Introduction to Multimodal Urban Transportation System
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Module No # 08
Lecture No # 39
Non-Motorized Transportation (NMT) Planning: Design of Cycling Infrastructure

Welcome back friends now that you have looked at designing pedestrian facilities at your urban streets, let us now focus on the other type of non-motorized transport, which is designing for cycling or bicycling infrastructure.

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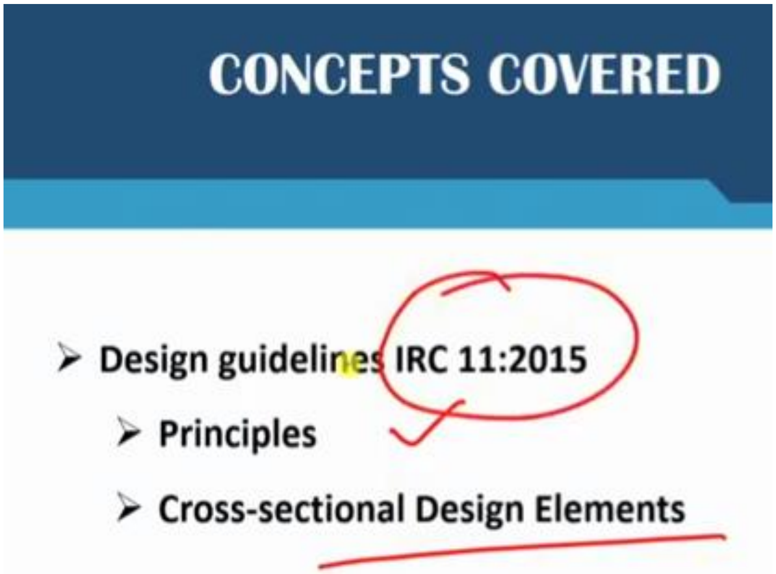

So, in this lecture we will be looking at the different principles, just as we had several principles of NMT infrastructure. Now we will specifically look at principles for designing bicycle infrastructure and also look at some of the cross-sectional design elements. These are all based on IRC 11 which was released in 2015.

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In designing for bicycle facilities, we have to again keep in mind that we are not only dealing with bicycles. We are also dealing with rickshaws, i.e., cycle rickshaws, cycle-carts, hand pulled carts, etc. There are different types of non-motorized bicycles that we are dealing with. Not only the ones that are adult-touring but there may be luggage-attached to it. That kind of a bicycle may be a cycle rickshaw, cycle-carts or hand-pulled carts. So, all of these combined together forms the design principles for cyclist. The design is also based on which type of road we are designing it for. The hierarchy of the roads in transportation network matters in this case, whether the street is arterial, sub arterial, or local. It matters on which street we are designing the bicycle network. The 5 basic principles to keep in mind while designing for a cycle infrastructure is coherence, directness, safety and security, attractiveness and comfort. Many of these are very similar to what we had looked at, when we are designing pedestrian infrastructure, where they have to be safe and secure in order to be attractive. They have to attract the choice users towards using this facility. To be comfortable, it has to be direct, should avoid detours, and so on and so forth. And the other thing that IRC recommends is that we should design facilities so that a speed of at least anywhere between 5 to 15 kilometer per hour can be maintained on such facilities. If it is too low then the bicyclist will be discouraged from using such facilities; if it is too high then there might be some safety repercussions for bicyclist. You may have already looked at such bicycle lanes which are also now available in few cities in India. Bicycle boxes are something that are coming up, which allows the bicycle to come up to the front of the intersection, such that when the signal turns green the bicyclist are the first people who can leave the intersection safely. And you must have also encountered some public bicycle sharing systems in your cities, which allow you to not own a bicycle, but still, you use the bicycle by renting them at an hourly basis and the rents are usually very cheap.

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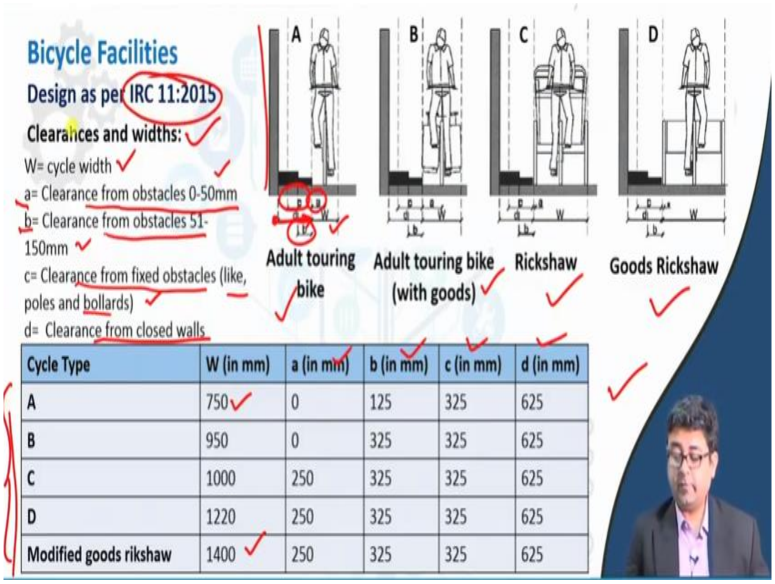

As per the IRC guidelines, there are some standards dimensions for different types of bicycles. IRC defines 4 different types of bicycles first one is an adult-touring bicycle, second one is an adult touring bicycle with goods, next one is a rickshaw, and a last one is the goods-rickshaw. Each class of bicycle has some standard clearances and widths. So, if you just look at one of them you would see that the first one ‘W’ is the width of the cycle itself. So, when we look at the width of the cycle for different classes of cycles, it ranges from anywhere between 750 millimeters to about 1400 millimeters. The next one ‘a’, is the clearance from obstacles which may be very close to the bicycle and anywhere between 0 to 50 millimeters away. So, this is ‘a’, you have to have no obstacles where the pedaling zone is. If you have any obstacles then you will not be able to pedal very smoothly, so that is what ‘a’ represents. ‘b’ is the clearance zone from obstacles anywhere beyond 50 mm but less than 150 mm. ‘c’ is clearance from fixed obstacles like poles and bollards. Again, remember, bicyclist usually prefer to ride on the edge of the roads. So, as you ride closer and closer to the edge, many of the street furniture also comes very close to you. But a safe design is to have a basic clearance from your street furniture or fixed obstacles like poles and bollards. ‘d’ is the final clearance from any kind of closed walls.

So, all these values of a, b, c and d and for different types of cycles are shown in this chart. These are again based on IRC 11 2015.

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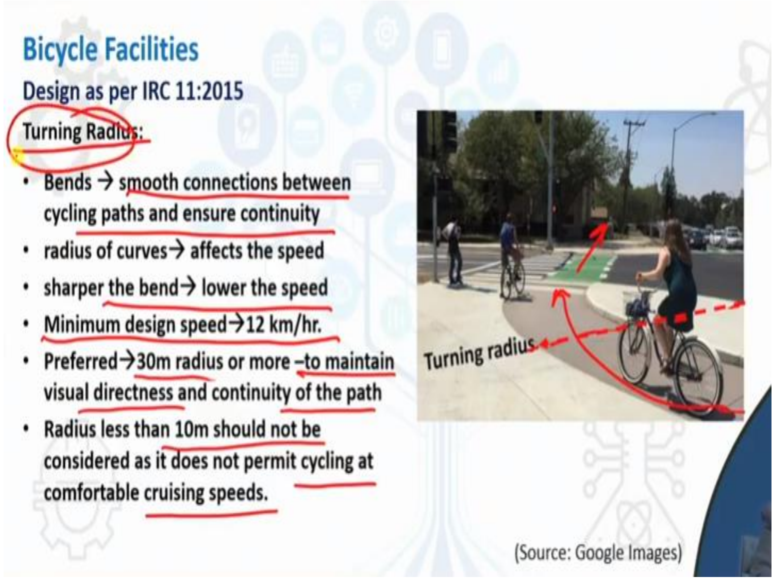

The next element in designing for a bicycle infrastructure or cycling infrastructure along urban streets is to look at the turning radius of the bicycle track or the shared used path whichever you are trying to design. There should be smooth connections between cycling path and ensure continuity. These bends that you are trying to design they depend upon the turning radius. You would be coming at a certain speed and you would be, wanting to continue at the same speed but bends always restrict the speed by a certain amount. By how much amounts they be restricting depends upon the turning radius that you provide. If there are sharp turns at the bend, lower will be the speed, but it is recommended that the minimum design speed of 12 kilometers per hour be maintained at all bends. So, if your cyclist is travelling at 12 kilometers per hour, comes at a bend, he or she should be able to negotiate the bend at that speed. It is preferred that turning radius of 30 meters or more is provided which also ensures that visual directness and continuity of the path is maintained. So, this person, after negotiating the bends, should be able to visually see and also the path would be continuous. The radius of less than 10 meters should not be considered as it does not permit cycling at a comfortable cruising speed right. So, these are some principles we have to keep in mind while you are designing for turning radius of a bicycle.

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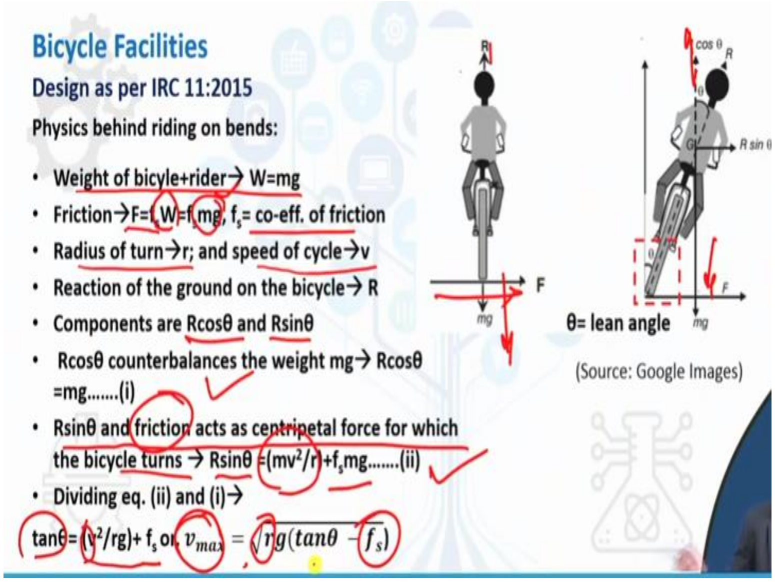

So, if you look at the turning radius and its basic physics principles, what happens is, the weight of the bicycle plus rider, acts downwards. There is some sort of frictional force with the road and is given by a coefficient of friction times W which is nothing but mg. So, fs times mg is the friction, so the radius at the turn if you provide r and if the bicycle speed is v. So, the reaction to the ground can be resolved into two components; R Cos theta (θ), and R sin theta (θ).

R Cos theta (θ) counterbalances the weight

Rcosθ =mg…….(i)

whereas R Sin theta (θ) and the friction acts as the centripetal force for which the bicycle turns.

Rsinθ =$(mv^2/r)+f_s mg$…….(ii)

So R sin theta is nothing but mv squared / r plus the friction which we already know is fs times mg. So if you divide equation (ii) with (i), you get:

tanθ= $(v^2/rg)+ f_s$

Or if you solve for v, you will realize that the maximum speed at a bend that cyclist can maintain depends upon the radius that is provided at that bend.

$$v_{max} = \sqrt{rg(tan\theta \ - f_s}$$

And there should be sufficient friction that allows the bicyclist to negotiate that bend and ensures that he or she does not skid at that bend.

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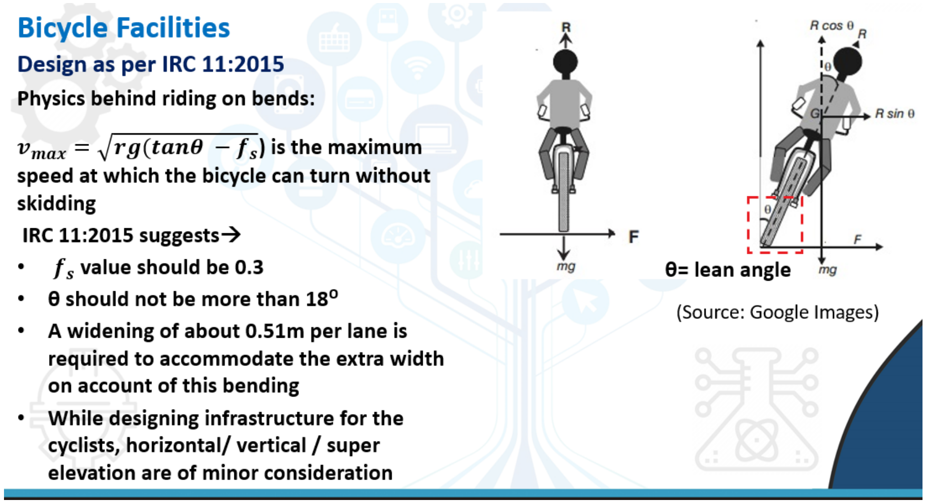

So, Vmax is the maximum speed at which the bicycle can turn without skidding. So, Vmax speed that is given by the square root of r time g times tan theta (θ) minus fs

$$v_{max} = \sqrt{rg(tan\theta\ - f_s}$$

IRC 11 suggest that the fs value (coefficient of friction) is 0.3. Theta (θ) should not be more than 18 degrees. So, people should not be bending for more than 18 degrees. And a widening of about 0.51 meter per lane is required to accommodate the extra width on account of this bending. So, at the bend the cycle track is widened by at least 0.51 meters in order to accommodate for that speed, okay. In case of bicycle lanes, super elevation is not necessary as opposed to when you are providing turning radii for motorized vehicles, but in thiscase super elevation is not required.

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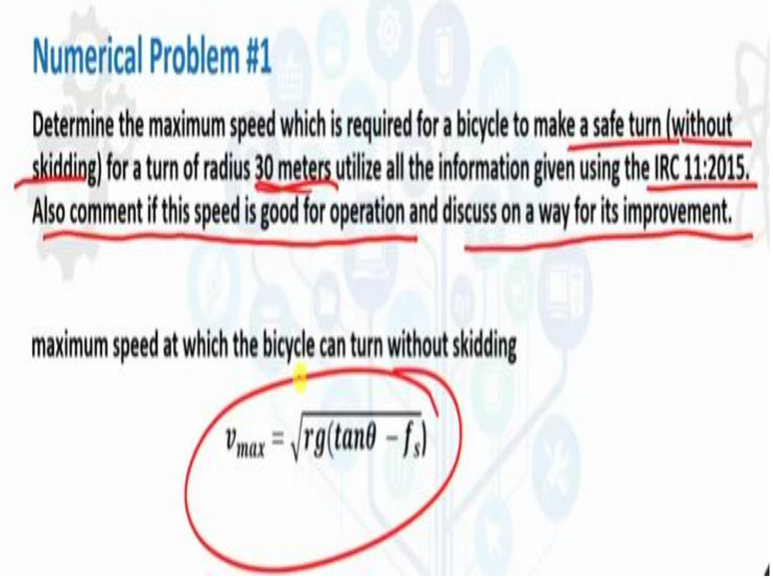

So, if you look at a quick problem, then you would understand how to determine the maximum speed. So, if you are asked to determine the maximum speed which is required for a bicycle to make a safe turn without skidding. For a turning radius of 30 meters utilizing all the information given in IRC 11 where all the information means all these values. Also, you have to comment if this speed is good for operation and discuss a way for its improvement.

So, let us see what is the result of this maximum speed based on 30 meter turning radius? So you know already the formula for it.

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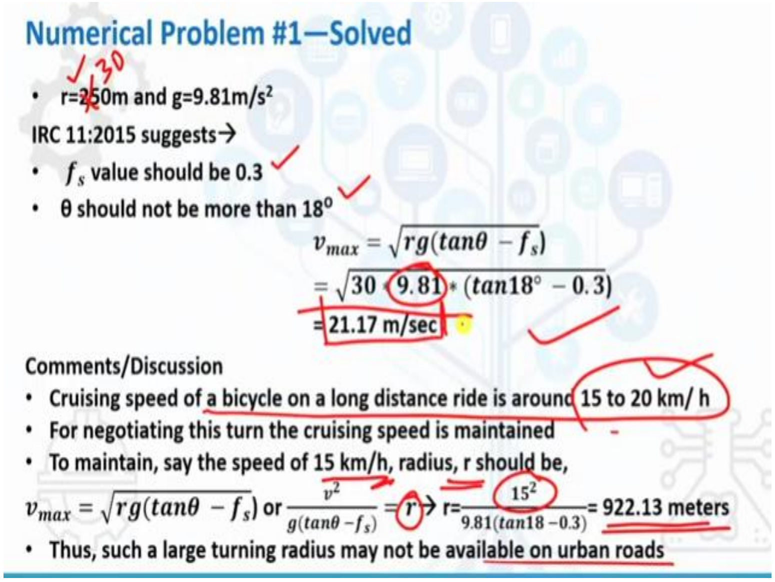

If IRC suggest fs value of 0.3 and the theta of 18 degrees and you already know that the turning radius is 30 meters and g is 9.8. If you put these values you will get a maximum speed of 21.17 meters per second. So, in your comments and discussing section what you can write is cruising speed of a bicycle is usually anywhere between 18 to 20 kilometers per hour. Remember, a few slides back we had told you that at least anywhere 5 to 15 speed is required. And also minimum design speed at bends should be at 12 kilometers per hour. So here what we are seeing is that for negotiating anywhere between 15 to 20 kilometers per hour and maintaining this speed of 15 kilometers, if you use the same formula, for maintaining a 15 kilometers per hour speed a high radius value 922 meters is required. Such large turning radius may not be available at urban roads hence the speed at the bends should be lowered a little bit while you are approaching a bend. So that is the discussion that you have to have.

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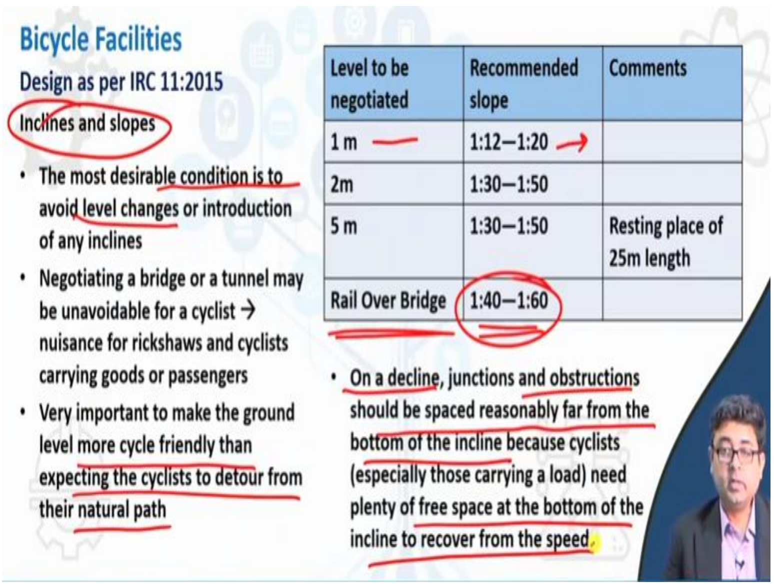

Now the next design element to remember is when you encounter any inclines or slopes. As bicycling involves lot of physical activity, usually bicyclist do not like to have very steep inclines or slopes. The most desirable condition is to avoid any level changes. But if level changes have to be made there are some standards that are provided by IRC, if the level to be negotiated is only about 1 meter then the recommended slope is in anywhere between 1:12 and 1:20. Whereas if railway over bridge for example has to be negotiated then the slopes become anywhere between 1 is to 42, 1 is to 60. Negotiating a bridge and a tunnel may be unavoidable for a cyclist and that becomes a problem. But if the recommended slopes are implemented it helps the bicyclist negotiate those such a rough or steep incline. Very important to make the ground level more cycle friendly than expecting cyclist to detour from their natural path. As much as possible we have to keep a level floor or the level has to be kept as low as possible. Otherwise, the cyclist will have to take a detour which means a longer distance. And if the distance keeps on increasing between the origin and destination then bicyclist would not want to use this NMT mode of transportation and go back to using their motorized vehicles. So, we want to avoid any such situation. Also on a decline, junction and obstruction should be spaced reasonably far from the bottom of the incline. Because cyclist need plenty of free space at the bottom incline to recover the speed. So usually what you will see is that when you are coming down, people usually do not recommend a speed hump at the bottom of the incline but the speed humps are usually placed a little bit later on. This is done so that there is some recovery time given to the bicyclist.

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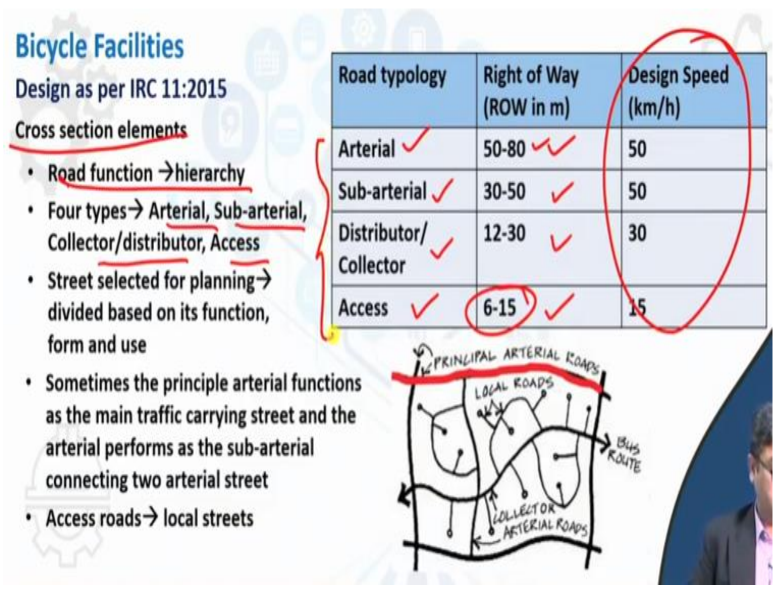

Because we had told you earlier that the design depends upon the type of road, you have to keep in mind for which type of road are you developing your design for the bicycle facility? It depends upon the hierarchy of the road, so if you look 4 different hierarchies are present—arterial, sub-arterial, collector and access roads. You will see that usually the right-of-ways of such roads are given here 50 to 80 meters for arterials. Whereas access roads are very less and in the range of 6 to 15 meters. The design speed of vehicles is given here. So when you know the design speed of vehicular traffic it becomes very essential to design your bicycle tracks according to such design speeds. Otherwise, they may become too unsafe for cyclist to use their cycle on any type of road-ways.

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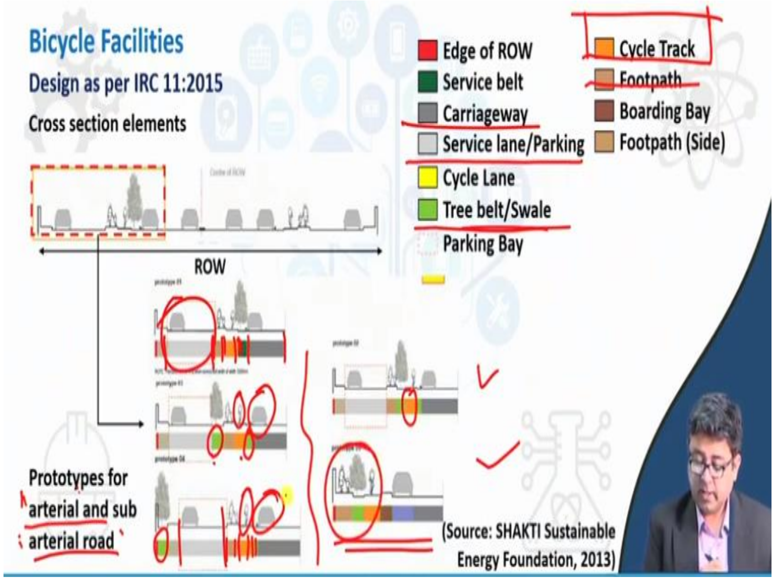

If you look at the cross sections of each of these, you would see that in any type of arterial or sub arterial road, there is a service road or a service lane which may be may or may not be used for parking. Then you may have your 'brown' area which may be a foot path; then you have your 'orange' cycle tracks and have your cycle track after the foot path, and then you may have a tree belt which separates the tracks from the actual carriage way. So, you may have this type of the design whereas the alternative designs are very close to each other. In the other type of design, you may have the tree belt or the swale on the left-hand side rather than on the right-hand side. And you may only have a very small vegetation that separates the bicycles with the vehicles on the main carriage way. On the other hand, you may have a tree line on the extreme left-hand side or even the left of the service lane, and you may have your sidewalks, cycle lanes, and little bit of vegetation between the carriage way and the bicyclist. So different cross sections of roads are shown for either arterial or sub arterial categories of roads but you can develop your own design for your cycle tracks. More or less, you see that the cycle track and the foot path are most likely to be next to each other. Apart from the last section where you see that there is no service lane and everything is at the left hand side of the road.

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The other prototype is a collector or a distributor street. In a collector cross section, you can see that usually you do not have any service lanes. At that point in time put your design of cycle tracks right next to the carriage way itself because what happens is, the average speeds of vehicles along collectors or distributors are low. So, the cyclist feels safer to ride along with the motorized vehicles when compared to arterial or sub arterials where the average speed of the traffic is very high. They would always need a separation from the traffic, so that is the main basic difference between when you are designing a cycle track for a collector or a distributor street versus when you are designing for arterial or a sub arterial. Again, you can go through each one of the different prototypes in this case.

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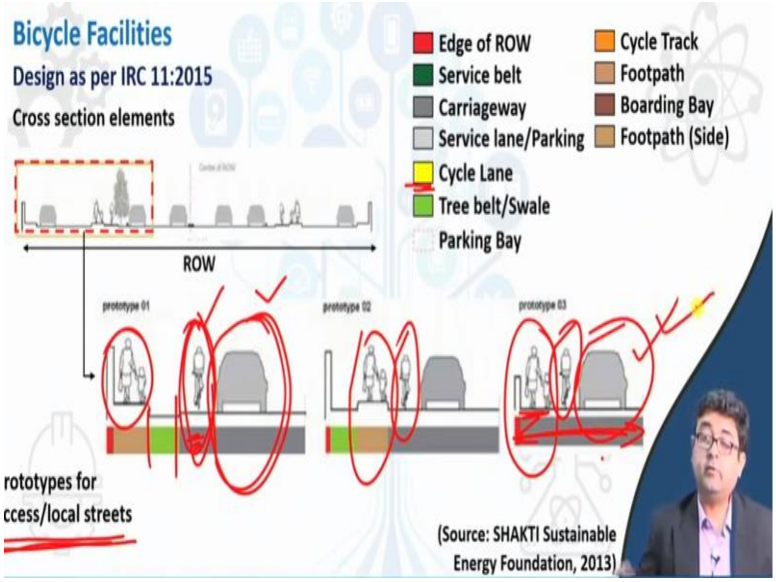

Finally, when you are looking at a local street or access street, it is very similar to the situation that you encounter for collector or distributor where the average speed of vehicles on the right-of-way is pretty low. So, you may not even have a different cycle lane or no yellow marking for cycle lanes. The cyclist and motorist can co-exist on the same carriage way because the speeds are pretty low. So, you can have a vegetation path between the cyclist and the pedestrians or you can have the pedestrian’s right next to the bicyclist. Or you can sometimes see in case of our Indian access streets or local streets, where this is no sidewalk for the pedestrian as well. They are walking on the same carriage way as the bicyclist and the motorist. This is okay when it is an access road or a local street because the average speed of vehicles is low. Similar types of prototypes are showed for more access and local streets**.**

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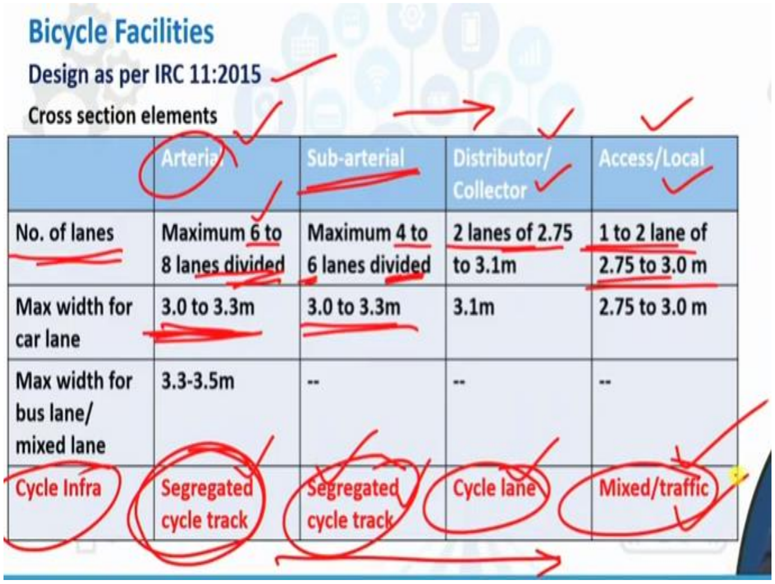

	Arterial	Sub-arterial	Distributor/ Collector	Access/Local
No. of lanes	Maximum 6 to 8 lanes divided	Maximum 4 to 6 lanes divided	2 lanes of 2.75 to 3.1m	1 to 2 lane of 2.75 to 3.0 m
Max width for car lane	3.0 to 3.3m	3.0 to 3.3m	3.1m	2.75 to 3.0 m
Max width for bus lane/ mixed lane	3.3-3.5m	--	--	--
Cycle Infra	Segregated cycle track	Segregated cycle track	Cycle lane	Mixed/traffic

Finally, we start looking at some of the dimensions and some of the measurements for different types of bicycle infrastructure. These types of bicycle infrastructure include segregated cycle tracks, cycle lanes or if they are riding with the motorized vehicles. If the number of lanes on an arterial is anywhere within 6 to 8 divided lanes and maximum width of the car lane is 3 to 3.3 meter it is always recommended that there be a segregated cycle track. Usually, it means that the average speeds of the vehicles are very high so the cyclists feel unsafe riding with the traffic or with the vehicular traffic and hence they need a segregated cycle track. Similarly, is the case for sub arterials when you have about 4 to 6 divided lanes and car lane of 3 to 3.3 meter you have to have a segregated cycle track. But you see as you start getting into distributor or a collector street and local or access streets where there are only 2 lanes, or maybe even 1 lane of width 2.75 to 3 meter, they can ride with mixed traffic or they can just have a cycle lane. This lane can be designed on the carriage way itself and they need not have a segregated cycle track. So as the hierarchy of the roads decrease, hierarchy decreasing meaning average speeds on the vehicle decrease, your need for a segregated separate cycle track also reduces. Cyclist become more and more comfortable riding with the traffic. So, they can ride with mixed traffic.

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Bicycle Facilities

Design as per IRC 11:2015

Cross section elements

	Arterial	Sub-arterial	Distributor/ Collector	Access/Local
Cycle Infra	Segregated cycle track	Segregated cycle track	Cycle lane	Mixed/traffic
Gradient	1:12-1:20	1:12-1:20	1:12-1:20	1:12-1:20
Desirable Lane Width	2.5-5.0m	2.5-5.0m	1.5 to 2.5m	No lane
Level/height	+50mm to +100mm	+50mm to +100mm	0.0m	0.0m
Min. Width	2.2m for two lane track/3-4 m for shared	2.2m for two lane track/3-4 m for shared	1.2 painted cycle lane	No lane

Similarly, look at other design elements such as gradient and then the width of lanes required. If it's an arterial which has a gradient of 1:12 and 1:20 and desirable lane width of minimum 2.2 meter for 2-lane track and 3 to 4 meters for shared lanes of segregated cycle tracks need to be provided. So, you also have to remember how much wide cycle tracks you need when in case of different types of gradients are available at different hierarchy of roads. So, when you are on a distributor you just need a cycle lane you can have a 1.2-meter painted cycle lane. When you are on access road you do not even need a lane because they are going to ride with the mixed traffic. So, I hope you have clearly understood how to decide for different types of bicycle facilities based on the different road ways or which these facilities are to be provided.

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That brings us to the end of this lecture. We have 1 more lecture left in this series for this week. In this lecture we have taken references from the IRC 11 which was developed in 2015. And some of the cross-sectional pictures have been taken from the planning and designing guideline for cycle infrastructure developed by the Shakti Sustainable Energy Foundation.

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You have been exposed to what are the different design principles for designing bicycle facilities, you have been exposed to how the bends at different cycling tracks have to be provided and what is the minimum cycling speed that has to be maintained and also how different cycling infrastructure has to be designed for different hierarchy of roads. Thank you very much!