you can mount them on posts and have fixed counts. This is an urban post that have fixed counters that can be removed, whereas these are fixed counters.

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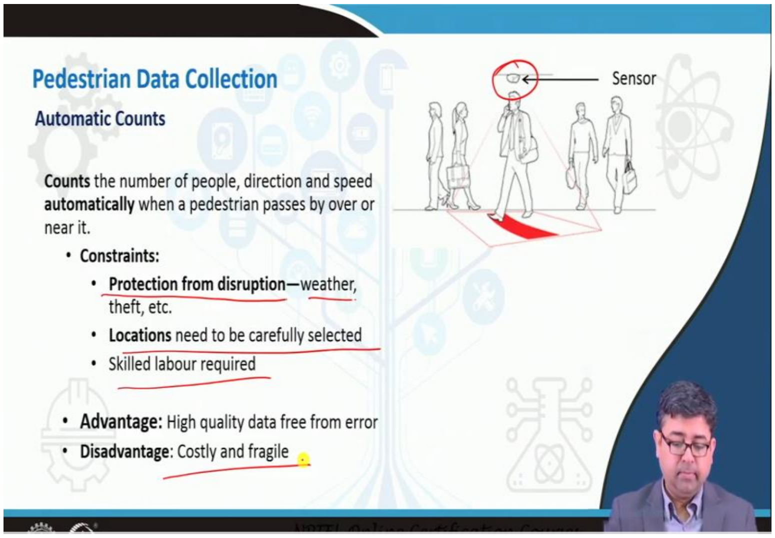

There can also be sensors that can be put on some kind of a structure above a sidewalk or above a gate. So you will see a lot of automatic doors that are nowadays present in different facilities. They will have sensors on top so that when somebody walks in and out of a facility through that gate, they get recorded. So, you can count the number of people that are coming in and out of a facility. However, there are some constraints. If it is especially in outdoor situation that you are putting these automatic counters, then they have to be shielded from weather or theft and locations have to be selected very carefully. Now that you are going to install something for automatic counts for a longer period of time, better install it at the right place and the right angle. So it can count people correctly rather than double counting the same person or, for example, what often happens with automatic counting is that if there are two people that walk side by side and you have a device that is not overhead, but that is on the side of the road, or the side of the footpath, then both of the pedestrians are counted as one. We call it as occlusion. In many situations two people are counted as one then the volume counts get half almost, so this causes a problem. The location and the placement of these automatic devices is very, very crucial. Again, they need skilled labour now, not only for installation, but for the extraction of the data, you will have to have people who understand how to extract this data and count them. Also, the devices itself are a little bit costly. However, the accuracy of the counts, if done properly, is very high. And you almost do not need to have these people stand on the side of the road for a long period of time to count them manually.

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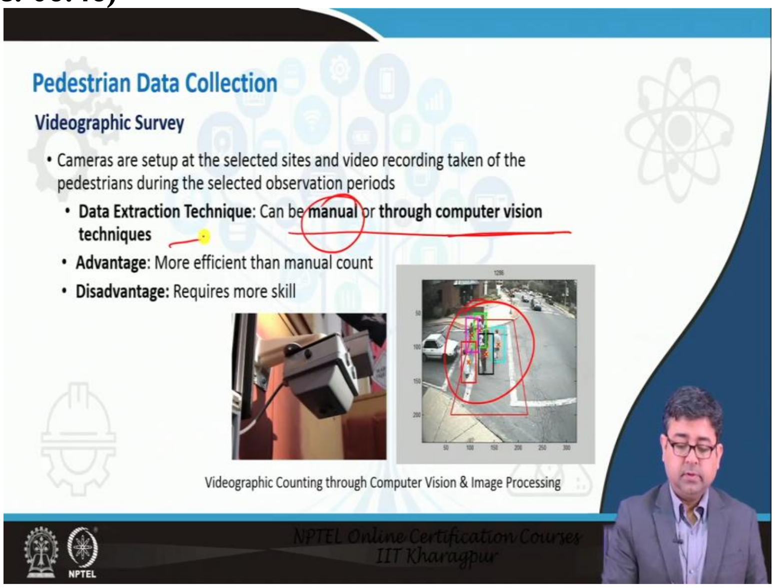

There are cameras also. So, rather than having sensors, people also have cameras or take advantage of the cameras that are already existing in many of the intersections. For example, you would see here, to count the number of people that are crossing the streets. Usually this counting is done manually, but usually nowadays there are a lot of computer vision techniques that can be used to count the number of people that are crossing that are captured on a video.

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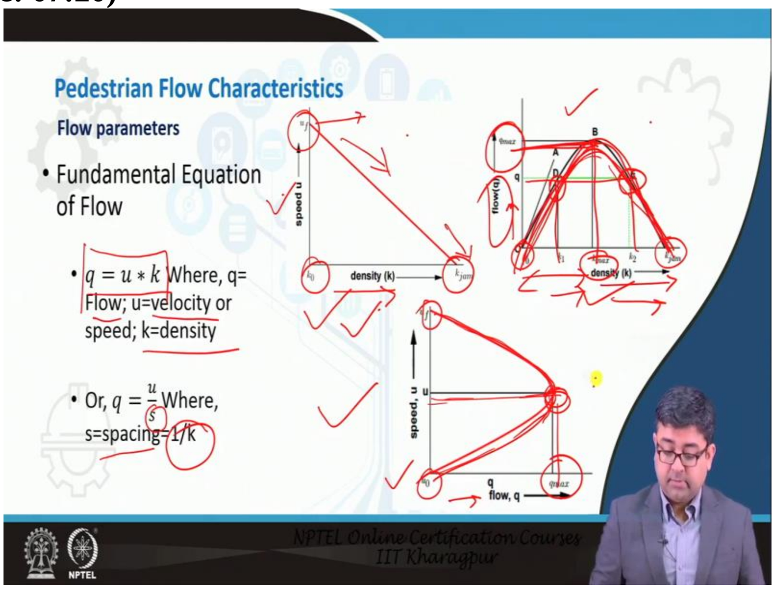

Now, in the last lecture, we introduced you to the basic three diagrams of flow parameters that are very fundamental to any traffic movement, these are borrowed from regular motorized movements. But they can be applied in case of non-motorized and pedestrian transport as well. So, if you recall, the basic equation is q is equal to u times k, where q is the flow, u is the velocity or speed and k is the density. So, now, you can also say q is equal to u by s where s is nothing but the inverse of density and that is called "spacing". So, when it comes to looking at these diagrams for pedestrians, we usually use spacing as the parameter, rather than density. We use it alternatively in different kinds of cases. If we look at each of these diagrams carefully, what we can see is that the speed and density have an inverse relationship. Density meaning number of people per square meter. So, if there are no people, no density, then you can walk at whatever speed you want to walk at. So, that is called free flow speed. However, as the density starts increasing, as more and more people start to walk along that given space or the sidewalk, then the speed of the individual's walking starts decreasing, and it comes to a point where we call it jam density, where nothing moves, you are stuck. When there is congestion, the vehicles are not moving. You experience that situation and sometimes when you are in a very-very crowded area, maybe there is an event happening and nothing is moving. So, that is kind of jam density. So, speed and density have an inverse relationship. Now, when you look at flow and density, you start to see that it is a parabola. So, when there is no density automatically means there is no flow. There are no people at that point in time that are walking on the street, as density starts picking up flow also starts picking up. As per the characteristics of any parabola you will see that you will attain maximum density at exactly the midpoint from max density and zero density. So, at that point you attain maximum flow and then again as your density starts increasing your flow does not increase anymore. So, there is a point at which there will be maximum people moving on that section per minute. Whereas if there are more and more people getting added, the speed does not go up, there is too much friction there is too much congestion. So, the number of people passing a point per minute decreases until again you hit jam density. So, there are as per the characteristics of parabola, a particular flow point will be occurring at two different times based on two different density numbers, that is how a parabola works. Similarly, if you look at the relationship between speed and flow. It is also parabolic in nature, where, when the flow is zero again when there are no people, you can essentially walk at whatever speed you want to walk. So free flow speed. Now as flow start increasing, your speed starts decreasing. Speed is maximum at q_{max} or maximum flow, Again, at the same time, your speed no longer increases after this point. So, I hope you understand the basic principles in the three different diagrams that are presented here.

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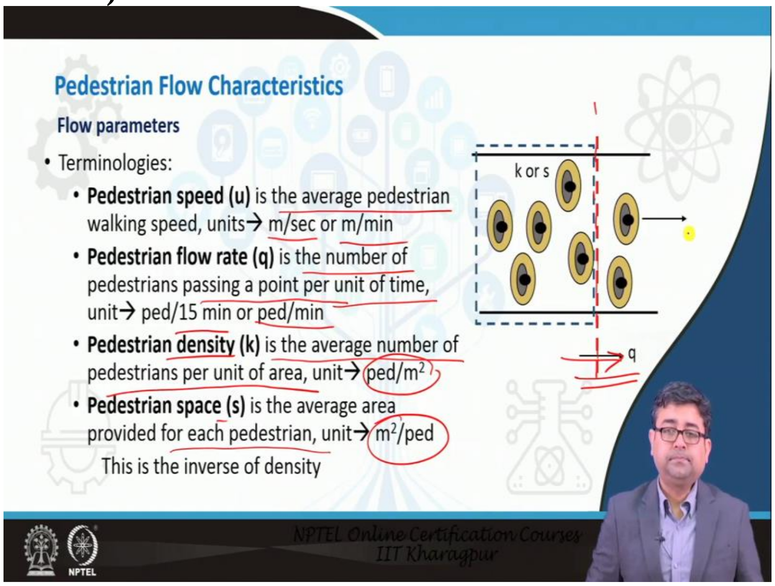

Pedestrian speed is usually the average pedestrian walking speed in terms of meters per second or meters per minute. Flow, which I was talking about, is the number of pedestrians passing a point per unit of time. We usually use number of pedestrians in every fifteen minutes or pedestrians per minute also can be used. Density is the average number of pedestrians per unit area, where we usually use pedestrians per meter square, and space is just the inverse of density. So, it is the average area provided for each pedestrian, in meter square per pedestrian. So, when we talk about flow, what we are saying is that, if this is a point, the number of pedestrians that crosses this point per unit time, so, per minute or every fifteen minutes, how many people cross this point that, is what is called flow.

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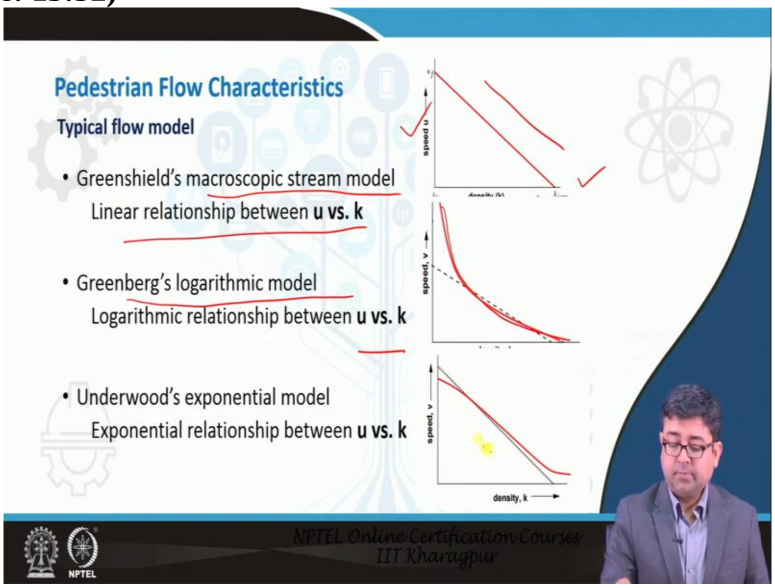

So, there are different models that can that have been developed over the years that captured the relationship between speed and density. The very simplistic model that I have shown you before, which is a Greenshield's macroscopic stream model, gives a linear relationship between u and k. Whereas, Greenberg's logarithmic model says that it is not linear, but the speed (u) has a logarithmic relationship with density (k). Underwood's exponential model now, says that, no it is not logarithmic, but it is exponential in nature, when it comes to the relationship between speed (u) and density (k).

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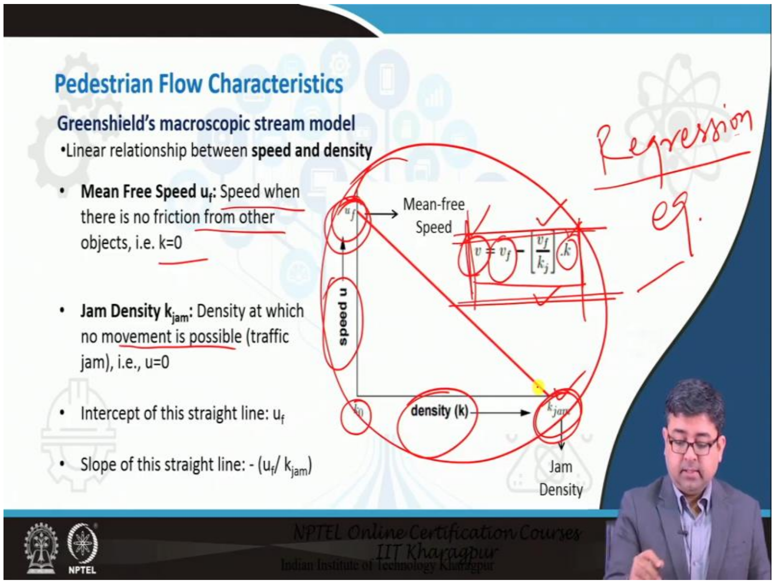

We have already explained to you about this figure. But the relationship between speed, and density is given by this equation. So, speed at any point will be equal to the free flow speed minus the ratio of the free flow speed to jam density times the density at that point. So, this is the relationship between speed and density in terms of the two values of free flow speed and jam density.

$$q = k_j.v - \left[\frac{k_j}{v_f}\right] v^2$$

Now, this is what we call a regression equation. These are equations which estimate the value of the speed of the pedestrian. Here, once you know what your free flow speed is, what your jam density is, what your given density is. You can estimate the speed of the pedestrians walking. So, this technique is used to estimate, and is called regression technique. Now, you already know that the speed when there is no friction from other objects, i.e. k is equal to zero you can reach free flow speed, jam density at which no movement is possible jam density intercept u_f and the slope is u_f / k $_{jam}$.

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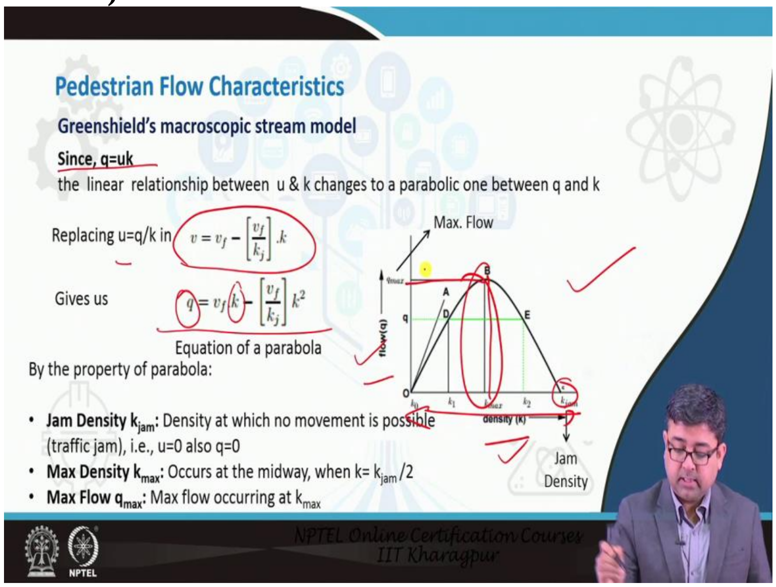

Similarly, we have also already looked at what is the Greenshield's macroscopic stream model when it comes to the relationship between flow (u) and density (k). So, since q is equal to u times k, you replace u by (q /k) in this earlier equation. We already know this equation, if you replace u = (q/k) in this equation, you will get an equation of the parabola. This gives you the relationship between q and k, again density at which no movement is possible that is jam density, max density occurs at midway. So k =k_{jam}/2 and max flow occurs at k_{max}

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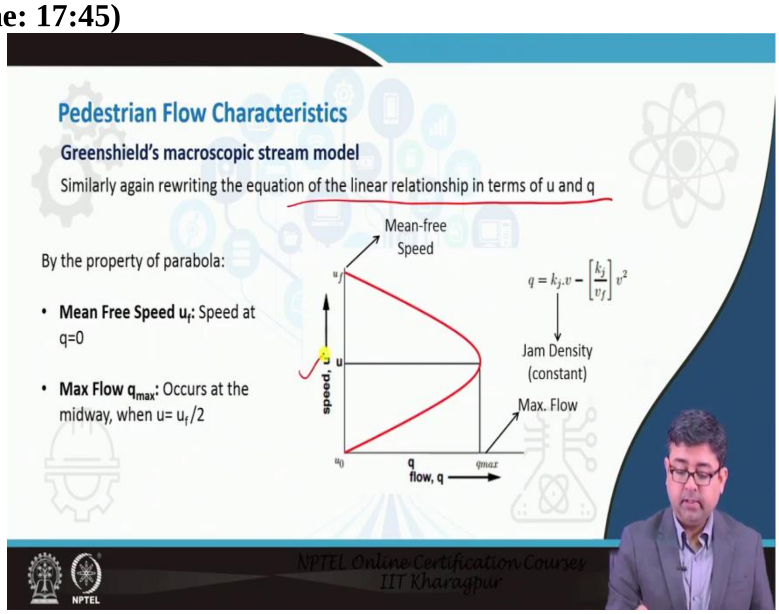

Similarly, rewriting the equation in terms of u and q, you can now get the relationship between u and q. So, basically if you understand this basic equation of u and k and knowing that q is equal to u into k, you can determine the parabolic equations of q and k as well as q and u. Again we have already seen at mean free speed when q is equal to zero and max flow occurs at a speed, which is half of the speed, or half of the mean free speed or free flow speed.

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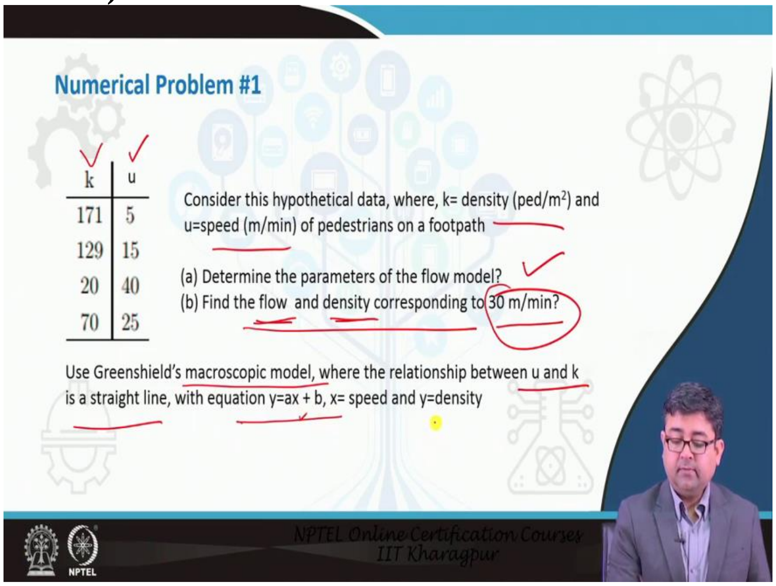

Now, for example, you are given this problem with these values of k and u. So k is density in pedestrian per meter square and speed u is speed in meters per minute. To determine the parameters of the flow model, now, you are told to estimate or determine the parameters of the flow model and find the flow and density corresponding to a speed of 30 meter per minute. So, you not only have to determine the equation, but you also have to substitute u =30 meter per minute in order to estimate what is the flow and what is the density at that speed. So, the Greenshield's macroscopic model is the relationship between u and k is a straight line and it resembles a very basic linear regression form. y= a*x + b where, x is speed and y is density. So, this equation and we all know how you can solve a simple linear regression equation.

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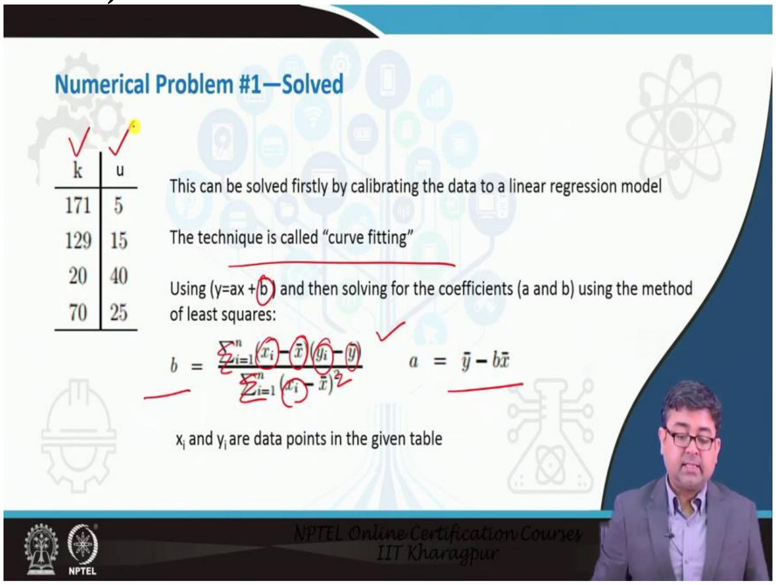

It is done by a technique called curve fitting where 'b' is given by this equation:

$$b = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

And 'a' is given by this equation:

$$a = \bar{y} - b\bar{x}$$

So, what are the elements of this equation, it says that all of the x values minus the mean of x value is multiplied by all of the y values minus the mean of y value and this product is summed and divided by the the summation of x values minus the mean of the x values to the power two. So, that gives you the b value. So, in this case we have already told you that speed is x and density is y. We are going to find out first the parameter b and then we are going to estimate parameter a, which is nothing but the mean of all the y values minus b times the mean of all the x values.

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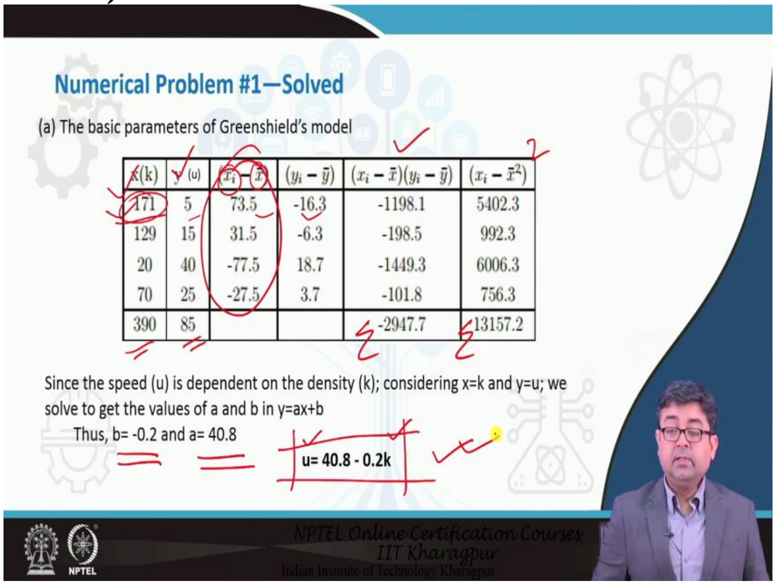

So, let us see. We have the x values and the y values. First sum all these up. We sum all the x values; we sum all the y values and find out the mean of x and mean of y. And then we start for each row, we take the x value, subtracted from its mean, we take the y value, subtract it from mean. We sum these two columns or we have the product of those two columns, and then we also develop this column raised to the power two. Once we have developed these two columns, we sum them at the bottom and we find out that using the equation given in the previous slide, we found out that 'b' is -0.2 and 'a' is 40.8. So then we get an equation which says the relationship between speed and density is u=40.8-(0.2*k)

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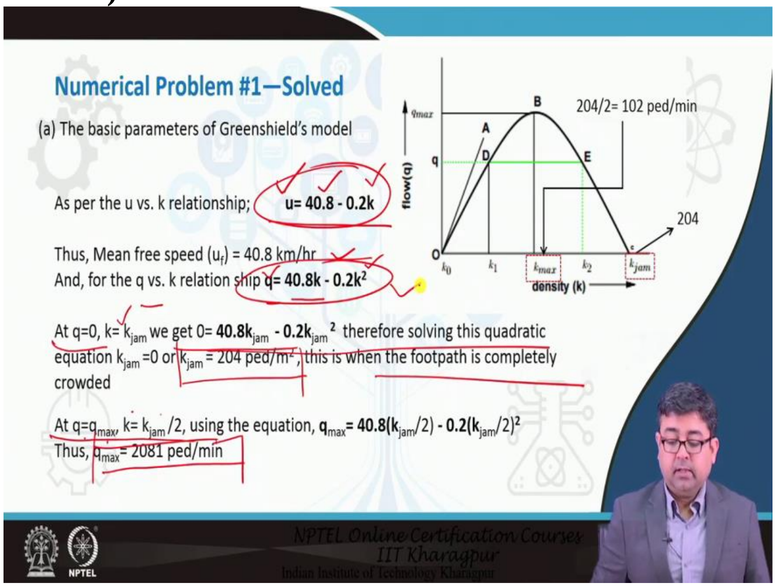

Now we also have to figure out the relationship between density and flow and speed and flow. So, as we know, mean free speed if we know this, we can tell that mean free speed occurs when k is equal to zero. So, mean free speed is equal to 40.8 kilometres per hour and for q for the equation of q versus k. The relationship now becomes q is equal to 40.8 k -0.2 k^2, remember how we derived it from earlier the relationship from with how we moved from the relationship from u and k to relationship from to q and k. This is a parabolic relationship whereas this is a linear relationship. Now, we also know that at q =0, k =k_{jam}. So if you substitute q =0 here, we can find out what is the k_{jam} equation by solving this quadratic equation. We found out that k_{jam}= 204 pedestrian per meter square, this is when the footpath is completely crowded. And also we know that at q =q_{max}, k= k_{jam}/2. We have already established that. So, if you use the same and put it in this equation, we will get the q_{max}=2081 pedestrians per minute.

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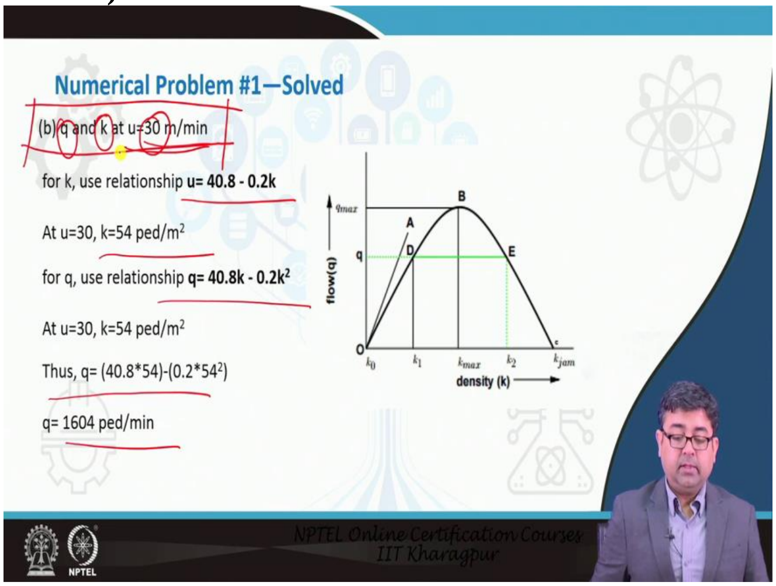

So, now we can solve the second part of the question asked what is q and k when the speed is 30 meters per minute. So, using our relationship that we have already developed, we can find out we can just substitute u is equal to thirty to find out what the k is and from this relationship, we can substitute, k as 54 to find out what the q is. So you see, what these equations help you to do is that now, for a different facility,you only have to determine the speed of people walking at that facility. And it will automatically using these relationships, you can find out what the q and the k are, you do not need to again, do the calculations and figure out what the k and q is. You just have to know what the speed is. And you can automatically determine the other two parameters.

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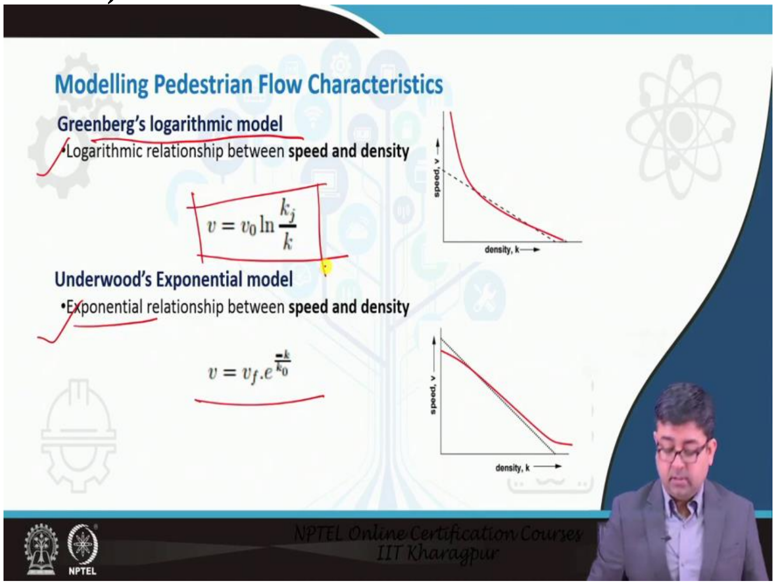

Like I said, this is a very simple relationship between speed and density which is linear, i.e. what Greenshield's found out. However, well, there are two other relationships that are also used or the equations in that case are a bit different. In Greenberg's model, the relationship between speed and density is given in this fashion. Whereas, in Underwood's model, the relationship is given in this fashion and as it is exponential. So, if you are asked to solve a problem given a certain method, so, if we say that, find out the relationship using Greenberg's logarithmic model, then you have to use this formula. Whereas, if you if you tell you to use Greenshield's model, then you have to use the formula that was shown earlier.

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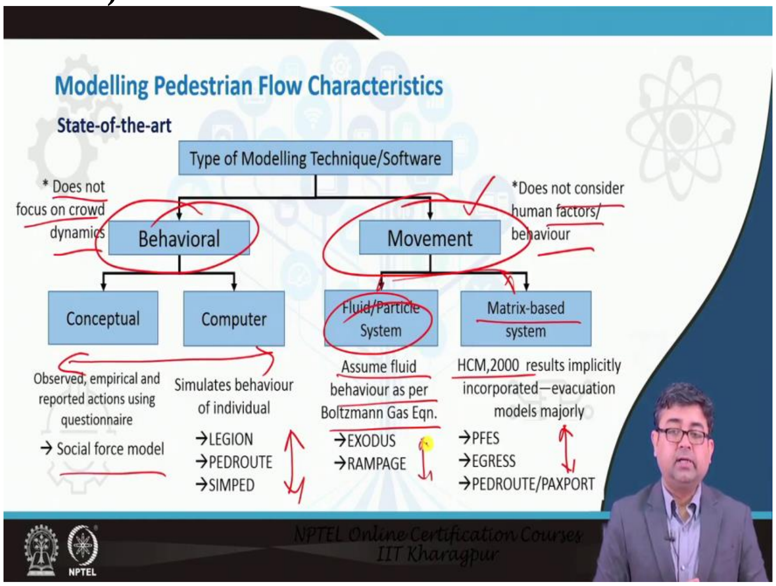

Now, if you understand these three basic flow parameters in pedestrian transport or in any forms of transport, you can then use these to build different models, some models may be very specific to your location, your country, your state, whereassome may be homogeneous. Some maybe the entire state follows similar model where as in other cases the entire country may follow similar model. But you have to understand the basic three parameters that were discussed. Now, based on this, there are different types of models that have already been developed. So, if you look at very broadly these modelling techniques or softwares are classified under two groups, one is behavioural models and the other is movement related models. So, the behaviour models again can be classified in two different ways. Conceptual models which usually follow or discuss a model that is developed based on the conceptual behaviour model, called the social force model. The other type are computer simulation models that simulates the behaviour of individuals. So, you have different kinds of softwares LEGION, PEDROUTE and SIMPED that does that. So, modelling techniques or modelling software that are available that model individual pedestrian behaviour. But they are all based on those three flow parameters, flow, speed and density. Now the techniques and softwares rely on movement, they do not consider any human factors or behaviours. The behavioural models do not focus on crowd dynamics, they are more dependent on individual behaviour or individual concepts. They do not consider individual behaviour or human factors. They are more focused on the movement of groups of people. Now, even in the movement type of models, there are two different types one which considers a fluid or particle system. So, it assumes that fluid behaviour, as per Boltzmann gas equation, holds true in case of pedestrian movement. Whereas, there are matrix based systems that are essentially used in the highway capacity manual 2000, and different software that are listed here, are based on each of those principles. So, we will not get into the different software in this class, however, we will you know the basics of how these software work, you are free to go ahead and explore any of the software or techniques that you may wish.

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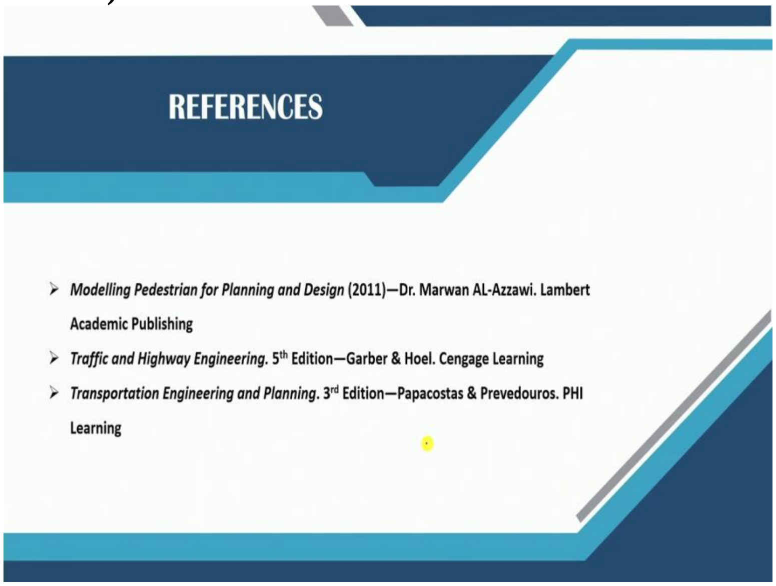

Again, these are some of the references from which the current module or the current lectures were developed and for your further reading as well.

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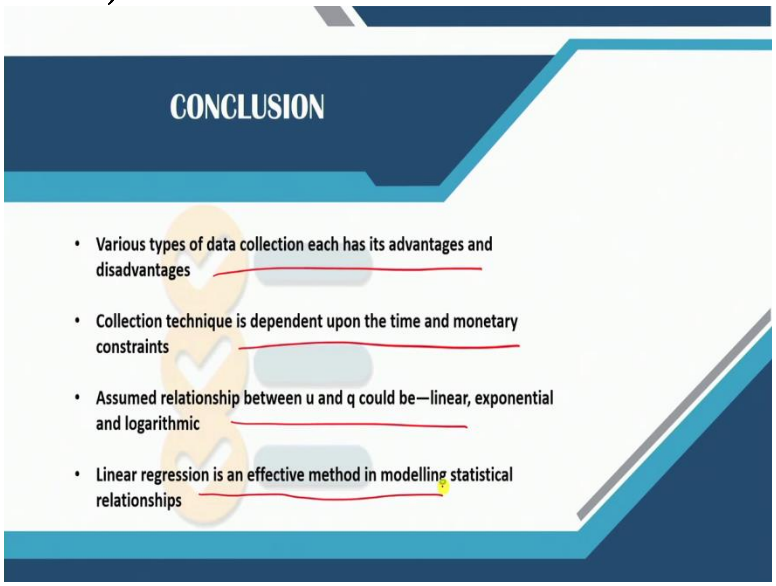

So, in conclusion, what we looked in this lecture are the different data collection techniques, the advantages and disadvantages of each, from manual to automatic to video data collection. Again, they are all dependent on the time and money that you have for your facility that you are building, you can use any one of those techniques. And then, we gave you the basic relationship between speed, flow and density, which are essential to understanding the flow parameters or flow characteristics of pedestrians walking along any facility. We use an example of the Greenshield's model which is a linear model and how the linear model can be estimated. We showed you an example of the regression technique that allows you to estimate the linear relationship between two parameters. Thank you very much.