Vehicle Dynamics
Prof. R. Krishnakumar
Department of Engineering Design
Indian Institute of Technology – Madras

Lecture - 26
Subjective and Objective Evaluation of Vehicle Handling (Part 2)

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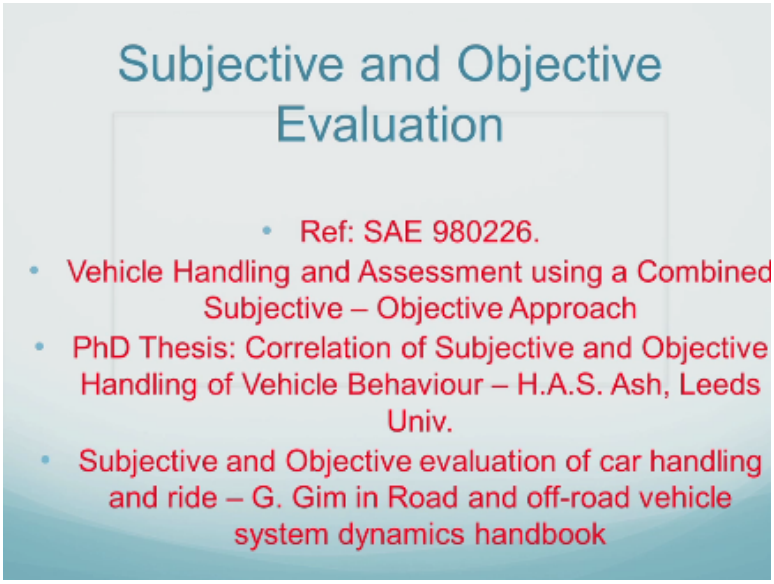

Okay in the last class we were looking at subjective-objective evaluation; we will continue this topic. This is probably one of the most important topics especially for people who design vehicles. They want to understand how to satisfy the driver in other words that is what we call as subjective evaluation. Usually there is jury of driver's 6-7 people who conduct a number of manures and then answer questions in terms of ratings.

For example, there can be a 1 to 7 rating for a question one being bad and 7 being the best and so on. Now that is what we called a subjective rating. Objective as I told you before it is the characteristic of the vehicle for example 4 of the objective matrix which we called as Mimuro matrix was already introduced to you and the most important thing for a designer is to correlate between the subjective evaluation of the drivers with the objective matrix.

So lot of rigid task, very difficult task. Number of papers are available in this particular issue. As I told you in the last class I am going to take so as references which give clarity to the subject yes

there are others which have appeared recently. So we will concentrate on these references though we have done some work on this and because some property rights we were not able to project all the results but we will-- so we will concentrate on published in order to understand this topic. Just to summarize of what we did.

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Understand that we were essentially subjective evaluation in subjective evaluation we concentrating on how steering is given and how vehicle is going to behave to that steering input, okay. Now that is the most important thing. Now the steering also involves the steering input also involves how the steering is going to get a feedback from the vehicle due to certain manures which we are going to do.

Already we have seen this we said that straightability as a vehicle goes straight in a road what are the things that we should look for a in a vehicle.

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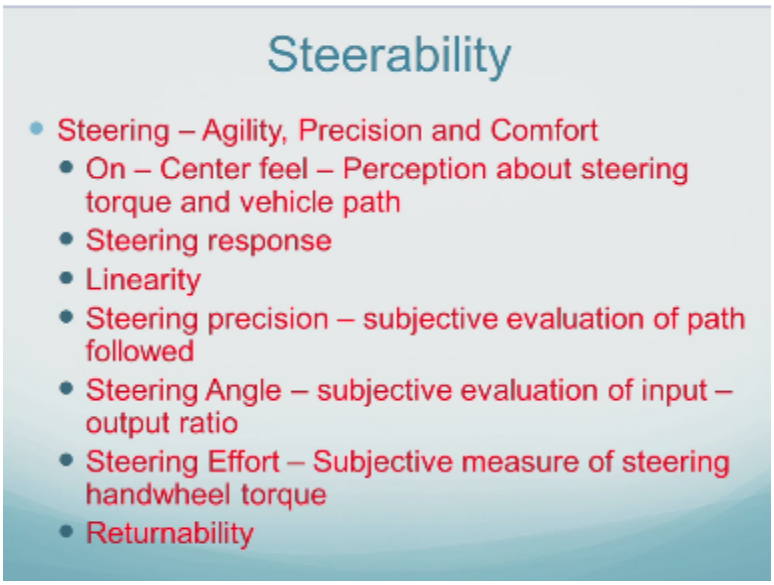

We were looking at steerability in the sense that how does the vehicle behave when you want to steer a vehicle, so in terms of agility in other words how much of steering angle you have to give in order that vehicle is going to listen to you precession or able to follow a path with precision with the steering angle which you feel should be given in other words what is the feedback that you get from the vehicle and comfort it is a steering torque that you apply is very high or very low and so on.

So these are the 3 things that are very important as far as the steerability is concerned. We have already seen On-Center feel; we have seen steering response; we have talked about you remember that we talked about the time delay and so on and then we had talked about steering linearity how much you know linear or nonlinear is the input as a path changes.

We were looking at what we called as steering precision, okay. Steering precision is actually a subjective evaluation of the path that is followed. How much of steering input that I have to give or how precisely is the path that is followed as I give the steering input. So that is again a subjective evaluation of the path to be followed. Then we have this steering angle. Okay. This again is the subjective evaluation of input versus output. Say for example you can draw.

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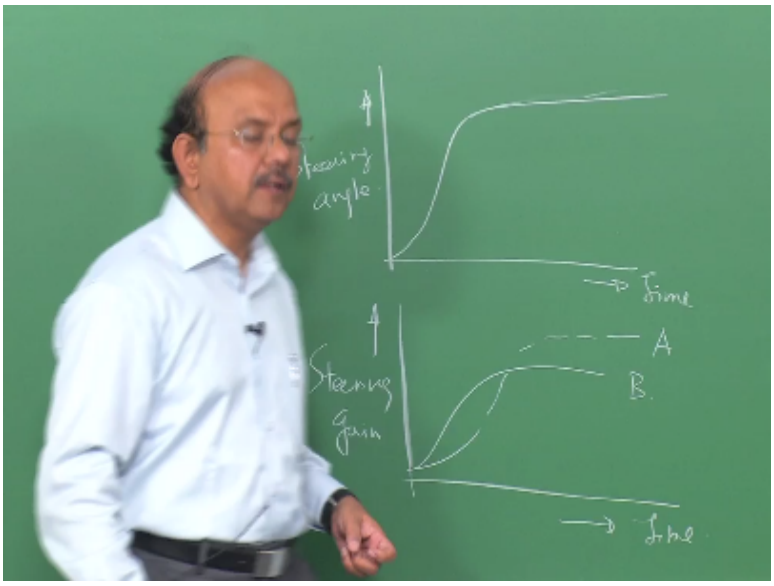

So you give a path a graph between time and the steering angle, right. For example, the steering angle of course you are going to take some time for to give the steering angle let us say that that is the steering angle you give, okay. So you steer the vehicle to go in a particular path. Now if that is the case you can draw another graph between steering gain versus time, okay.

In other words, how much since we are talking right now about steering angle, how much the angle turning because of this steering angle with respect to time that you have given. See it can be-- there can be 2 graphs one say let say that one graph is like this okay the other graph is like this. Please note that when the steering gain is low you have to give more steering, right. So this maybe due to 2-tiers say tier A and tier B 2 different tiers. Okay.

Now, this is where subjective evaluation comes into picture. If you look at the tier B for example, it response quickly to the gain in other words to the steering input that you gave, okay it realizes the steering input in quickly gets that gain that is required, okay or the what we call as hand wheel to road wheel you know, the road wheel quickly realizes raises and then one of the input is realized.

But the gain stops in other words, the gain is constant which means you have to give please note gain is the ratio and so you have to give more steering in order to achieve what you the path you want, right. So raise time is high but lot most steering has to be given. But on other hand a tier B

the raise time low but the amount of steering you have to give is less okay. So this is what is realized or this is what we call as subjective evaluation.

How does the driver feel or when does the driver feel comfortable with tier A or tier B. Okay, this is what we feel or what we say as subjective evaluation. Yeah, then we have what we call is a steering effort in steering effort you talk about the steering torque that you have to give you know the amount of torque that you have to give is steering effort.

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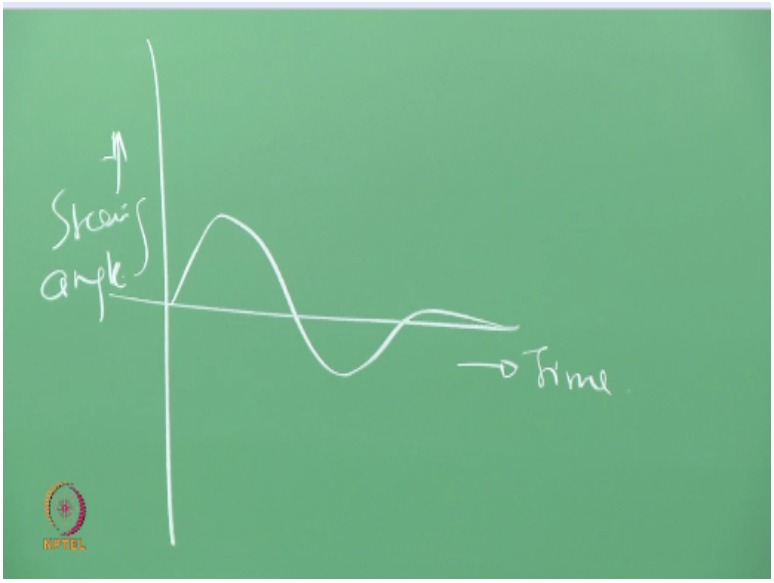

Returnability, we saw that when I leave the steering how fast time versus the steering angle, so how fast the steering comes back to where it left, right, so that is the returnability. So it returns to its original position.

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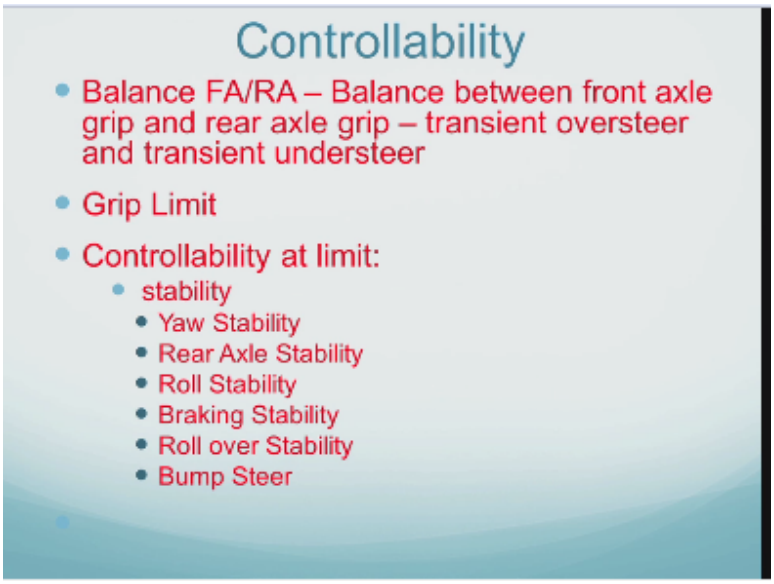

One of the most important thing so—just go back so here we are talking all these things we are talking about is the steering and its affect on the vehicle. Okay, so that is what we call a steerability ability to steer, that is what we call as steerability, term used by Gim. Then we have what is called Controllability, okay.

Am I able to control the vehicle and controllability comes especially at limit driving it does not come you know on a very ordinary driving at 30 kilometers or 40 kilometers per hour in the city roads. So when we talk about controllability we are talking about the limit driving at limit. So with the grip if you are going lose a grip what is going to happen, okay this is what we are looking at.

So in controllability one of the first things that people today look at is what is called as balance FA/RA. Balance between the front axle grip and rear axle grip. Actually, when talk about this is the common terminology that is used when they talk about balance between the front axle grip and rear axle grip actually what they mean is the slip angle that is developed between front axle and the rear axle.

Though this term grip is loosely used it is actually the force generated or in other words it is the slip angle that is created okay between the front and the rear that is what we call as balance FA/RA. It depends upon of course on the characteristic of the front tier and the rear so this to a

great extent this is a tier characteristic which you can see that this in many of the websites of the tier manufactures were they will talk about balance FA/RA and usually its talked in a scale, or in terms of a scale.

Right, so in other words balance FA/RA is a measure of a transient oversteer or a transient understeer. We already talked about transient oversteer and traniset understeer remember that when I am going to take a turn okay I am going to take a turn I am in a transient situation and we talked about whatever usually analysis we have done with respective to K was in steady state. So transient oversteer and understeer is when I enter a turn; when I power on and power off okay accelerate in other words accelerate or brake and so on.

Please understand that this again the confusion in the literature on braking acceleration power on power off okay. These are rather power off and power on. In other words, we are looking at the vehicles behaviour in deceleration. It does not matter whether you are applying brake in order to decelerate a vehicle or taking a paddle of the accelerometer sorry accelerator. Okay taking the parallel of the accelerator is as much as braking as you apply brakes, right.

Or in other words power you do not give power off is also braking. So usually, I would say that they are synonyms that you take your paddle I mean leg off the accelerator paddle is braking. Okay. So both of time-- it is very important how the vehicle behaves is in both of this conditions. Why? As we have said before whenever there is a load transfer there is going to be a change in the, what? Slip angles.

We saw that whenever the vehicle rolls there is a change in the slip angle. In the same fashion whenever there is a roll-- sorry whenever there is a pitch or in other words whenever there is a transfer of load between the front and the rear again I am going to have a difference in alpha f and alpha r.

So whenever there is a transfer like that alpha f alpha r gets affected and hence okay I get into a variation in the oversteer or understeer characteristics of the vehicle, okay so this is what is tested this is what is tested when what happens when I power on and power off in a turn whether

a vehicle is going to become; how much it is going to become; understeer or oversteer because of this transfer of power. Clear? Okay, yes.

"Professor – Student conversation starts" What is the difference between the deceleration and I mean if you when you left your leg of in accelerator and braking? Yes, I agree with you because, yes I agree with you. We are—I fully agree with you that grade system characteristic is become important and the rate at which is braking is important. No doubt about it. Okay. Good question, good observation. **"Professor – Student conversation ends"**.

But from a vehicle dynamics point of view, okay I am looking at deceleration. So when I take my leg off this paddle automatically the vehicle speed comes down that means in other words it is decelerating. Right, this is what I meant. Of course deceleration or power off okay is no substitute for braking there are other issues because the intensity of deceleration also is different. But I just wanted to tell you that the behaviour is similar.

In other words, you can look at the behaviour from both prospective, right okay. So usually when we say controllability we are looking at the limit of the grip. Now I am going to go bit fast in this. In other words, we are looking at the stability of the vehicle at the limits. I am going to lose the grip okay or I have almost lost the grip or I have lost the grip, how does my vehicle behave, this is the condition, you know at the limit conditions.

The first thing under this conditions that you look at is what is called as Yaw stability. So look at the slide what are the things that we are looking at. So the first thing that we are looking at is Yaw Stability. What is meant by Yaw Stability? So the vehicle at the-- at this limiting conditions would actually Yaw okay. This is because --- there are number of design maybe because this is the lateral compliances differences and so o, okay.

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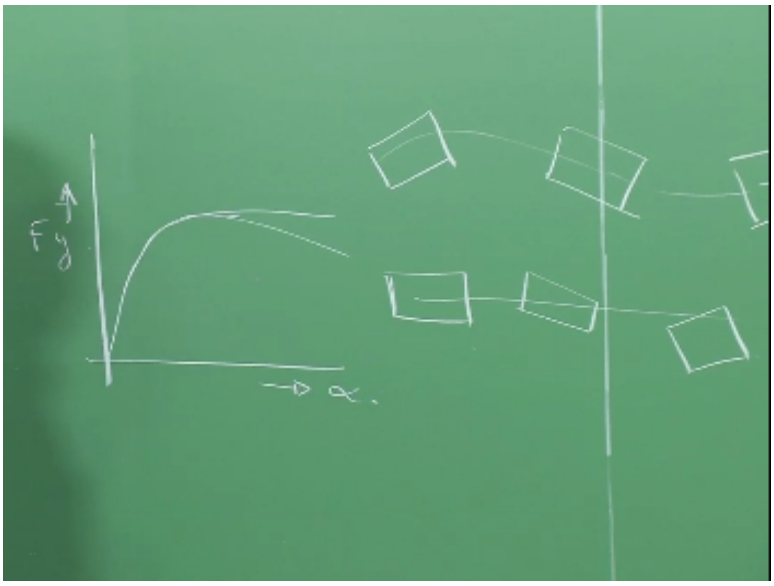

So the vehicle would be Yaw; the vehicle would like this, then would like this and then would like this and so on. Okay. So the yaw the vehicle yaw as the vehicle yaws what also becomes important is your damping. Okay. How much is it going to go it is going to be difficult control the vehicle as it yaws okay; does it yaw; how much it yaws, and difficult it is to control the vehicle, how does the yaw damping bring it back okay bring back the oscillation to a steady condition and so on is what we mean by yaw stability. Okay.

So that is the oscillation allow around yaw, right. The other thing is what we call as Rear Axle Stability, which means that it is the-- if this is the vehicle okay so how much-- so the-- actually it goes you know, this slips up and down like that. So it is a straight line where the rear backs vax the tail, okay so that is rear access stability. Again, it is a question of oscillation okay about the rear access.

Braking Stability, sorry rolls Stability, how much as a take a turn okay the vehicle rolls, right. And this is slightly different from rollover stability where we are looking at the propensity of the vehicle to rollover, okay. This is a very severe test should, usually done with steering robot; there are standards for this and so on. So roll stability is what does the driver perceive as a roll and rollover is that the vehicles just rolls over.

Then we are talking about Braking Stability, that means that you go straight break the vehicle okay, how much of attitude of the vehicle I lose. Is it braking straight and standing there as I go or does it move and so on. Then Bump Steer, the change in the 2 as you go over a bump, okay this you all of you who drive would have felt it in your vehicle as you go over a bump the actually the steering steers and you have to hold the steering and so what is the steering that input that is given without our effort due to bump, you know this is bump steer.

So these are some of the things that you have to look at. So in the nutshell, when you test a vehicle you look at how the vehicle behaves in a straight line when you go straight; how when you give an steering input or what is affect to the steering and how the vehicle can be controlled, these are the 3 things that you get. **"Professor – Student conversation starts"** When you say you controllability at the limits, you look at how controllability of the vehicle (()) (17:58).

No, no at the limit means I am talking about the grip, okay at very high speed when it takes turn and so on, okay. We are not looking at – see this goes with the limit of the handling of the vehicle. Okay, we are not talking about these things at very low speed that is what I mean. Okay, under normal 40 kilometers per hour conditions of operation. Okay that is what I said that controllability at the limit. So what are the things that you do in the subjective test, yeah?

Sir we are talking about yaw stability, there are cases when the driver only want to steer- Yeah of course that is what a subjective rating. So how much the driver in one case there may be a yaw of the vehicle and the vehicle may come back okay. In another case it may go out of control, he may feel very uncomfortable. So these are the feelings you know that is what we call it as subjective rating.

No, sir if there are cases when vehicle just runs forward without driver being able to steering (()) (18:58) it will just keep going straight without the driver have a driving. Yes, see again see that is true, that is what that is what we are calling as the subjective evaluation, when we say about subjective evaluation the limit is not that the driver has lost the complete control and gone and what happens, no, okay.

What we call at this point when I reach a limit that additional input that is given, how does it behave? So the additional steering effort at the limit is what we are looking at. It is not that I have lost control, okay. For example, if you look at grip okay grip is again a loosely used term just for a force that grip is used. For example, you know that alpha versus Fy force, right if you know that it is going to reach a limit and it can be come down or it will come down, okay.

So this is what we call as unstable reachable. But a tier may not have a very sharp unstable region, it can be quite flat. Okay. In which case the controllability of this tier or at the limit or the grip as we call it okay this is better than this, okay. So what are we trying to do when there is a change this is get exactly next half an hour of the shot we are going to see-- when there is a change in the characteristic okay how does the driver perceive, okay.

Just wait for some time and we will look at all these things. **"Professor – Student conversation ends"**

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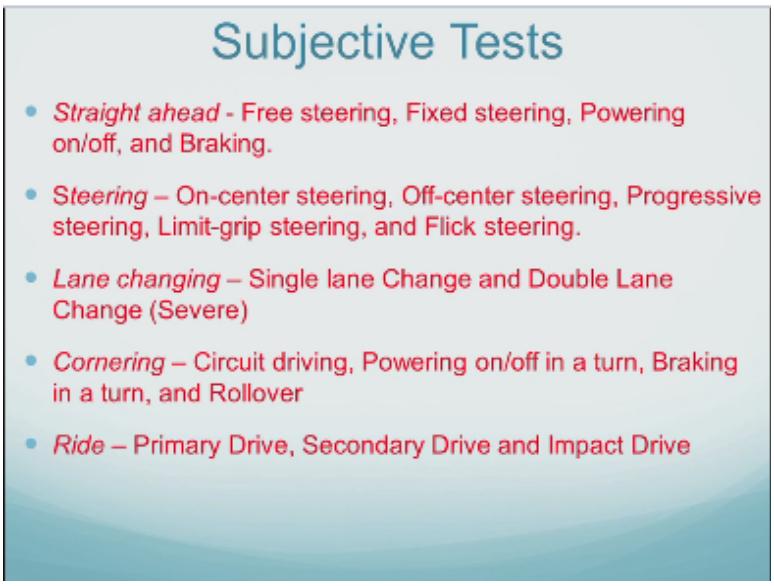

So in other words, quickly summarizing this we are going to look at Straight ahead okay. Free steering—Free steering I am going to give an input, fixed steering I am not going to hold I am going to look at the torque or the feel in my hand. Power on and off, okay and braking. We have introduced braking because a friend here said that yes often braking are different okay so we have introduced braking.

Steering, On-Center steering we have already saw On-Center steering, Off-Center steering when the steering is not at the center how does it behave, Progressive steering this we called as a linearity as it increases a Limit-grip steering is what we have been talking about and Flick steering when I just flick this steering what is remunerability so that is what is given by Flick steering.

So we give a number of steering input, when the steering is straight or when the steering is Off-Center away from the center. This is what we are looking at. We are also going to going to look at the vehicle Lane changing that is single lane change. So in other words if the vehicle go straight and then does a single lane change or what is called as double lane change.

So you go straight due to some reason you have to take a sudden severe lane change okay because of some obstacle here okay you have to do a double lane change so this is what we call as lane changing. Cornering- Circuit driving, circuit driving is very important there is a circuit and how do you-- you know travel in that circuit. Next time when we when you watch this formula 1, car racing you look at how actually drivers drive their vehicle; this is very, very important.

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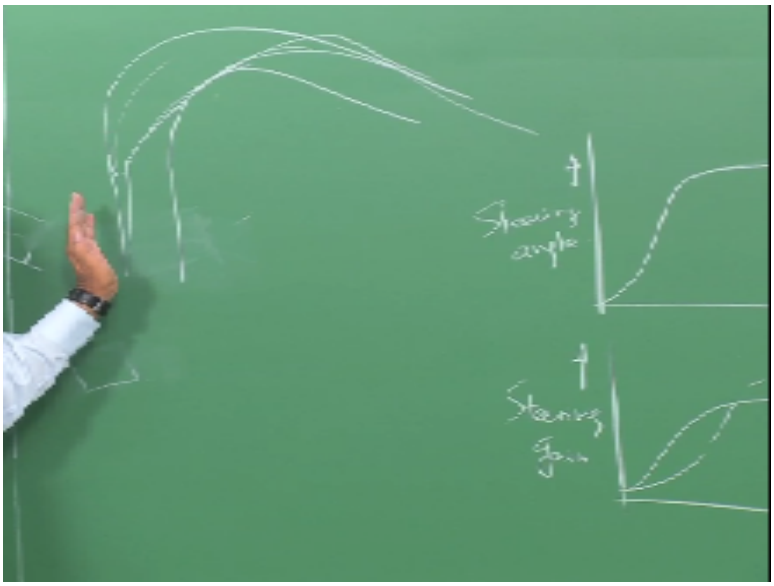

For example, if you let us say that there is a sharp corner length there are number of things that driver has to do in order to efficiently, a least time with least in a risk and so on they have to take a turn. They have to what is that they have to do, actually start breaking they have to start braking. Okay. At what distance I want to brake, okay how are they going to hold the pressure okay then where do we they take the turn.

What do they do is what usually it is called as Apex hitting. So they will not go like that so they would go like this. So they would heat apex and go. Okay. In other words, as far as possible these drivers will not take a large or a small curvature of this or small-- large curvature or small radius they will not take it. As long as, as far as possible they will go like this and you would also see that in any of these formula cars or racing cars they would go out and come down, okay.

You would see next time when you see you see that that is because they want to hit the apex okay brake hit the apex and then power on when-- as they come out of corner there will be power on. So there will be a power off, power on okay and then get into the straight line. So it is very important that one understands this is what we meant by cornering, okay.

So what happens when I power on and power off in a turn, okay and what happens if I brake in a turn, okay and I hope there is no rollover propensity. We will talk about rollover propensity in the next class but this very important, right. And we are not going to talk about Ride now, ride is what is called the primary sorry not drive ride primary ride-- mistake this ride and secondary ride and impact ride, okay these are the 3 things that depends upon the we will talk about that later.

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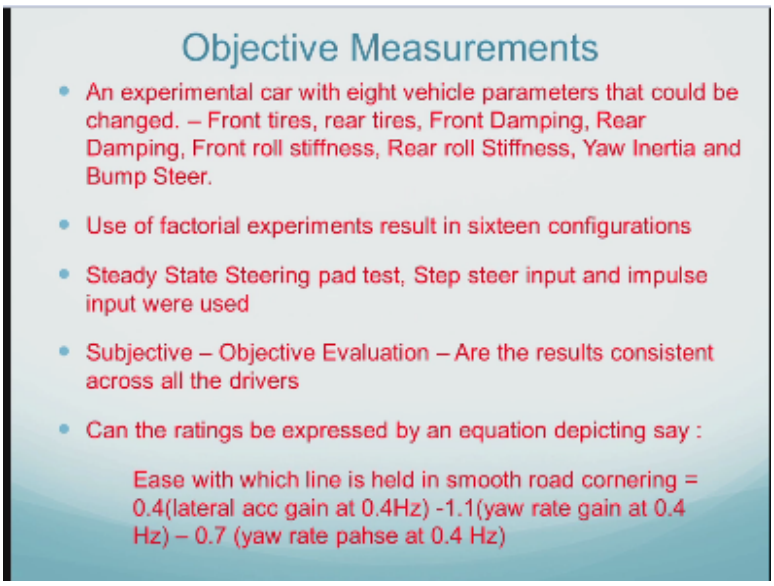

So this with this subjective rating Corolla and his group, okay they did the University of Leeds they did a number of test. The whole idea is to understand what are the questions that you have to ask the driver, okay; what are the-- in other words-- what are the questions which are related to certain matrix, okay of the car, right and what should be the optimum range of this matrix. So this is sort of an objective of this whole study. Okay.

So what is more important what is very important what are the type of questions that you are going to ask. So in order to do that what they did was very interesting very elaborate study done with the help of MIRA. So-- you would see that the changed 8 vehicle parameters, they change front tire, rear temping, front damping, rear damping, front rear roll stiffness, rear roll stiffness, yaw inertia and bump steer and all these things they changed in the vehicle, okay.

So they get different you know ,16 configuration 8 vehicle parameter they changed it and they got 16 configuration. In other words, they had 16 vehicles with various parameters, okay which are these are the parameters that they changed. Then they did test, okay what is called Step steer test they which a J turn test which they give steering hold the steering then they did an impulse test and then a steering pad you know they went around and so on.

So ultimately they wanted to know whether it is possible to relate the objective question. For example, if there is a question like each with it lane is held in smooth road cornering, okay if this

a question; they wanted to know whether this can be related to matrix like lateral acceleration gain at 0.4 hertz. Yaw rate gain at 0.4 hertz and Yaw rate face-- sorry there is a spelling mistake again at 0.4 hertz.

So in other words they wanted to relate the matrix which is a vehicle characteristic with a question answer, right. **"Professor – Student conversation starts"** Is that clear, any questions? Right. Now, the first thing you may ask is what happened we have left that Mimuro model in the air. What is the subjective-objective evaluation of Mimuro model you know where do we stand. Very important question, so the first question it was answered here.

Why is Mimuro model is important because there are only 4 parameters. You see that in this study the parameters increase, 4 parameters are easy to study, okay. So what happens is that subjective evaluation correlate well with these 4 matrixes that is the first question. Right, okay we will look at. And (()) (27:57). Yes, there are whole set of statically techniques is used. Okay what is called as regression analysis and so on. Okay.

When I am going to details of it I will give you the reference look at the reference very nicely written, okay. Right, so you can look at the references how it came up with it. Ultimately, did they come up with this and what is the driver – see one of the major problem here is that they had a number of drivers remember right 7 drivers, so that drivers have to agree, okay. It is-- there was substantial difference between the drivers, okay there inputs.

Because it is subjective rating the drivers you know that is why we have 7 drivers and if the group is not well behaved then there will be difference between drivers themselves, one guy would say that each with lane is held in a road cornering this again sale of say 1 to 7, he may give rating of 3 another can give a rating of 5, okay and the average maybe 4 but the range maybe very large and so on.

Right, so there has to be a number of statically measures that has to be introduced given in the thesis. But in the objective evaluation we are going replacing that with proper balance. Yeah, exactly that is what I am going to see now. But does it have-- see subjective evaluation is as I

said is a ultimate because whatever be the objective numbers, okay you should feel that the car is good that is what we call subjective evaluation. So in objective evaluation we had 4 nice matrix; Do they will really correlate with the rating by a driver, okay that is what we are looking at. **"Professor – Student conversation ends"**

For example, we said that the Mimuro rhombus is bigger better; is it really better, can I get some cars and drive it with various Mimuro matrix, various Mimuro and say what you are doing that is what is done here. So I have now 16 cars, what-- what Mimuro for example was to take a 20 Japanese cars and showed that this 20 Japanese cars had really a good correlation the handling of this 20 cars had a good correlation with those 4 matrix this is what he said. But this study here again wants to confirm whether that really works.

Right, so that is very interesting that is interesting part of the study. **"Professor – Student conversation starts"** Do you understand? Any questions, yes. Sir, we consider that bigger the rhombus better the part the why we (()) (30:43) Exactly, is that true? That is what I am telling just wait for a wait for some time okay then I will take the questions. Sir, what is steering pad time?

So you have a steering pad in which you give a constant steering and go in the circle in a circle, okay just go like that. There is a steering pad where the circular path which you follow. Okay. **"Professor – Student conversation ends"**

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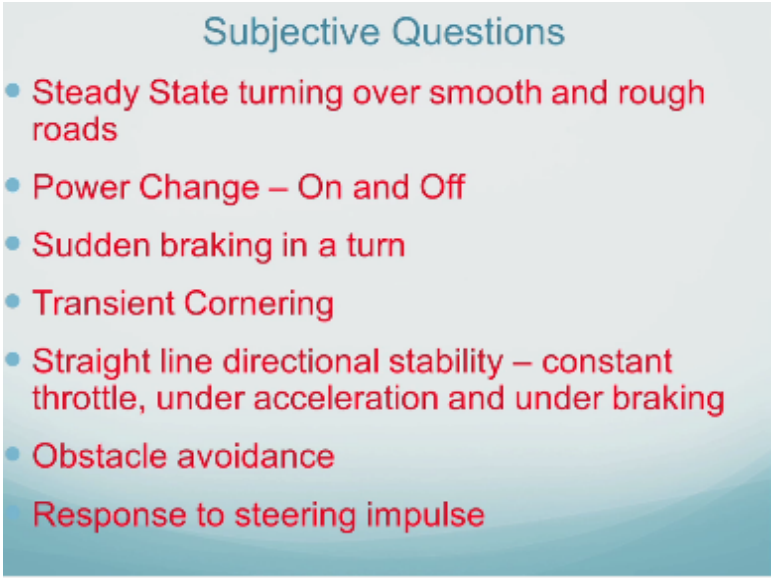

So these are the things we have already seen that Steady State turning, Power on, Power Off, Sudden braking, Transient Cornering these are the subjective question, subjective questions were based on all these things, we have seen this list already.

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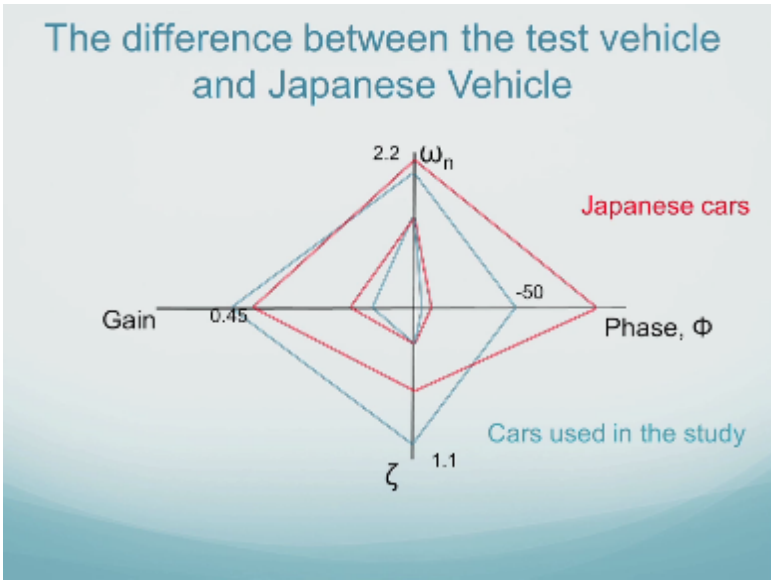

Okay, now comes to the interesting part. The first thing he did was to check whether this Mimuro model okay which is Mimuro rhombus is good to give us a clue about driving. Okay. So remember that there were cars tested by Mimuro and that is there in that red-- redline indicates the range. In other words, between the 2 redlines-- say for example all the Japanese cars which was tested by Mimuro were between those 2 lines you know this is the least and that is the biggest, okay.

So all these Japanese cars were between those 2 red boundaries, right and when a Chen who did a PhD in this group Ash when they got these cars tested for the Mimuro rhombus there Mimuro rhombus which is depicted in the blue where between this boundary and this boundary. Okay the first very first thing that you see here is that the Japanese car had more understeer characteristics, okay.

So when I go to the right that side more understeer characteristics when come back to what was tested by the Leeds group which had more oversteer characteristics, okay see the complete difference. Okay, then the next question you would ask is-- see these cars where you know an experimental car these guys are doing their PhD so they had experimental cars. Okay. So there experimental cars are oversteer okay the Japanese cars you say are understeer cars okay.

What about European cars for example, okay. How much are they understeer or oversteer where do the actual European cars fall in this Mimuro model, okay. In other words, practically where do they stand? Interesting, they did that. So this is where okay the 2 cars fall between what is been done by Chen the European cars and before that we will let compare that. So this is where this is what is the difference between the European cars and the Japanese cars. Okay the range of the European cars where much less, okay what is been tested then the Japanese car.

In other words, what it simply means is that what the experiment that they did the Chen and as there experimental car even when compare to the European cars had much more over oversteer characteristics. **"Professor – Student conversation starts"** Both are similar? No, no, no. See this is between the Japanese car and their car okay they had oversteer and Japanese car understeer characteristics. The European cars do not have that kind of understeer characteristics like the Japanese cars which was tested. Okay.

But they still do not have sort of its more towards the neutral steer they do not have as much oversteer characteristics as was tested by this group. Okay. So clearly oversteer characteristics of the car tested where much more much more for the study. Okay. Now, so they asked these

questions, what are the questions for which there was a correlation? Okay, do you understand this graph? Any questions? Why we are different from the car (()) (35:43)?

I mean that is the design. This is not a question of country there is no generally tested you know; Japanese cars have that kind of understeer characteristics. Okay. That is the philosophy, right. The more important question is which we are going to ask is what makes them like this. What are the characteristics of the car which makes Mimuro rhombus like that. Do you understand?

So this is what is been observed, observed when we take-- I think about 6, 7 the European cars and then they tested they take 20 Japanese cars and tested, okay what is the difference between 2, it is this. But that would have been put into them by their manufacturers right they should (()) (36:33) some logic, right? Yes, this is put by the manufacturer so the one car is different from the other. **"Professor – Student conversation ends"**

So maybe you can say that the understeer characteristics of the Japenese car are more which means that much safer especially when you drive fast and so on, right. So it is a question of philosophy of the car designers, okay. So that is we are not-- what we are going to do, is we are going to answer your question by looking at an optimized car, okay.

Let me not go that side let me go this side. Please understand that we are still we-- this is theory this is objective, okay. The more important questions you should be asking is, do people like Japanese cars or do people like European cars, okay we are live so still I do not want to answer that question, okay but which car is better from a subjective evaluation that is the more important question, right.

So this is an objective evaluation. And I am not going to answer that question I am not going to talk for one car or the other. Okay. That is not my intention. I am saying that ultimately that is what you should be asking. **"Professor – Student conversation starts"** (()) (37:52) No, that is exactly the point okay. That is why we have expert drivers for subjective evaluation. It is not a question of who is driving okay.

If you are driving-- when we talk about subjective evaluation that is why I repeatedly said that we are not driving at 40 kilometers per hour in our Chennai roads that is not the issue. Okay, we are talking about driving at the limits we are talking about--That is why I gave all those conditions here. So it is not a question of who is driving, okay. So when we say when we talk about subjective evaluation we are talking about expert drivers.

We are not talking about Novexx drivers. Okay drivers who understand cars who is being doing this for a long time. (()) (38:36) Absolutely, but it is usually felt that if there is a expert driver who feels that it is good so that is why you choose an expert driver okay in such a fashion that you test a car and he test the car is the same feel is the same, of course you are free to choose whatever car you want when I am not advocating for you to by this car or that car.

You know you go to showroom get a car that is why you have cars for test drive and you buy a car you know. That is your will and your pleasure and your money that does not matter. Okay, we are talking about a subjective evaluation is an by expert driving. Yeah let us go ahead. When we bought this plot there were number of perceptions right, is it all are subjective question? Exactly, that is what I am going to come to.

Can you wait till I finish you know then you ask questions. so that I understand, I understand you have lot of questions, can you just wait I am going to answer all your questions or these guys are answer all your questions so wait, right. **"Professor – Student conversation ends"** So the first thing is whether the drivers felt that this Mimuro rhombus as it expands okay the car becomes better.

There was a small I would say error in what they have said. Mimuro in his paper in fact very clearly said, I think I have paper here with the clearly states that the face angle 5 right is better okay. So in fact you would see that I will just reading that statement. The right access denotes following controllability the smaller in other words to the right is better. So smaller is not by magnitude it is not -80 is small than 0 that is fine.

But he has very clearly said that the smaller that means to the right is better. But there is a small confusion in what Chen and Ash has said and what is been said in this paper by Mimuro, okay. So first thing is that whether the car straight steer and the drivers input how did it correlate with expanding the Mimuro rhombus; that is the first question, right. That is very interesting. Okay.

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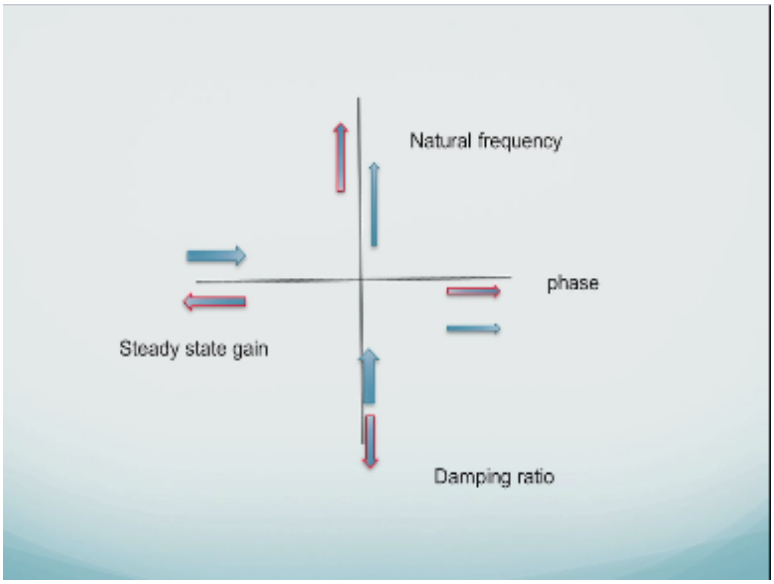

Now, this is what happened. The red ones are by Mimuro as you move away like that from the center okay they agreed. The blue ones whereby the Chen's group okay. In other words, there was a small difference there is a difference between what is been said by Chen-- one second just. I will just give you the-- I hope giving you the reference.

If you want you know you can also look at this reference subjective-objective assessment of vehicle handling and performance by Corolla in Seoul 2000, FISITA World Automotive Congress. I mean there also you can see what I am talking to you about. Okay that is the reference. Okay, now you can look at that-- so there is a difference, now in other words is—is Mimuro is saying this, is that is the question.

Is it that when he said that I want steady state gain to increase in order that the car should behave better was contracted by saying that this by this group that it has to be less, is there a controversy or is there a difference? No. The most interesting fact that comes out is the-- that the that is what

I presented some time back the type of characteristics of the car tested by this group more oversteer, okay but the car tested by this guys I repeatedly said by Japanese is understeer.

In other words, the sentences that it is not there is a monotonic increase, okay of this parameters. It simply means that there is a range, okay an optimum range which would give you the best performance. Okay. So if you want to design a car it should be an optimize it is not that I can keep on increasing the Mimuro rhombus from the steady that is what you get. Okay. It would become better.

It was better from Mimuro basically because that the cars he was testing had that characteristic, so slightly better it become better. But, when you test a car with a completely different characteristic then this statement may not make a meaning.

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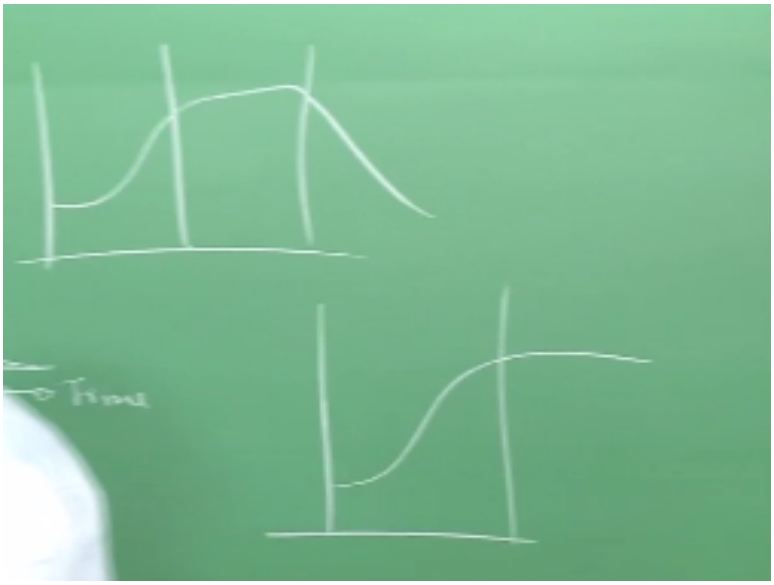

So in other words, there is always a range a range in which the driver is going to feel good okay or in other words his subjective evaluation is going to increase because it is a range. And maybe it is a range or maybe it is a value where after a certain value he is going to say it is better. Okay, right. So what this group did was to expand this; 4 they wanted to make it 8 and so on, expanded. Okay.

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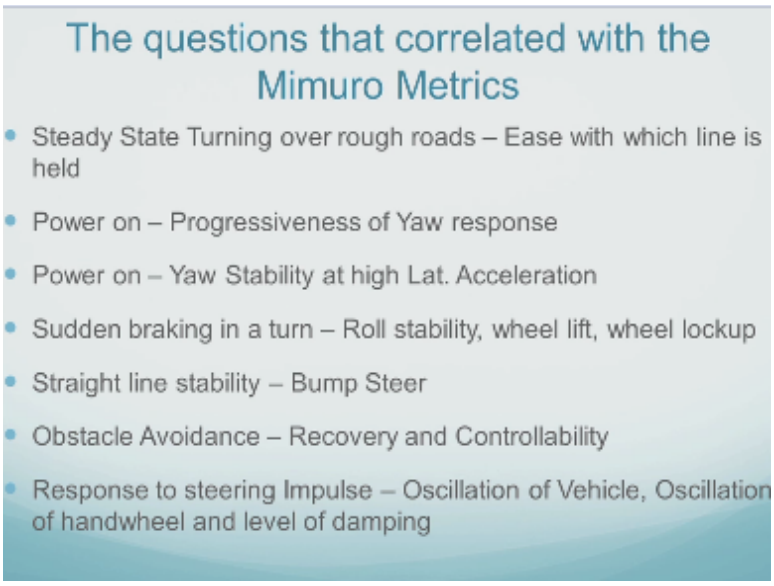

So there were a number of questions which I am not going to go through this now but there are number of questions which actually correlated with Mimuro matrix. Okay. Look at the paper.

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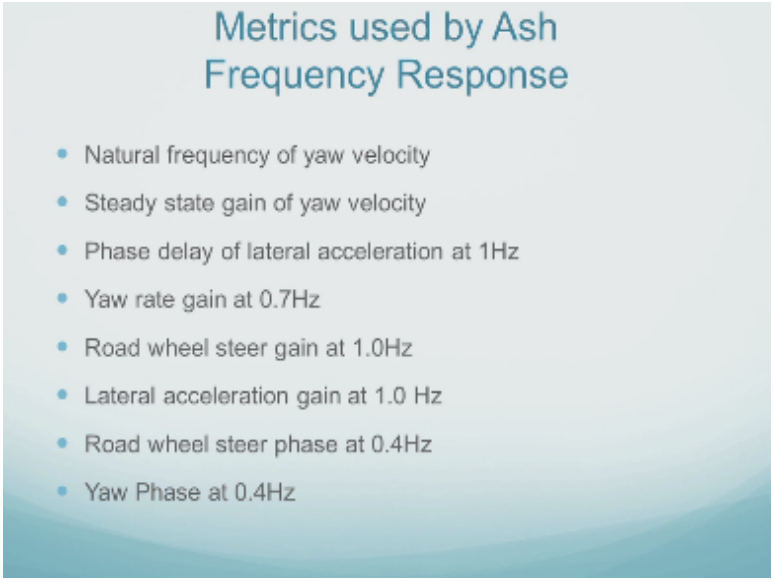

We will come back to this but we will. So what this people did was to expand the matrix okay instead of 4 they started using-- in my opinion 4 is very good the correlation is been good but if you want to more closer interaction with the subjective rating then you can expand that matrix. So for example natural frequency we have asked, steady state gain of your velocity, Phase delay at 1 hertz is fine. Then they introduce also Yaw rate gain at 0.7 hertz.

Road wheel steer gain, road wheel is steering wheel to road wheel okay the road wheel steer gain at 1.0 hertz. Lateral acceleration gain at 1.0 hertz. The road wheel steer, steering of the road wheel okay the phase of this road wheel steer at 0.4 hertz. Yaw at 0.4 hertz. Okay. So these are the further matrix that was added as far as the frequency response is concerned. So they expanded the matrix, no more 4 guys who are going to form a rhombus.

Okay, so numbers are increasing. These are the vehicle parameters which correlate with subjective rating okay. In other words, when the vehicle is driven straight or whether when it takes a turn when you break during cornering all those things are affected by these parameters. Okay.

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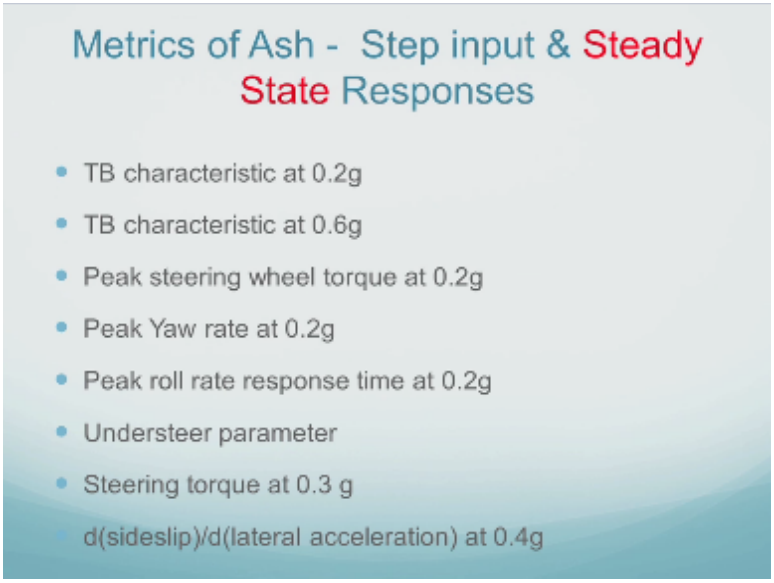

Apart from that, you know other further matrix are we will talk about TB characteristics at 0.2g; TB characteristic at 0.6g, Peak steer velocity torque at 0.2g; what is the velocity torque Peak steer.

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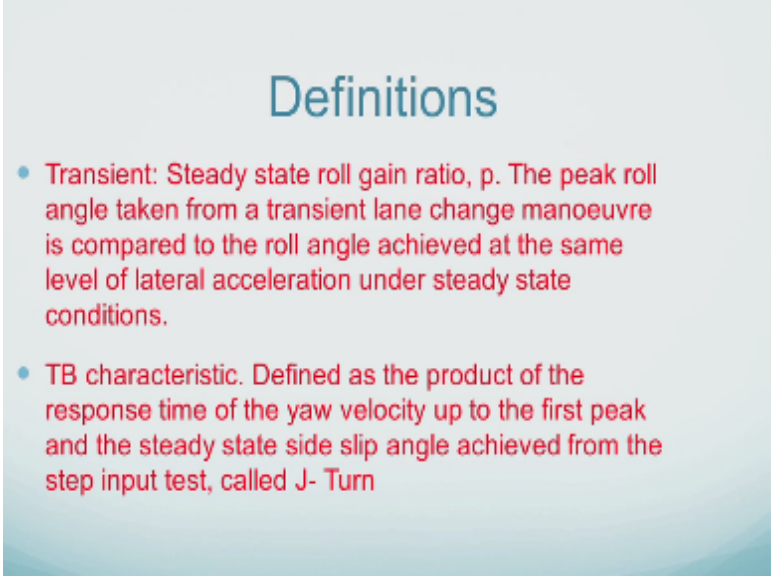

TB is -- what is called as the-- you know, defined as a product of the response time of the yaw velocity is quite involved, okay. Just read this, define as the product of the response time of the yaw velocity to the first peak to the first peak and the steady state slip angle-- it is a product and the steady state slip angle okay achieve from the J-turn test. Okay. Things are becoming complex, right so the numbers are increasing, right. Okay.

So TB which is a product of these 2 things time and the slip angle at 0.2g when you take a turn or when you take a J-turn okay and when the acceleration is 0.2g what is TB characteristics. Then, 0.6g which means that you increase the velocity and take a turn so that the lateral acceleration that you have achieved is 0.6g. Peak steering wheel torque, okay. Peak yaw rate at 0.2g, Peak roll rate response at 0.2g, understeer parameters K understeer gradient, steering torque at 0.3g then these D slip/D lateral acceleration at 0.4g. Okay.

"Professor - Student conversation starts" The next question, Oh god! List is becoming okay-- we will losing track, Next question is which is not been answered is why are we looking at these things, okay. Who told you or what is the logic of suddenly coming and telling me that TB characteristic at 0.2g or Peak yaw rate at 0.2g has a correlation with vehicle performance. We are saying that these things are important for vehicle performance. Okay. **"Professor - Student conversation ends"**

Why is that, 0.2g; why is that steering torque at 0.3g is important? Why is it that you are looking suddenly at Road wheel steer gain at 1.0 hertz? Okay, and why is that we are looking at other things like D slip angle/D-- that is the slope of the slip angle to lateral acceleration at 0.4g taken at 0.4g. **"Professor - Student conversation starts"** Why are they important? Not clear? Sir, but the bases we are choosing was from the statically study, right?

Correct that is all. It is a question of curve fitting if-- when I have these parameters when drivers answer at questions okay number of questions and when they agree when I look at these 2 things okay looks like these are the parameters which are affecting. Okay. This is an open research yet. Why it should be at 0.6g may be different. Okay. So this is actually an open—

Yes, it has a science because you look at some frequency response at this position and so on. But I would say that still it is an open thing it maybe-- I mean there is still lot of scope to understand this. That is what makes one car different from the other. Okay. So the interesting point is this-- we close this--**"Professor - Student conversation ends"**

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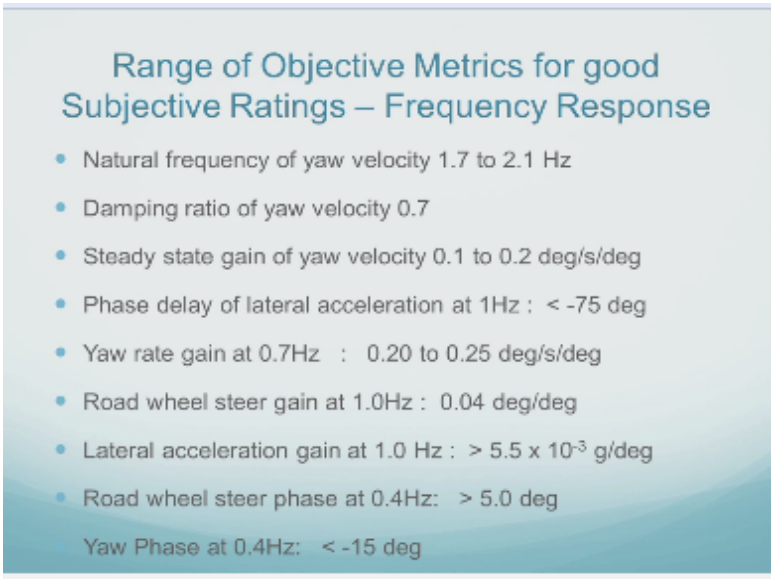

Ultimately, we come up today's class with this. So ultimately we come up with the range of objective matrix for good subjective rating. So in other words, if you want to design a car and if you want to this to be approved by expert drivers hopefully the customer will follow the expert

drivers then how do you design the car? That is the question, right. So I will design a car with a natural frequency of yaw velocity between 1.7 to 2.1 hertz. Okay.

Looks like if this is the range people are happy, right this is the range that is what I said this is the range, when the damping Yaw ratio I mean damping ratio of Yaw velocity is-- I do not have that figure but I will get that. So steady state gain of yaw velocity 0.1 to is between 0.1 to 0.2 degrees per second per degree; Phase delay of lateral acceleration at 1hertz is < -75 degrees, Yaw rate gain at 0.7 hertz is between 0.2 to 0.25 degree per second per degree.

So you have—I will just leave this maybe next class we will again go through this. You see that each one of them has a range a < or approximate values. Okay. So that is the important of the study that it gave a sort of numbers for designers. What should be your aim, where should you stand if you want to get a good car whose handling characteristics are good, okay. So that is the important of this study.

We will continue this in the next class, we will look at questions and these things in the next class.