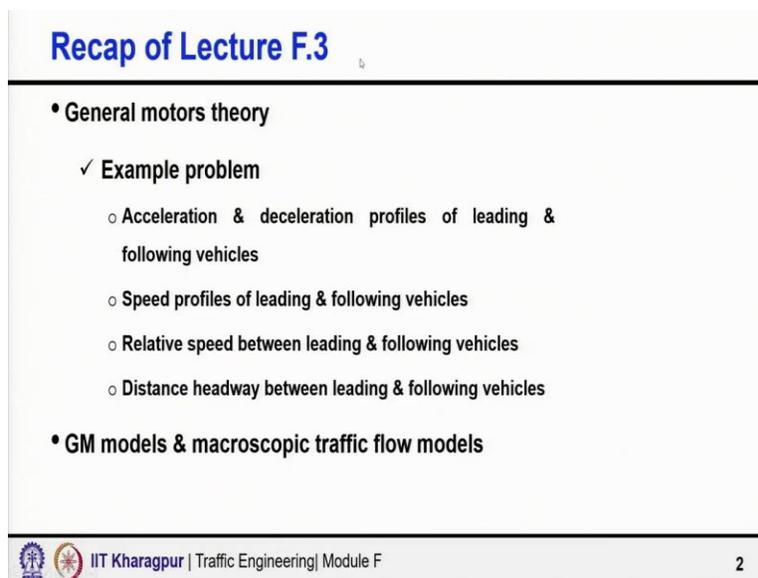**Traffic Engineering**
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Lecture 47
Car Following Theory - IV

Welcome to Module F, lecture 4. In this lecture, we shall continue our discussion about the Car Following Theory. In fact, today will be the last lecture on this particular topic car following theory and the next 2 lectures will be on traffic simulation.

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What we discussed in lecture 3 is an example problem, we took an example problem based on the General Motors car following models, the generalized model and all other generation, first generation, second generation, third and 4th generation models are specific cases of the generalized fifth generation model. So, how to really took an example problem to tell you how with the given input or given set of inputs, how you can calculate each and every parameter value as per the example problem we took based on the third generation General Motors model.

Then, we also discussed about the connection between the General Motors module which is microscopic model connecting it to the macroscopic models, speed flow, density relationship green field, Greenberg, how actually they are connected we discussed in details about Greenberg's model and also indicated that it can be connected also to Greensfield model considering specific values of l and m.
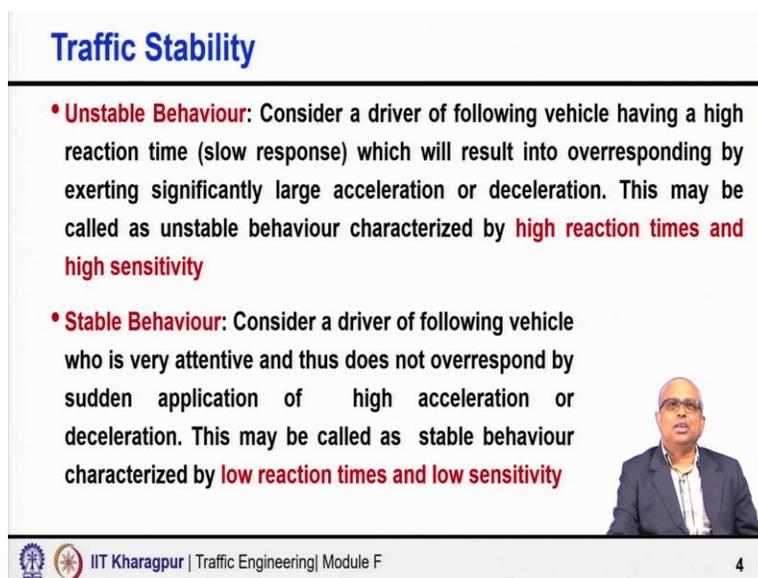
Traffic Stability

Traffic Stability

- **Unstable Behaviour**: Consider a driver of following vehicle having a high reaction time (slow response) which will result into overresponding by exerting significantly large acceleration or deceleration. This may be called as unstable behaviour characterized by high reaction times and high sensitivity

- **Stable Behaviour**: Consider a driver of following vehicle who is very attentive and thus does not overrespond by sudden application of high acceleration or deceleration. This may be called as stable behaviour characterized by low reaction times and low sensitivity

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With this background, today, we shall discuss about first about the traffic stability. Now, when you say the stability of traffic, it is based on the behavior, behavior of vehicles, particularly the following vehicles how the following vehicles, vehicle or vehicles is or are behaving. The behavior could be called could be called unstable behavior or stable behavior.

When it is unstable, let us consider a driver of following vehicle you have a lead vehicle and you have the following vehicle and consider a driver of a following vehicle who has slow response, slow response means what high reaction time. So, if the reaction time is high, then what will

happen you can generally expect that he has to apply higher acceleration or deceleration for the safety reason.

So, once the reaction time is high or the response is slow then it will result into over responding by either applying large acceleration or deceleration depending on the case. Now, this will be called as unstable behavior and this will be characterized by high reaction time high sensitivity, reaction time is high, so the sensitivity is also high that means, the acceleration or deceleration as the case may be this will have high value.

On the other hand, stable behavior would come when suppose a driver of the following vehicle is really attentive, completely focused, reaction time is normal not response like previous case it is not like a slow response, regular response attentive and therefore, does not require to over respond by sudden application of high acceleration or deceleration it will be like a comfortable regular for most vehicle under most operating conditions can apply.

Now, whatever then the whole behavior under such kind of circumstances, we can call it as stable behavior. So, stable behavior may be characterized by low reaction time and low sensitivity. The reaction time is low, low means it is normal. That is what we mean and low sensitivity means it is a regular acceleration or deceleration. So, the behavior could be stable or unstable, unstable case high reaction high sensitivity stable case low reaction time low sensitivity.

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Traffic Stability

- Another important aspect related to traffic stability is whether only the behaviour of one following vehicle or a long line of car following vehicles is considered

- The driver of single following vehicle may behave in erratic manner, but a collision may not occur

- But a line of vehicles following erratic driver will accelerate/ decelerates continuously

- As a result two vehicles somewhere within the long line may collide

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Traffic Stability

- **Unstable Behaviour**: Consider a driver of following vehicle having a high reaction time (slow response) which will result into overresponding by exerting significantly large acceleration or deceleration. This may be called as unstable behaviour characterized by **high reaction times and high sensitivity**

- **Stable Behaviour**: Consider a driver of following vehicle who is very attentive and thus does not overrespond by sudden application of high acceleration or deceleration. This may be called as stable behaviour characterized by **low reaction times and low sensitivity**

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Now, one more thing is also important in this context when we are talking about stable or unstable behavior is how many numbers of vehicles we are considering in the car following state. Is it that it is a single vehicle, is the following vehicle that means, you have altogether only 2 vehicles that we are considering one lead vehicle and one following vehicle. If that is the case, this is something, the other could be a line of vehicle following erratic behavior obviously, will accelerate or decelerate continuously.

So, it is not one but maybe n number of vehicles are there. So, anything happens does not get limited only to 2 vehicles, but it actually impacts goes, goes in the upstream to all the vehicles and as a result, it may happen that any 2 vehicles somewhere within this long line may come very close and may eventually collide.

So, the same response or same reaction time and sensitivity even under unstable condition may not have the same impact on the traffic stream considering if there is only one lead vehicle and one following vehicle vis-a-vis a situation where there is a line of following vehicles. So, in the second case the impact is second likely to be more severe and eventually collision may happen.

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Now, altogether then, the traffic stability largely depends on 2 issues or rather I will say 2 aspects rather than issues first is product of reaction time and sensitivity term, because we are saying that higher the sensitivity more likely it is to be a higher reaction and higher sensitivity will mean unstable, low reaction low sensitivity likely to be stable. So, the product is a good measure.

$$C = \alpha. \Delta t$$

So, that is considered and denoted here as C which is the product of reaction time and sensitivity term reaction time is delta t alpha is the sensitivity term. So, higher the C values it is more likely to be unstable traffic condition and lower C values results in stable traffic conditions. So, this is

one part, reaction time and sensitivity both are important and, in this case, it is logical to consider the product of reaction time and sensitivity term, so that is what is taken.

The second thing is how many number of vehicles in that car following process based on this discussion in the previous slide, whether it is only one lead vehicle one following vehicle or a long line of car, which are in the car following state. So, number of vehicles in the car following process. So, based on both these considerations, that means product of reaction time and sensitivity term which is we can call it a C factor and then number of vehicles in the car following process based on these 2 considerations, we can define the stability as either local stability or asymptotic stability.

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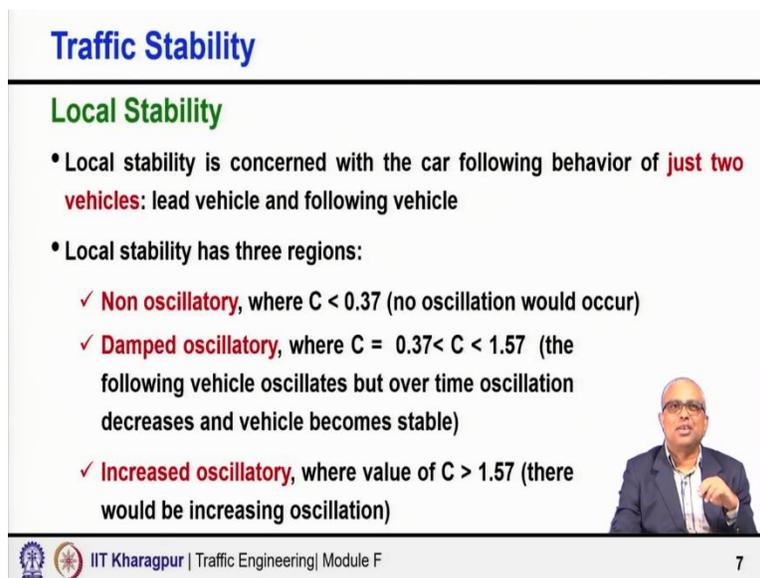
Traffic Stability

Local Stability

- Local stability is concerned with the car following behavior of just two vehicles: lead vehicle and following vehicle
- Local stability has three regions:
  - ✓ Non oscillatory, where C < 0.37 (no oscillation would occur)
  - ✓ Damped oscillatory, where C = 0.37< C < 1.57 (the following vehicle oscillates but over time oscillation decreases and vehicle becomes stable)
  - ✓ Increased oscillatory, where value of C > 1.57 (there would be increasing oscillation)
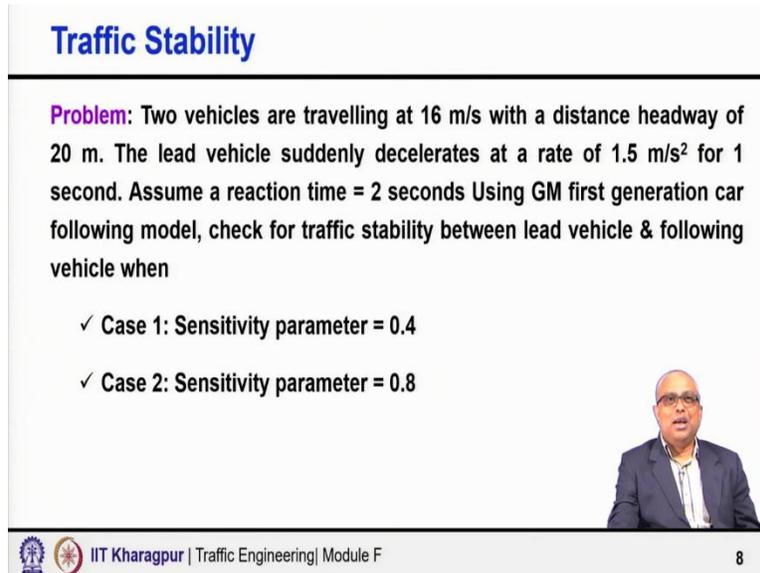
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What is local stability? Local stability is concerned with the car following behavior of just 2 vehicles, one lead vehicle and one following vehicle. So, it is said that the stability has 3 regions it could be non-oscillatory. You understand the meaning of oscillation. So, it could be non-oscillatory, damped oscillatory, so that is another possibility that it could be damped oscillatory or it could be increased oscillatory.

So, non-oscillatory, damped oscillatory it will oscillate, but then diminishing effect will be observed and increasing oscillatory means you can understand we keep on increasing the oscillation. So, non-oscillatory may be observed when C is less than 0.37. So, no oscillation would occur in this case. Damp oscillatory where C is greater than 0.37 less than 1.57, in this case the

following vehicle oscillates, damped oscillator so it oscillates, but over time oscillation decreases and eventually the vehicle becomes stable. Third increased oscillatory this you are likely to get when the value of C is greater than 1.57. So, there will be increasing oscillation.

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Now, let us take up a problem to understand it in a much better way. Of course, some calculations I will not show because you already know in the previous lecture, I have taken a problem, example problem and have explained you how each column in that table you can calculate itself you can calculate rather. So, I will omit those detailed calculations. Now, let us consider 2 vehicles are travelling at 16 meter per second with a distance of 20 meters.

So, the speed is known and the headway, distance headway is also given the lead vehicle suddenly decelerate at a rate of 1.5 meters per second square for 1 second and assume a reaction time of 2 seconds, so, you are taking the action time 2 seconds, then we want you to check the traffic stability between lead vehicle and following vehicles assuming GM first generation car following model, when sensitivity parameter equal to 0.4 and another case sensitivity parameter equal to 0.8. What is sensitivity parameter? You remember this is the term. So, reaction time and sensitivity term. So, for 2 values of C, 2 values of the sensitivity parameter we need to calculate check the traffic stability between lead and following vehicle.
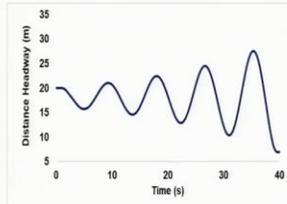
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Traffic Stability — Solution (Slide 9)

Traffic Stability — Local Stability (Slide 7)

So, you know General Motors first generation model. So, I have shown you the calculation each cell how we can calculate based on given input data that I have shown you for third generation model. So, exactly the similar way you can calculate for this given problem and you can for the first-generation model apply the first-generation model which is even a more I would say simpler version. And you can calculate the distance headway both cases when the sensitivity parameter 0.4 or sensitivity parameter 0.8 and I have just directly plotted the values here what is the distance headway vis-a-vis what is the time vis-a-vis the corresponding distance headway in case 1 and also in the case 2.

You can clearly see that this is a case where oscillation happens. But then finally it becomes stable. The change in headway over time indicates that whereas in this case the oscillation is becoming higher and higher. And if you check with the value of actual C, C is 0.4 into then 2 second is the reaction time that is what is mentioned here. So, 0.4 into 2, 0.8 and second case 1.6. Incidentally, the threshold values whatever is given that it is said that damp oscillation is expected damped oscillatory, it will be damped oscillatory for the C in the range of greater than 0.37 and less than 1.57. So, 0.8 goes in between.

So, that is why it is damped oscillatory you can see actually it is happening whereas in the second case the value of C is 1.6 and anything greater than 1.57 is going expected to be increased oscillatory where from I am taking it have just mentioned it here. Remember this is the slide less than 0.37 is non-oscillatory we are not getting values in that range for this example, problem 2 cases one case is coming as damped oscillatory and another case coming as increased oscillatory.

And what is I am trying to tell that as it is said that it is expected to be in one case damped oscillation and another increased oscillation, actually, if you apply General Motors car following model and calculate the distance between a different time, scale, plot it you will actually see the distance headway is actually showing a trend of increased oscillation in second case, first case the same distance headway is going to show a double oscillation. So, that shows the connections.

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Traffic Stability

Asymptotic Stability

- Asymptotic stability is concerned with the car following behavior of a line of vehicles consisting lead vehicle and, theoretically, infinite number of following vehicles
- Asymptotic stability is divided into two regions:
  - ✓ Damped oscillatory
  - ✓ Increased oscillatory
- If C < 0.5 , none of the following vehicle will collide
- If C > 0.5 , two or more of the following vehicles would have eventually collided

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Now, the other possibility is asymptotic stability. So, as I said here, the first case was the local stability when only one lead vehicle and one following vehicle, simple case. Second case is asymptotic stability when it can occur, it can occur when we are trying to describe car following behavior and a line of vehicles consisting of lead vehicle and theoretically any number more than one. So, infinite number of vehicles theoretically present in the traffic stream.

So, in this case, because not one following vehicle, multiple vehicles are present. So, you are unlikely to get non-oscillatory situation. So, when multiple vehicles are involved, not just one lead vehicle and one following vehicle, but multiple vehicles, theoretically, in finite number of following vehicles are there theoretically then non-oscillatory you do not expect. So, what is given here? 2 situation damped oscillatory or increased oscillatory that means the other 2 cases damped oscillatory and increased. So, this case will be missing.

So, what is said here, if the value of C is less than 0.5, understand this threshold values are not same. There the thresholds whatever we mentioned and this threshold is different. So, C less than 0.5, none of the following vehicle will collide. So, it is going to be damped oscillatory, it will oscillate, but eventually everything the whole following vehicle stream will become stable. Nothing bad is going to happen. It is likely to happen. Nothing bad is likely to happen. And in this case, when the C is greater than 0.5, 2 or more of the following vehicles would have eventually collided. So, down the line somewhere 2 vehicles may collide. Because of this impact.

Traffic Stability

Problem: A line of vehicles is in car following mode and all vehicles are travelling at 18 m/s with distance headway of 30 m. The lead vehicle (at position of 300 m) follows the following acceleration profile.

t (Sec)	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10
$\ddot{x}_1$ (m/s²)	0	0	-1	-1	-1	-1	-1	-1	1	1	1	0	0	1	0	0	-1	-1	1	1	0

Plot the trajectories of the lead and all following vehicles for every second until the distance headway between two vehicles is less 7 meters or upto 30 seconds

Use the GM first generation car-following model. Reaction time = 1.5 s & Sensitivity Parameter = 0.5 s. Check for asymptotic stability.

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Let us again take an example a line a vehicle is in car following mode and all vehicles are traveling at 18 meter per second with a distance headway of 30 meters that is what is the traffic state. Now, the lead vehicle at position of 300 meter it is with reference to a point type to show that what is the x value for the lead vehicle, the lead vehicle at position of 300 meter follows the following acceleration profile. So, at different time t 0, 0.5, 1.5 to the 0.5 second interval what is going to be the acceleration or deceleration as the case may be for this lead vehicle.

So, these are the x double dot x1 meter per second square 0 some up to sometime minus 1 indicating deceleration then acceleration then somewhere no acceleration, no deceleration again acceleration combinations. Now, plot the trajectories of lead and all-following vehicle for every seconds, so, we want the plot at every 1 second interval until the distances between 2 vehicle is less than 7 meter considering the average length of the vehicle, the 7 meter is taken as a threshold here for this problem and in fact, it is not so, unrealistic as well it is very realistic I would say to less than 7 meter means, it is considered that almost there are collision is going to happen or because we do not know really collision may happen or may not happen or up to 30 seconds continue the calculation up to that.

Now, here for this problem, we are going to use General Motor first generation car following model with an assumption of reaction time as 1.5 second and sensitivity parameter 0.5 second and we are trying to check for asymptotic stability because here why it is asymptotic stability because

a number of vehicles are there a line of vehicles in the car not one lead and one following, multiple vehicle are involved in the car following.

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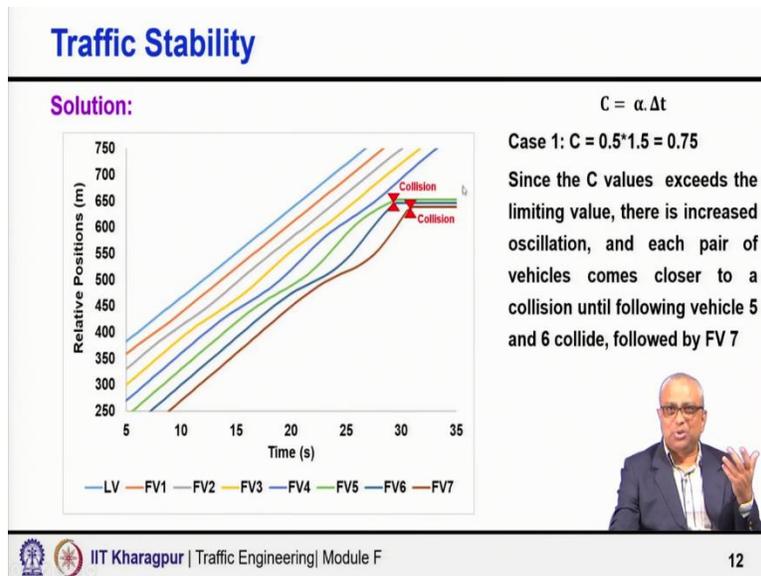
So, as usual again you will know how to calculate the relative position, I have explained you in the previous lecture with that example problem how to calculate each step the speed of following vehicle the acceleration of the following vehicle and then the x1 value, x2 value similarly x3, x4 all the vehicles we can calculate and then select the position also we can calculate it is plotted here. Now, it may look that yes for the first vehicle it is going perfect straight line it is nearly because look at the you know the scale of plot.

So, even there are small fluctuations in between it is almost looking like straight, but what is really happening here you can see these things start getting reflected very clearly from vehicle this is the first lead vehicle so, first following, second following even the third following fourth following fifth following and then sixth fifth and sixth eventually is going to have collision because the difference is coming less than 7 meters.

And once this collision happens, then the standstill situation will occur. So, even the next vehicle also will go and collide. So, something happened in the front but the impact is there somewhere in the upstream vehicle and eventually we will find the collision is happening. In fact, it happens so in the reality that is what is captured, the truth, the whole attempt is to capture that behavior when

multiple vehicles are there in the car following mode anything happened is sudden application of brake or something and you will find the impact is going.

So, maybe the first 2 vehicles or second and third vehicle nothing happened. But somewhere 2 vehicles may eventually collide because of that. Things are much more complex behavior wise when there are multiple vehicles and we are trying to check the asymptotic stability considering there are n number of vehicles, following vehicles. So, that is what is shown here and in fact here also if you calculate the C value, the C value is coming to be 0.75.

So, here if you look at the threshold 0.75 means it is eventually indicating that some 2 vehicles will collide. And that is what you can see here in this example problem also this happened. So, these are very, very interesting phenomena which we are able to capture in this kind of model. And the real behavior is like this, if there is a suddenly in a high-speed facility you know suddenly 1 vehicle apply break and multiple vehicles are in actually car following mode, how it is going to impact.

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Wiedemann Car Following Models

- Wiedemann proposed two car-following models that were developed based on **psycho-physical** aspects of **driving behaviors**

  ✓ Wiedemann 74: Suitable for driver behavior on urban arterials

  ✓ Wiedemann 99: Suitable for driver behavior on freeways (Researchers nowadays usually use for all situations)

Different Driving States for a Driver

- Wiedemann's traffic flow model is based on the assumption that there are four different driving states for a driver

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Now, we go to another car following model, which is worldwide people use it these days also majority of the so many traffic simulators they have inbuilt this model, wiedemann car following model. Now, this makes certain assumptions, wiedemann proposed car following models that were developed based on psychophysical aspects of driver behavior, very interesting and I really do not have much scope to go into details of this Wiedemann model, but these Wiedemann models are used extensively these days all over the world.

Of course, the calibration and many other challenges are there local condition has to be replicated properly, it needs to be calibrated. So, the complexities actually in the calibration process, which I will not discuss somehow, because, I just want to give you a very quick understanding quick overview of development model, there are 2 models which are suggested by Wiedemann and these are called Wiedemann 74 and Wiedemann 99. 74 is primarily for development in urban context for urban arterials and the next model is suitable for driver behavior on freeways.

But these days researchers generally use this model wiedemann 99 for all situations because there are more parameters which are there, it appears to be more realistic, more parameters are there. So, I mean even for rural urban both cases we use wiedemann researchers use this wiedemann 99 model. Now, wiedemann traffic flow model is based on the assumption that there are 4 driving states for a driver what are those 4 states in this context.

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Wiedemann Car Following Models

Free Driving

- **No influence of preceding vehicles** can be observed and the driver seeks to reach and maintain his desired speed

- In reality, the speed in free driving will vary due to imperfect throttle control and therefore, will always oscillate around the desired speed

Approaching

- Process of the driver **adapting** his/her speed to a lower speed of the preceding vehicle

- Driver decelerates, so that there is no difference in speed once he reaches the desired safety distance

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One is first is free driving that means, no influence of preceding vehicle, the traffic volume itself is so low the density is so low, speed is high, and it is almost like everybody is enjoying the freedom of movement and your driving is not influenced by the presence of the vehicle preceding vehicle. So, no influence of preceding vehicles. So, driver seeks to reach and maintain his desired speed. But of course, really if we think it is not going unlikely to be just a constant value, because of the imperfect throttle control.

So, what is going to happen how you are pressing the accelerator pedal. So, it may not be exactly at 80 kilometers per hour for example, but it may be sometimes a little higher a little lower. So, it may be around that desired speed. So, it will still have some oscillation, but not so significant will always have some oscillation around the desired speed. That is what is generally expected that is the free driving.

Then approaching means the process of the driver now adapting his or her speed to a lower speed of the preceding vehicle. Now, the preceding vehicle's presence is felt. So, you want to slow down you want to decelerate so that there is no difference in speed once he or she reaches the desired safety distance. By the time, we come closer and where the desired safety distance whatever is to be maintained. Now, my speed has been reduced to the speed of the lead vehicle so that there is no difference in speed with the lead vehicle once I have reached the desired safety distance, that is what is the approaching. So, free driving do not bother, no influence of preceding vehicle and then vis-a-vis I am approaching.

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The third is now, I have reached some car following state. So, driver follows the preceding car without consciously accelerating or decelerating and keep the safe distance more or less constant. Again, it cannot be just a fixed value because drivers may not be able to judge every precise point, a small change in the speed, a small change in the spacing or space headway even may not be recognized. So, we are saying that driver follows the preceding car without consciously accelerating or decelerating and keeps safety distance more or less constant.
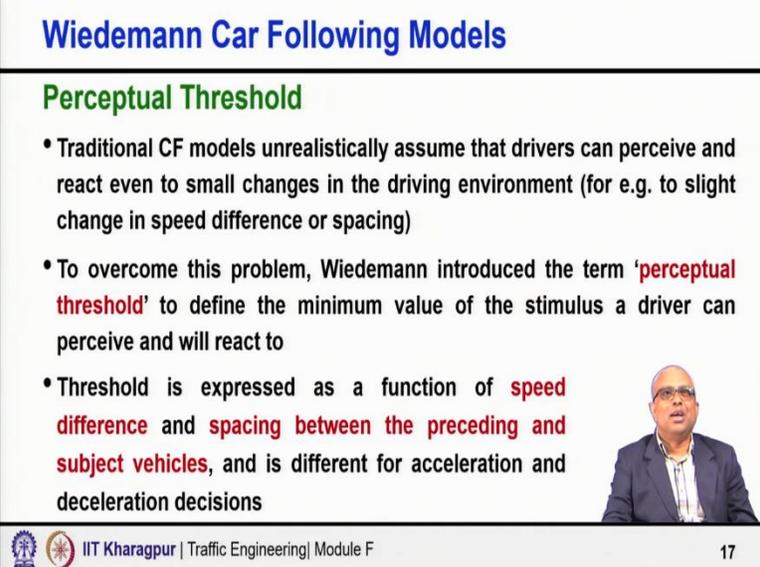
Then, next stage braking, in this case, this is a situation where a driver applies medium to high acceleration, medium to high deceleration rate because you are coming closer and you find now the big somewhere the gap whatever the spacing is required, you are actually it is lesser. So, you apply brake so, driver applies medium to high deceleration if distance to the preceding vehicle falls below the desired safety distance. What is really desired? Desired still have some margin.

So, desired following below desired does not means collision is going to happen, but you are saying that now you are following below the desired safety distance how this can happen when you are in a car following mode. If nothing happened, if the vehicle in front travels at more or less uniform speed and you are also following then it is a peaceful condition.

But this time the braking situation will arise if the driver of the preceding vehicle abruptly changes his speed say suddenly apply brake, then this kind of your case also the braking can come for the

following vehicle or which is again common very much in Indian condition if third vehicle changes lane to squeeze in between 2 vehicles. So, you are traveling there is a vehicle, another vehicle which was traveling and other than now trying to enter so the braking situation.

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So, another difference in the wiedemann model is that perceptual threshold, this is something slightly new to you, traditional car following models whatever we have discussed so far, let us take all those models. To some extent, I will say unrealistically assume that driver can perceive and react even to small changes in the driving environment, that means even slight change in speed difference or slight change in spacing drivers can perceive and react.

In reality, this is unlikely as I said more or less you want to maintain, more or less you can assess but every small change in speed or the speed difference or the spacing specific way cannot be perceived so accurately. So, to overcome this problem, Weidemann introduced the term perceptual threshold to define the minimum value of the stimulus a driver can perceive and will react to bring that concept of threshold.

Now obviously and very logically, this threshold is a function of speed difference spacing between the preceding and subject vehicle and is again different for acceleration and deceleration. Because acceleration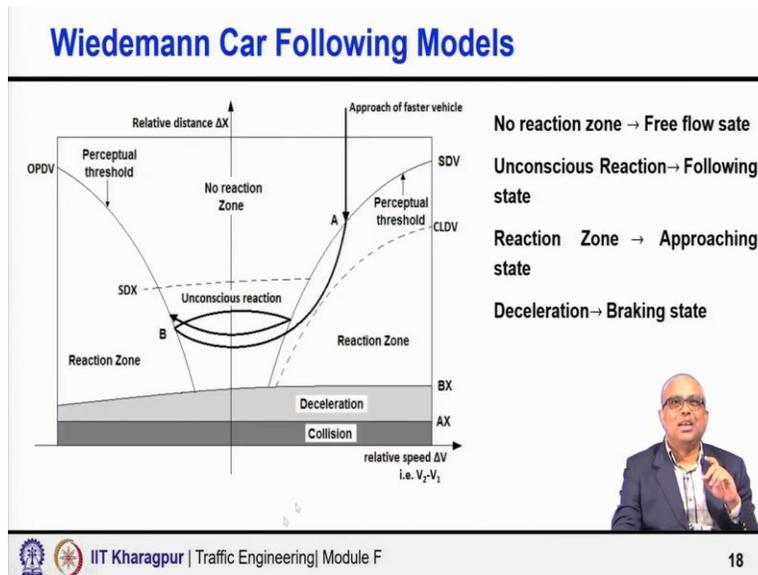 you do for a different reason, deceleration you do for a different reason. So, the values cannot be same for acceleration and deceleration decisions different.

Now, based on that, we have shown here how the whole thing can be represented in a diagram. Here the X is the relative speed between 2 vehicles, the relative speed, how we are calculating V2 minus V1, following vehicle speed minus the vehicle, which is the lead vehicle that speed and this x axis is the relative distance delta X. Now, the first here when this relative distance will be high, the relative distance will be high under what condition, free flow state. So, what I have said I have said free flow state, following state, approaching state and breaking state.

So, this whole area is actually shown no reaction zone. You do not need to react even the presence is not failed presence of a preceding vehicle is not failed, that is the situation. So, no reaction zone then following state kind of unconscious reaction type then the reaction zone comes sequence wise where it is the approaching state. So, that is what is the reactions zone this side and this side as well that is the reaction zone.

And the solid lines are demarcating between no reaction zone and reaction zone what is called, but the traffic state wise it is free flow state and this is the approaching state. Then here it is shown unconscious reaction following state consciously you do not really when you are following little bit up and down may happen, but not any conscious acceleration or deceleration then the braking state comes this part deceleration.

So, the remember that this is the axis. So, as you go up, your relative distance is increasing, and as you go to this side, the relative speed is also increasing and then below is the collision. Now, obviously, the solid lines this one, this one also the dotted line, this one this line and also this line, these are what demarcating from one traffic state to another traffic state or from one zone to another zone, no reaction zone, reaction zone, unconscious reaction deceleration different zones. So, it is demarcation.

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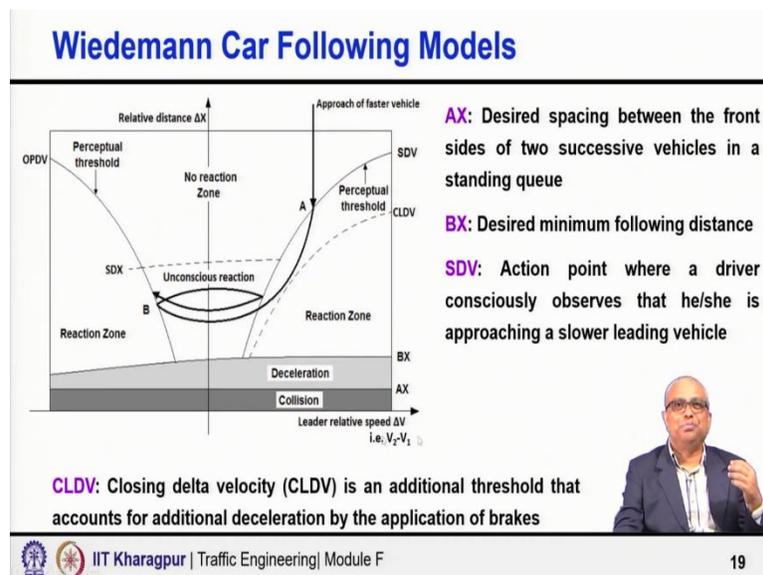
So, now, what is then AX? AX is that this is the value of the relative distance threshold value below which collision may happen. So, what is saying it is the desired spacing between front side of 2 successive vehicles in a standing queue what even in a standing queue what gap, what spacing you expect, if the relative distance is going to fall below that, then the collision may happen.

BX this threshold is the desired minimum following distance if the distance falls below that, then you definitely apply deceleration because now, you are you know that if I do not apply deceleration it further it drops, I may go eventually to this AX line or I may cross this AX line. So, collision may happen. So, this is the deceleration thing. So, mean desired minimum following distance beyond which you must apply deceleration.

SDV this line no reaction to reaction zone, it is the action point where a driver consistently observed that he she is approaching a slower leading vehicle and therefore, once it cross it will try

to reduce the speed so, that by the time you get the safe, desirable distance, your speed and the speed of the vehicle in front is same. That is what is SDV.

Now, this CLDV another dotted line within this reaction zone, this is another kind of threshold that here it is where applying once you have crossed this SDV and have gone to reaction zone you will apply deceleration. But before if you fall really below this line CLDV then you are closing delta velocity. That is what is called this is an additional threshold that accounts for additional deceleration by the application of brakes. Now, additional deceleration because you are you have crossed that initial threshold. Now, additional deceleration may be required.

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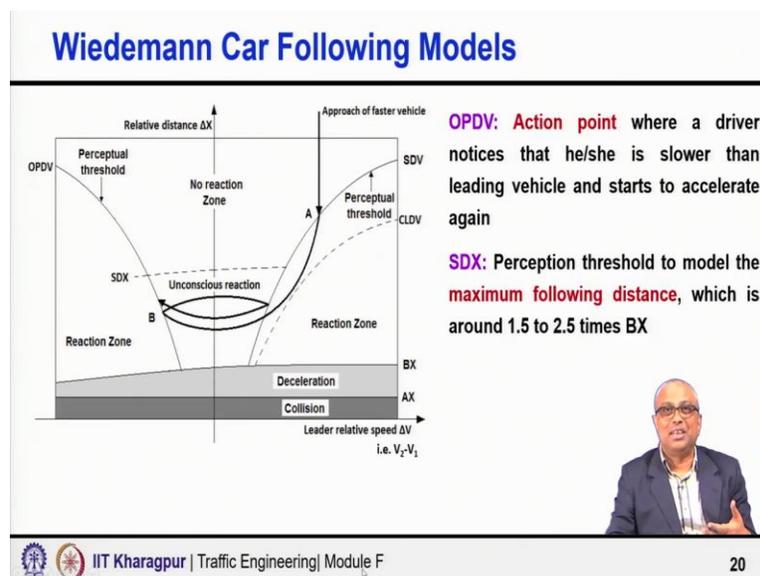
Now, this threshold OPDV this threshold on the other side this is the action point where a driver notices that he sees slower than the leading vehicle and start accelerate again here before you below if you fall below this you start deceleration, but here you explain that maybe now the gap has increased gap has reduced or gap is reducing. So, you start deceleration gap is increased. So, you will start acceleration that is the threshold.

So, action point where a driver notices that he or she is slower than the leading vehicle and starts to accelerate again and what is this is SDX? SDX is the perception threshold to model maximum following distance which is around 1.5 to 2.5 of BX. BX is what below that you must apply deceleration, but here it is generally like a car following state. So, generally the perception

threshold to model the maximum following distance and which is, 1.5 to 2.5 times of this BX. So, you have a margin.

So, consciously you do not want to decelerate or accelerate you are happy. So, the threshold has got a higher threshold and then a lower threshold when you have gone below this then you apply immediately deceleration to decelerate. When you were in this range, you do not conscious reaction is not there. So, unconsciously sometimes it goes not that exactly the same speed same assessment, every small thing can be assessed that may not happen that is why it is called not it is in no reaction zone, but it is unconscious reaction, reaction may happen but not conscious reaction.

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Wiedemann Car Following Models

- A vehicle travelling faster than the leader will get close to it until the deceleration perceptual threshold (SDV) is crossed (at Point A)

- The driver will then decelerate to match the leader's speed

- However, as a human being, the driver is unable to accurately replicate the leader's speed, and spacing will increase until the acceleration perceptual threshold (OPDV) is reached (at Point B)

- The driver will again accelerate to match the leader's speed and the process continues, as shown in the unconscious reaction zone

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Now, a vehicle traveling what is this line suppose a vehicle approaching a faster vehicle it is coming and the moment the SDV is crossed, then what we will do the vehicle will start deceleration. Now, if start decelerating and finally, if it goes to this threshold of OPDV point B it will reach then it realized no the gap has increased they have decelerated, but now the gap has increased. So, it will start doing the acceleration. But by doing the acceleration, sometimes he may reach there again I have touched this threshold of SDV.

So, again, we will start to decelerate. Again, go back, then say, I have decelerated now, I have got enough gap. So, again, little bit tried to accelerate. That is what happens in reality, it follow you are telling close you apply deceleration, then the gap increases now you feel no, I have not enough

gap. So, I again start accelerating, then the moment I cross that threshold, and then again, I start decelerating. That is the way the behavior is expected to happen, which is shown here in this slide.

That a driver traveling at a faster than the leader will get close to it until the deceleration perceptual threshold is SDV is reached or crossed at point A then the driver will decelerate to match the leader speed however, as human being the driver is unable to accurately replicate the leader speed and suppose the spacing increases and then until the acceleration perceptual threshold is reached at point B. So, now the distance has increased. So, then the driver will again accelerate to match the leader speed and the process continue as shown here.

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So, Wiedemann 74 model consists of 3 parameters average standstill distance, that is the average desired standstill distance between 2 cars minimum and then additive part of safety there are 2 components, one is additive part of safety. The safety distance has got 2 part one is the additive part which is bx add is the addition plus and the other is the multiplicative part, but this is also for safety distance both are safety distance one is additive one is multiplicative. So, V here is in this equation is the vehicle speed in meter per second, z is a value which may be in the range of 0 to 1 and normally distributed around 0.5 with a standard deviation of 0.15. So, these are the 3 parameters which are considered by wiedemann 74 model.

$$d = ax + bx$$

$$bx = bx_{add} + bx_{mult} * z * \sqrt{v}$$

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Wiedemann Car Following Models

• The Wiedemann 99 model consists of 10 parameters

Notation	Unit	Description
CC0	m	Average standstill distance between two vehicles
CC1	s	Desired headway time between lead and following vehicles
CC2	m	Additional distance over the desired safety distance. At this stage, the driver recognizes a preceding slower vehicle
CC3	s	The time in seconds before a vehicle starts decelerating to the safety distance
CC4		Negative speed variation between lead and following vehicles. Low values result in a more sensitive driver reaction to the acceleration or deceleration of the preceding vehicle
CC5		Positive speed variation between lead and following vehicles
CC6		Influence of distance on speed oscillation. Large values lead to a greater speed oscillation with increasing distance
CC7	m/s²	Oscillation during acceleration
CC8	m/s²	Desired acceleration from standstill
CC9	m/s²	Desired acceleration at 80 km/h

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Wiedemann 99 model considered 10 parameters very enriched one. I do not have really scope to go into detail. So, I have mentioned here these are called CC0 to CC9 and what they mean average standstill distance to desired headway, then additional distance over the desired safety distance, then also something like this positive speed variation, influence of distance on speed oscillation, then oscillation during acceleration, desired acceleration from standstill, desired acceleration when the speed is nearly 80 kilometer per hour not exactly 80 but I have round it off. So, all these parameters are there. So, it really fantastic model which need to be calibrated locally before you apply and you try to replicate a local traffic situation in the micro simulation platform. So, it is widely used model.

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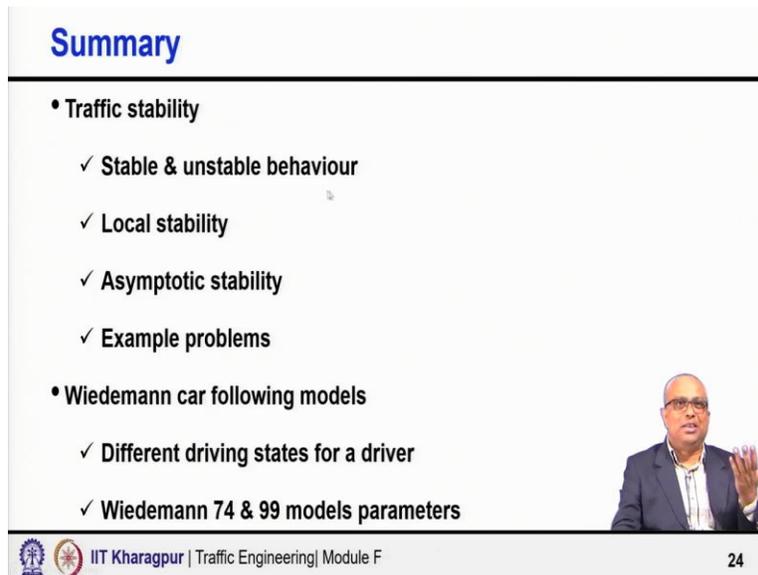
So, with this, what I discussed today is about the traffic stability, unstable stable behavior, local stability, asymptotic stability also example problems to explain, then, briefly introduced you very briefly introduced to you about the Wiedemann car following model, different driving states and how the things happen and then just indicated what are the model parameters that are used in Wiedemann 74 and Wiedemann 99 models. With this, I close this lecture. Thank you so much.