Traffic Engineering
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Lecture 48
Traffic Simulation-I

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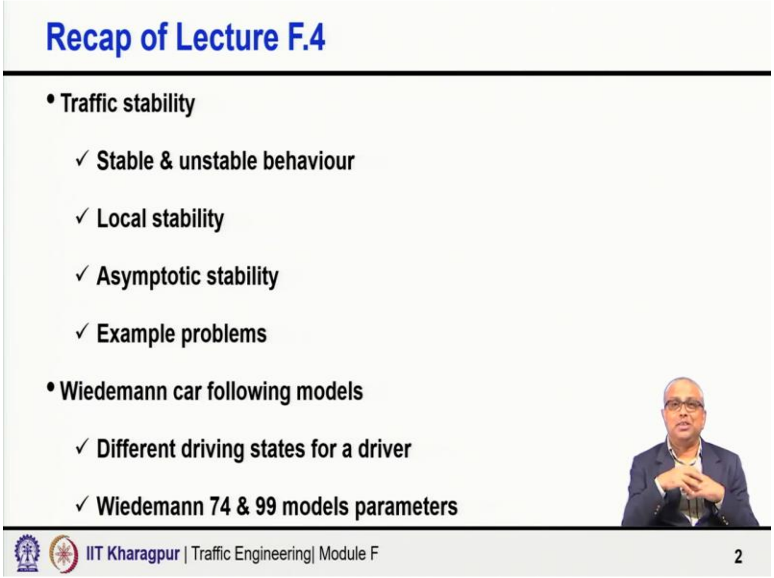

Welcome to Module F, Lecture 5. In this lecture, we shall start our discussion about Traffic Simulation and we only have three lectures in this module under Traffic Simulation. In Lecture 4, we were discussing about the traffic stability, the stable and unstable behaviour, local stability, asymptotic stability and then also took some example problems to show you how really the data can be analysed and the stability can be observed.

And then, before closing, we discussed about briefly about the Wiedemann car following model which is very popularly used in several micro-simulation platforms. What are the different states for a driver that are assumed as proposed by Wiedemann? And then a very very brief intro to this Wiedemann 74 and Wiedemann 99 model parameters.

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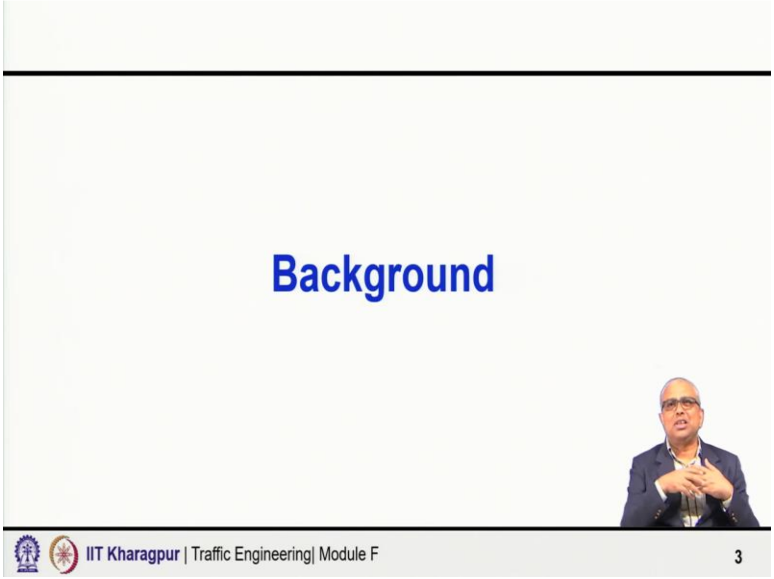

With this background today, now, we go to a different topic that is traffic simulation and today's lecture is essentially some of the elementary aspects of simulation. What is system? What are the different ways systems can be analysed? And starting from that going up to what is traffic micro-simulation and so. And then the next two lectures will be specifically focusing on traffic micro-stimulation.

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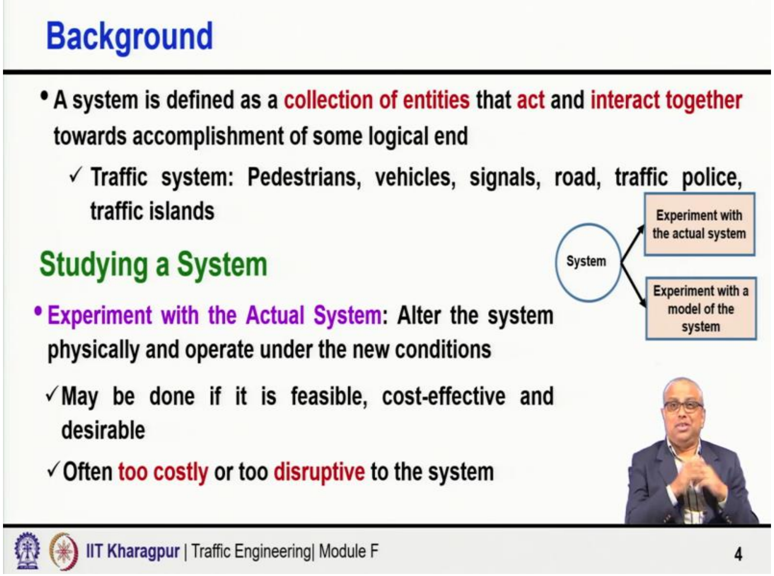

When we are talking about the simulation, basically we are trying to somewhere or other trying to analyse the system. So, it starts, the discussion should start with then what is the system? There are many ways a system can be defined. I have mentioned here is a simple way of defining the system like this, a collection of entities, a collection of entities which act or interact together towards the accomplishment of some logical end. Very simple way of defining the system.

So, it is a collection of entities not one but multiple entities, individually and collectively, that is why this thing: they act and interact together individually and collectively. Through interactions they help to accomplish some logical end or collectively they achieve some objectives.

So, that way also you can say: entities or activities meaningfully connected and individual and collectively they achieve the goal. So, multiple entities, individual and collectively they work. They interact with each other and then finally, accomplish some logical end or achieve the given goal or objective. We are essentially talking about traffic system in this course because this is a course on Traffic Engineering.

So, if we look at the traffic system, yes traffic can also be considered as a system and in fact it is a traffic, it is a system which includes several entities like pedestrians, vehicles, traffic signals. You have road, you have traffic police, traffic island are there or channelization there to channelize movement. So, all these together, they include traffic system and every individual entity is playing a role and collectively also they are paying playing a role. And of course, they are all interacting with each other.

A vehicle is moving. Every time the vehicle is interacting with every element of the road and control system. So, interaction exist. Individually they perform, they interact and collectively, they are saying how good or bad the traffic system is working. What is the safety level? What is the efficiency level? What is the delay or emission? So, many ways you can evaluate the performance.

Now, how to study system a system? A system can be studied grossly or broadly in two ways as I have shown here in this figure. One is do an experiment with the actual system. Yes, you play around the actual system or carry out the experiment with the model of the system, not the actual system but with the model, with a model of the actual system.

Let us discuss a little bit about this. Two things, first experiment with the actual system. The real system, with the real system you are doing the experimentation. So, you alter the system physically and operate under the new conditions. Suppose for example, you want to see that if I install a traffic signal at a junction, what will be the impact. So, you physically go and install a signal, design the signal, operate it with signal and then you compare it how it was working without signal and how it is working with signal, and then you know you check how effective it is to install the signal.

But such kind of things may be done under only certain conditions. First of all, it has to be feasible to implement it. Maybe at a junction you can install a signal. Still, it is not so easy. A lot of other works need to be done. Still, you need probably model. But I can, let me assume that you can do it.

But always it may not be even feasible. It may not be even cost effective. I cannot do and take a chance to see the how it works. I cannot you know if it is a large-scale construction or something which requires really a lot of hardware/software or you know expense, a lot of expenses are involved, I cannot do field experimentation unless I have some level of confidence I have that this will work.

Yes, the performance I am saying that delay will be x minute, whether it is x minute or some 10 percent more or 20 percent less that much we can take a chance. We can experiment and see that. But grossly I cannot keep on doing the experiment with the real system. There are other implications. And sometimes it may not be even desirable that you cannot you know let people suffer just because you are doing the experimentation. So, many cases it may not be feasible, it may not be cost effective, it may not be even desirable also.

So, if it is feasible, if it is cost effective, if it is desirable, we can go ahead. We can go ahead with the experiment with the actual system. But as I say, you will find often things may not be feasible. It may be either too costly expensive or too disruptive to the system. A system is working, I cannot go and let me go and construct a traffic island and I will keep on experimenting with the size of the island, the shape of the island and then say based on field experimentation, I will do it. Sometimes that may have safety implication. That will have also implication on the quality of service and it may not be desirable.

So, often, although it is not that we cannot do it, we do it. But often it is too costly or too disruptive to the system. So, the scope of doing the experimentation with the actual system is often limited. What we do in most cases? Suppose we want to see if we provide priority to buses at a given signal, what kind of design is optimal and how it is likely to be effective? We do it using modelling, the other approach, even simulation.

And then finally we may go and when we decide that this is the best one based on my theoretical models which are calibrated, we want to validate it from the in the field, how really it is getting implemented? You may implement take one intersection and try to implement it.

But getting the whole thing only based on field experimentation or experimentation with the actual system may not be very practical because it often may be too costly. It may not be cost effective. It may be disruptive. It may have safety implication there. It may not be desirable. All these issues will be there.

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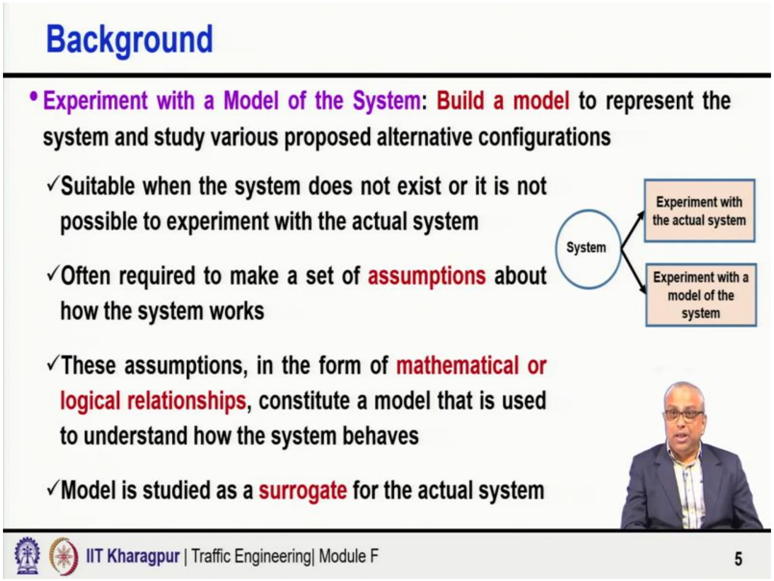

So, alternatives is the other one, experiment with the model of the system. We do not play around the system but we create a model, we build a model to the represent the system and then study various proposed alternative configurations with that model. So, not playing with the real or the actual system but playing with the model of the system. That is fine.

And there we can see different alternatives. You can see if I do a channelization, proper channelization in a signal in an intersection, how it works? If I use traffic signal, how it will work? If I have an elevated corridor or some grade separator, how it is going to impact? Number of cases, number of possibilities you can check, you can evaluate and then you can take a call.

So, the experiment with the model of the system is much more practical, then the scope is much much bigger than what is the scope of playing around the system itself. So, this is suitable when the system does not exist. There could be something that today it does not exist. We are simply talking about a planning stage and we you want to take a call. We have a forecast volume. We know that this is going to be the turning movement and this new road once it is built, this is new junction is going to come up. So, it may not exist today. There could be many other examples. It does not exist.

So, there is no scope that you will play around the actual system or as I said, it is not possible due to some reasons. Maybe too disruptive. Too expensive. It is not desirable because there could be some safety implication. So, either it does not exist or when it exists but experimentation with the actual system is not possible, then this is very good. This is an acceptable alternative. And when we go with this approach like trying to model the system, we often required, we are often required to make a set of assumptions about how the system works, understanding and assumptions.

Because I said multiple elements or entities are involved in the system. Now, these assumptions in the form of mathematical or logical relationship constitute a model and which is eventually used to understand how the system behaves under different scenarios. Remember that a model is studied as a surrogate of the actual system. It is not really the actual system. So, what, whenever you do models, model depends on what we are trying to achieve.

So, accordingly, we shall make assumption and try to build the model, try to capture the relationship using mathematical or logical form. There will be assumptions. There will be approximation. There will be limitation. So, model is not really the actual system but it is, it is studied as a surrogate of the actual system. That is very important. Now, if you go ahead with the model. So, within these two I said what is experiment with the actual system, what is scope and then the alternative is experiment with the model of the system.

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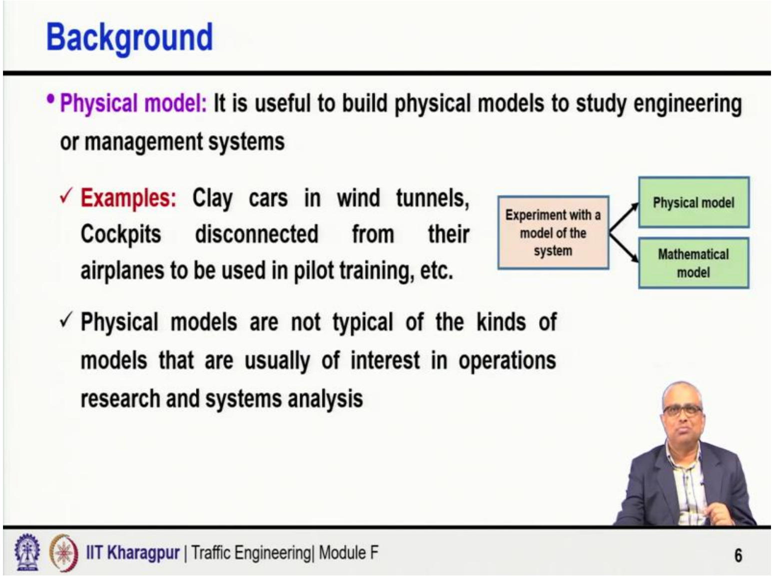

Now, if we go or if we think that we are taking up this, experiment with a model of the system, then again, we have two alternatives. One is either we develop a physical model and work with that or we develop a mathematical model not a physical model and start working on with that mathematical model. So, what is the physical model? We are developing a physical model, a replica we are making it. Physically we are making something. And it is useful to build physical model to study engineering or management systems.

Examples suppose clay cars in wind tunnel. You make model, whole thing is model, not the reality. But we create cars, we create wind tunnels and then you know you see. You can do that also how it works? Rail system, how it works? You can make physical model. Or even a cockpit disconnected from the aeroplanes maybe used in pilot training. You show them a photo but you show them the model also. You go to them and you can even tell them to, go inside and sit there. How the cockpit looks like? How, feel it.

So, that is possible in many ways. The physical model also range is quite wide not just one thing. So, many possibilities are there. Often very useful as well. But remember that physical models are not typical of the kinds of model that are usually of interest in operation research and system analysis. The physical model has its own value.

As I say you want to do training, you want to have capacity building and you want to let people feel actually, many a times when I maybe drawing a sketch in a board, you cannot feel. But when you see the system, physically you see. You understand, you get a better feel of the whole thing. So, it is quite useful. But remember that these are not the models which are usually of interest in operation research and system analyst, analysis. So, for operation research and system analysis, what we do mostly? We go for mathematical model.

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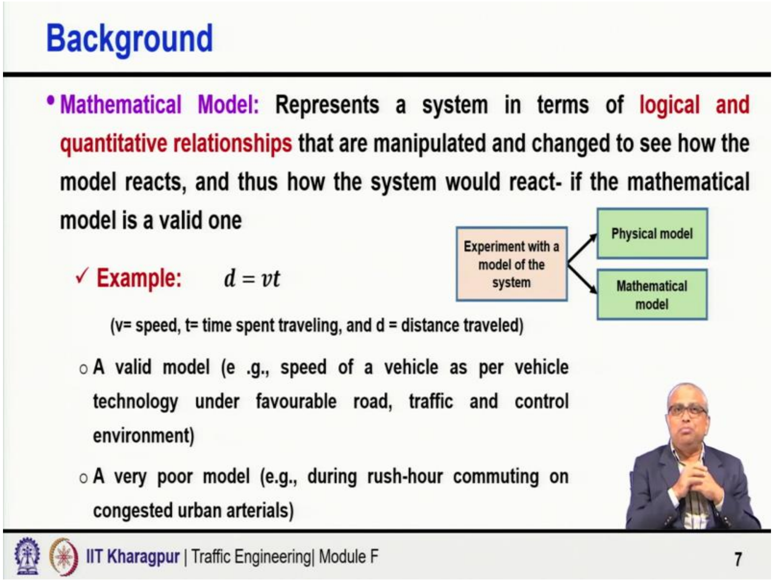

What is the mathematical model? Mathematical model represents a system. It is again, all are representing, trying to represent a system. Physical model also trying to represent a system. So, it is the represent system in terms of logical and quantitative relationship, quantitative as well. Logical and quantitative relationships that can be manipulated and changed to see how the model reacts and therefore, how the system would react, provided the mathematical model is a valid one.

The same model under some condition may be valid, some condition may be valid. It is all what assumption you are making. Where are you applying? The applicability of the model. Any mathematical model, it has his own application domain. I have taken an example here to explain you that. Maybe better examples are possible but I have taken something. Say, this you are all familiar with this d equal to distance travelled equal to v speed of vehicle and then t is the time spent traveling.

$$d = vt$$

Now, what I am trying to show you? I am trying to create scenario where this is a valid model and where this is not a valid model. I am trying to create scenarios to explaining. For example, now if I am considering that v is you have ideal road, control and environment and the speed is only based on the technological capability of vehicle. Every vehicle has got a based on the technology has got a capacity to travel at maximum speed. So, now you consider that the road, control and environment none of the other factors are posing any restriction.

So, I have got a road, maybe theoretical but let us consider it that you can travel at any speed you want. The road side environment is like that. It is safe to travel at any speed you want. You are only restricted, your capacity is restricted by the speed capability of the vehicle. Fine? So, what will happen? If now homogeneous traffic environment, you take a car. Probably yes, that you can cover a distance and v is the speed of the car, speed capability of the car for at what maximum speed it can go. Then d equal to v into t is could be a valid model there.

But now think the same vehicle traveling during the rush hour and on an urban arterial. The speed capability of the vehicle which was used as v in earlier case, and now also again we are trying to use the speed capability. What is the safe speed for the for the vehicle considering its technology? That means a three-wheeler and a car and a track and a two-wheeler, just considering the vehicle as an entity, the safe speed is not safe. So, that that speed I am indicating. Not influenced by the other factors in the first case.

Second case, that is not the only thing. You will have traffic signals. You will have heterogeneity. The volume level itself is high, rush hour. So, the volume is taking away your freedom of movement. You may have to stop at intersections. You never know how much delay it will be. There obviously there will be delay.

So, if I, can I use the same model with the same description of v and d and t? Same speed limit of the vehicle? Because that is getting influenced by other factors. So, if this way I define v, d and t, maybe in the first case it is valid, in the second case, it is not valid because the traffic and control condition is actually going to influence.

And the actual speed on which the vehicle will travel is not actually function of only this speed capability but rather it will get more dominated by the congestion, by the volume, by the roadside, urban environment because it is urban arterial, presence of signals and all other factors. So, the applicability of the mathematical model is very important.

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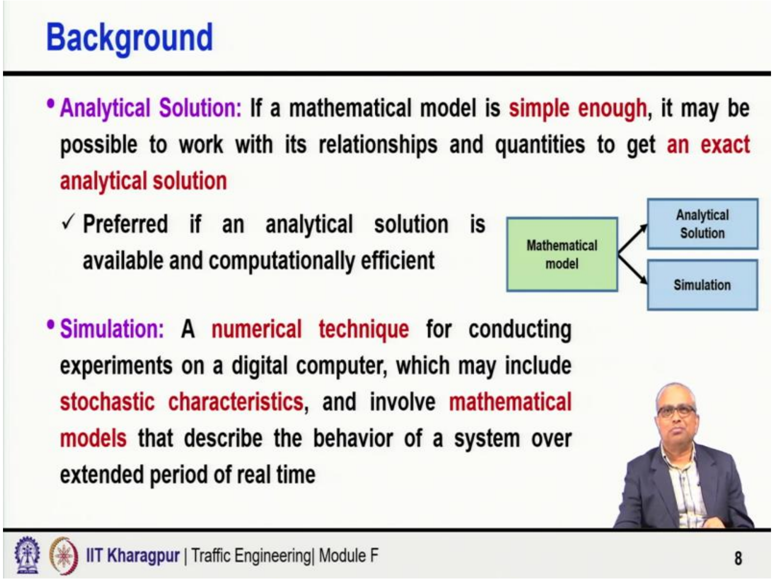

Now, suppose you choose now the mathematical model. For most cases, that is widely used especially for what kind of work we do, we cannot do every experiment in the field because public road and you know unless you are fairly confident about something. Like final field experimentation always will be required. But the whole thing cannot be studied only based on field experimentation. I can do it in the field. The final one once I am confident, I can go ahead and implement it and to test how in real world it works.

But I cannot do the whole experimentation. Every day I cannot go and change something and then keep on experimenting with people because there are safety implications, there are other implications as well. So, suppose we take mathematical modelling. Then now there are two possibilities. One is we can go ahead with analytical solution or we can go with simulation studies. What is analytical solution? If a mathematical model is simple enough, not so complicated, clearly the relationship is understood, it may be possible to work with its relationship and quantities to get an exact analytical solution. You will get it.

And if you get it, if you can get it that means the mathematical model is simple and you can get an exact solution. So, you prefer that we prefer the analytical solution. Why should we go for other kinds of analysis? So, it is preferred if an analytical solution is available, and if it is computationally efficient, go ahead with that. If not, often it will not be so, so in that case we go for simulation studies. So, what is simulation?

It is a numerical technique for conducting experiments on a digital computer which may include stochastic characteristics and involve mathematical models not one model but probably multiple models. You have so many entities. There is relationship, inter-relationship. So, overall, how the system output will come, it depends on not one relationship. The multiple things are involved and the stochasticity is involved in the process of it. So, to describe the behaviour, as I say, a numerical technique for conducting experiments on a digital computer which may include stochastic characteristics and involve mathematical models that describe the behaviour of the system over an extended period of real time.

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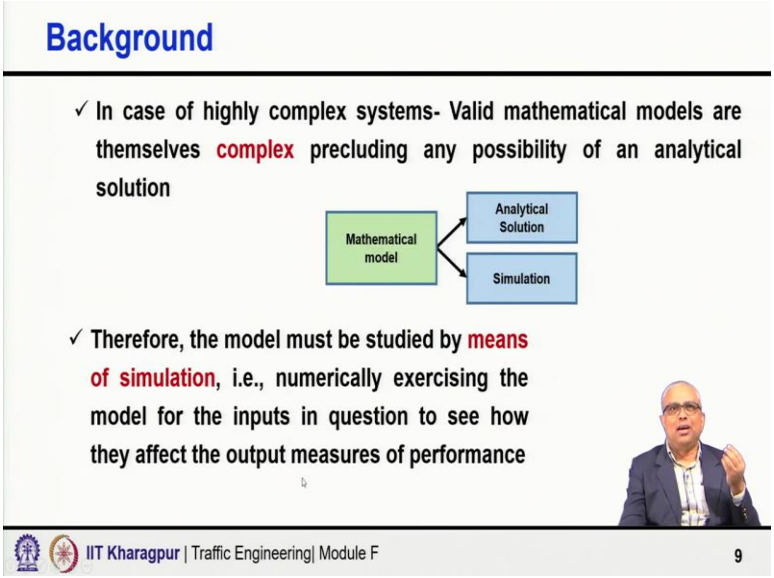

And in case of highly complex systems, like the traffic system, so many entities, so many things. Everything interacts with all other elements. Over all a complex process. Just you cannot express the whole thing using one simple mathematical equation. as we often try to, what we expect in case of analytical solution.

So, in case of highly complex system, valid mathematical model themselves complex, are themselves complex, precluding any possibility of an analytical solution. So, the model must be studied by means of simulation. That is numerically exercising the model for the inputs in question to see how they affect the output measures of performance.

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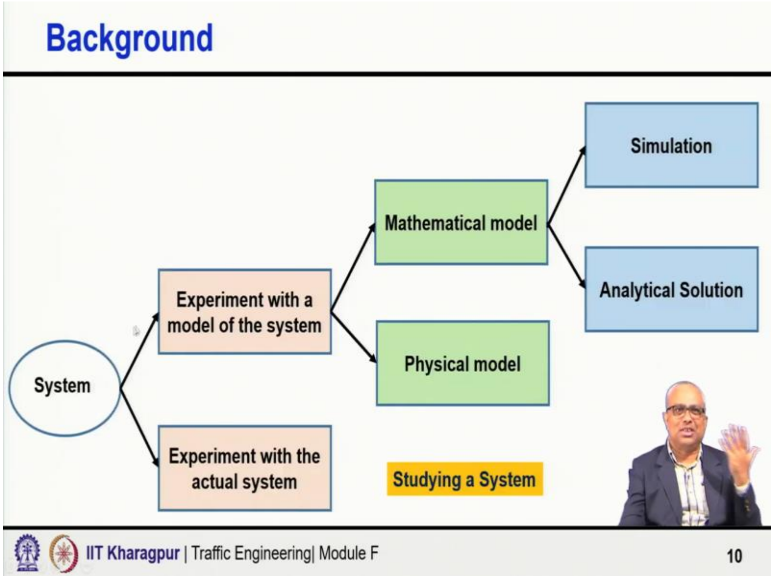

Now, the whole thing I have shown here. The system can be analysed by doing actual experiment with the system or by developing a model of the system. If you develop model, then you can develop a mathematical model or physical model. If you develop mathematical model, then again it could be analytical solution or you can simulate and get the solution. So, it may be simulation model. That is what it brings the context of simulation. That that is the path we wanted to travel quickly.

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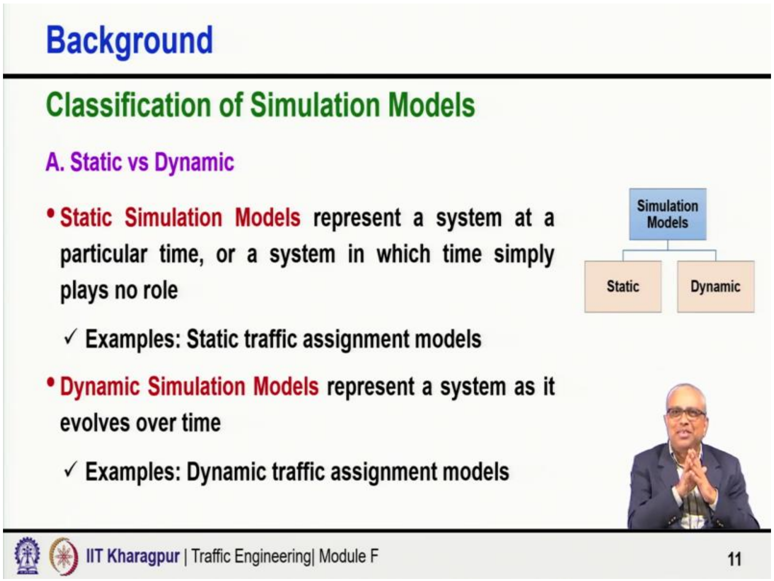

Now, classification of simulation model. Simulation model may be static or dynamic. That is one way of looking at it. Static simulation model represents at a particular time or a system in which time simply plays no role. It is not a function of time. Either the way we are analysing, our time is not important. We are ignoring that or quite the simple time does not play any role. For example, you have studied traffic assignment model and several traffic assignment model which we can call static traffic assignment models. You are analysing the peak hour traffic state.

So, the peak hour volume is this, road is this and then capacities are these, travel times are this one so forth and you try to get then what will be the equilibrium flow. It is an example of static model. We can even simulate also. We often use many iterative procedures where you can use as well simulation. So, that is static simulation model.

Dynamic, dynamic over time. So, represents a system as it evolves over time. With the same example of traffic assignment, what we try to achieve when you use dynamic traffic assignment models? We are trying to see how the whole thing changes because what has happened at time t will have impact on what is going to happen at time t plus delta t. So, the traffic starts building right from 6 o'clock, no traffic. It starts going up, going up. 9 o'clock, a 10 o'clock, maybe maximum, then it comes back.

So, every interval the way and any intervention we take, it will influence the whole behaviour of traffic, behaviour of vehicles during this entire period. So, altogether what is happening in traffic t is very important because that also dictates, that also influences the behaviour at time t plus delta t. So, time is very important. Time clock is very important. So, dynamic simulation model represents a system as it evolves over time and as I said the example could be dynamic traffic assignment model.

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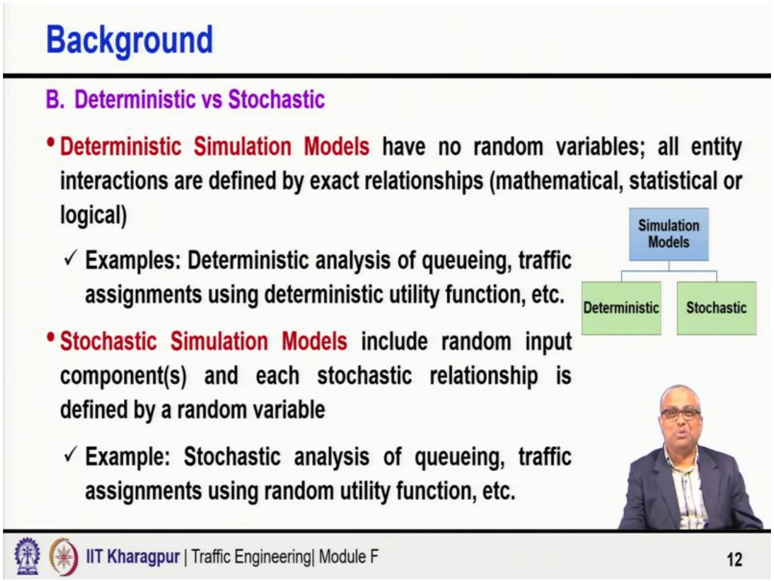

Another way of looking at the simulation model as deterministic versus stochastic. You are again familiar with this term. Again, I have taught you in urban transportation systems planning course when I talked about the traffic assignments. Even the concept of mode choice also it was there but the traffic assignment is a very perfect place where the simulation is used heavily, most appropriate to use simulation.

So, again, the it could be deterministic or stochastic. What is deterministic? When we have in the model no random variable. Only you are using deterministic variable. So, all entity interactions are defined by exact relationship. That relationship method maybe mathematical logical or statistical. But exact relationship is known and there is no involvement of random variable. So, then if we are simulating the whole process, where there is no random variable, we will call it deterministic simulation model.

So, example could be deterministic analysis of queuing. I have taught you in Traffic Engineering course that queuing analysis you can do. Deterministic analysis you can also do, stochastic analysis. So, that is the deterministic analysis. If we are trying to use simulation under the same umbrella, it will be deterministic simulation model. Or think of traffic assignments using deterministic utility functions where there is no random component. The true utility is known and that true utility you are using to your traffic assignment assuming some equilibrium, target equilibrium.

On the other hand, it could be stochastic simulation model. Obviously, the fundamental differences such kind of models include random input components or components and each stochastic relationship is defined by a random variable. And obviously, when there is a random variable, there is a distribution as well. Random variable we always express using a distribution. It follows certain distribution.

So, again the example could be as I said there, deterministic analysis of queueing theory. Here it could be stochastic analysis of queuing or as I have said, the traffic assignment using deterministic utility function. All the traffic assignments you can do. You can simulate using random utility function. That means where the true utility is the deterministic component of utility plus an error which is a random variable, follows certain distribution. So, that is one.

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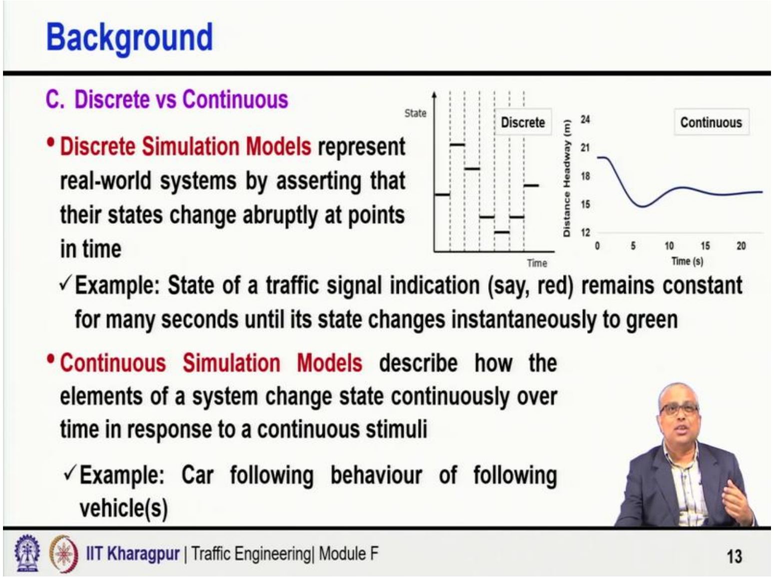

Another way of looking at it is discrete versus continuous. So, discrete simulation model represents real world system by asserting that their states change abruptly at points in time. Very simple example, I will give. State of traffic signal, say red, remains constant for many seconds. Then suddenly it changes to green. Or it remains green over a time period, then suddenly it changes from green to red. So, whenever it is green, traffic is discharged. When it is red 0.

So, discrete state. It could be continuous simulation model describe how the elements of a system change continuously over time in response to a continuous stimulus. Very simple example. I can, there could be many examples, maybe more appropriate examples are possible but I am trying to tell you something which you can easily connect relating to this course, Traffic Engineering course.

I have taught you here itself, in this module, about the car following behaviour. So, if you are using a car following model and then trying to get the distance headway as the time at different times and trying to plot it to check probably the traffic stability. I have taken the same graph. That is a continuous simulation model. I can simulate and get it from simulation output.

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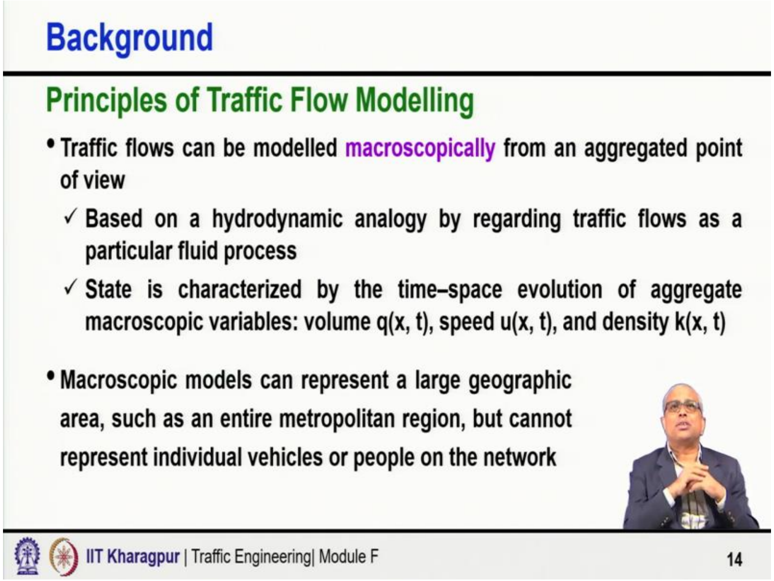

Now, let us quickly discuss about the principles of traffic flow modelling. Traffic flow can be modelled macroscopically from an aggregate point of view. Macro means overall. So, based on hydrodynamic analogy regarding the traffic flows as a particular fluid process and state is characterized by the time-space evolution of aggregate macroscopic variables, you know very well: volume, speed, and density.

So, overall macroscopic characteristics we are taking. Stream as a whole represented by volume, speed, density. And all these are function of x and t, location and time, it changes. Macroscopic models can represent large geographical area. Macro means we want to analyse a larger geographical area. Maybe the whole, the whole metropolitan region.

Now, obviously, the gross level, overall level, at a macro level, analysis is more appropriate there. So, it can represent the entire region but cannot represent individual vehicles or individual people at individual road element like at a particular intersection exactly what is happening. That kind of things are not of interest to us. Then we can use macroscopic analysis.

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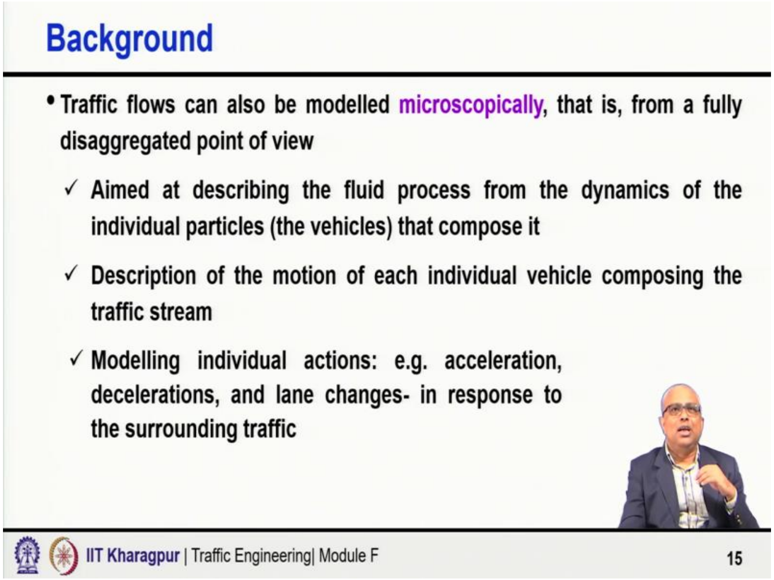

It could be analysed microscopically. Micro so that means, fully disaggregated point of view, detailed one. So, obviously now, we cannot think of the whole urban area or metropolitan area. We are interested in a specific corridor, a specific interaction, intersection, a specific intersection and so on.

So, aimed at describing fluid process from the dynamics of the individual vehicle or the vehicles individual particles and in this case, we are drawing an analogy. So, it is vehicles that composes it. So, description of the motion of each individual vehicle that is composing the traffic stream. So, modelling individual actions we are doing. How vehicles, each vehicle is accelerating, decelerating or lane changing in response to surrounding traffic.

Those are the micro-level, detailed-level, how exactly vehicle is taking turn in an intersection and then how the intersection geometry can influence that behaviour or how the behaviour is getting influenced by the intersection geometry, micro-level. So, this cannot be applied for the large-scale network.

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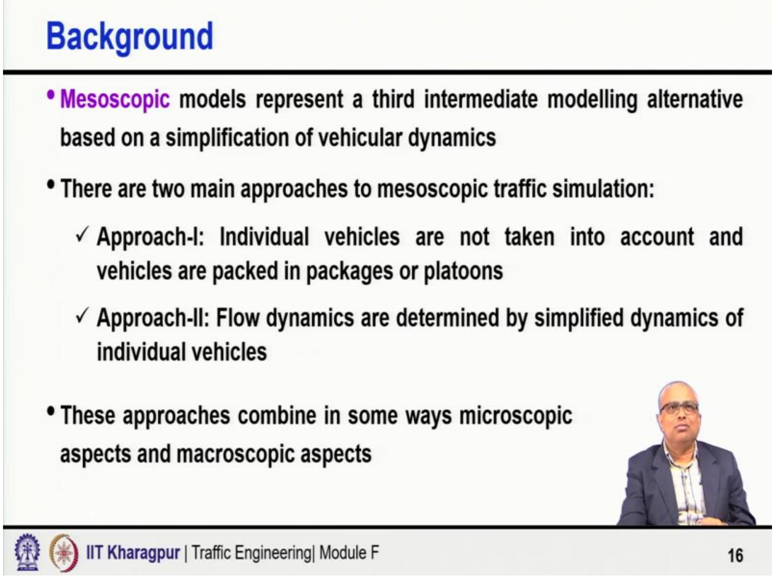

The third, mesoscopic model which is in between micro and macro. Third intermediate modelling alternative. It represents a third intermediate modelling alternative based on simplified or simplification of vehicular dynamics. So, there are two approaches we often follow. In approach one, individual vehicles are not taken into account and vehicles are packed in packages or platoons.

So, individual vehicle we are not considering but vehicles are packed or packaged or in a platoon and that we are analysing. Or alternative another alternative effort could be the flow dynamics that determined by simplified dynamics of individual vehicle not rigorously as using modelling as we did in microscopic case. Every individual vehicle, acceleration, deceleration, lane changing, the kind of model, the depth of analysis, what we are doing at what depth we are trying to analyse them. That we are not doing here.

So, these approaches in a way combined, in some ways, microscopic and macroscopic aspects. Not fully going in every sense microscopic, not fully in every sense going macroscopic. Somewhere the depth could be there but then maybe the not every aspect type. So, it balances between the breadth and depth, I would say. And that is why it is neither fully microscopic nor fully macroscopic, in between.

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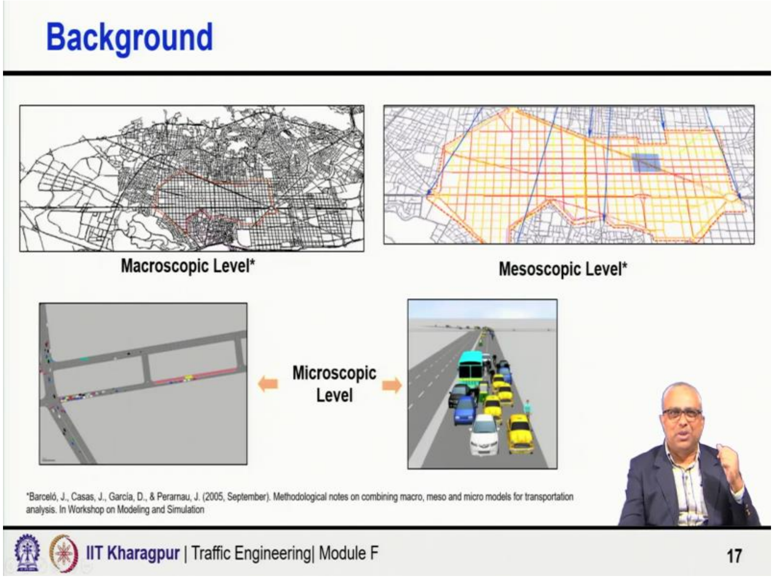

So, if I have to represent it, I will say that the macroscopic level the whole urban area, large geographical area, you are, whole urban area you are analysing. And when you are going to mesoscopic in between: a smaller one with little with more details, not the big area but only a part of that. Microscopic level, individual link, individual junction. Individual junction, what interventions we you do? How the junction is going to behave? If I have bus priority, if I keep a queue jump lane. For different length of queue jump lane, different design parameters, how the exact intersection is going to behave. And therefore, what would be the delay to buses? What will be the delay to cars? All these kinds of detailed thing if you want to get, that is the microscopic level.

So, generally, simulation model could be operated at macroscopic level or traffic analysis also. It is the same thing. The traffic analysis can be done at macroscopic level, mesoscopic level and also at microscopic level. And with this background I will stop and next two lectures will be only on traffic microscopic simulation. So, we will focus on microscopic simulation. How we do micro-simulation, traffic micro-simulation? And entirely focus on that.

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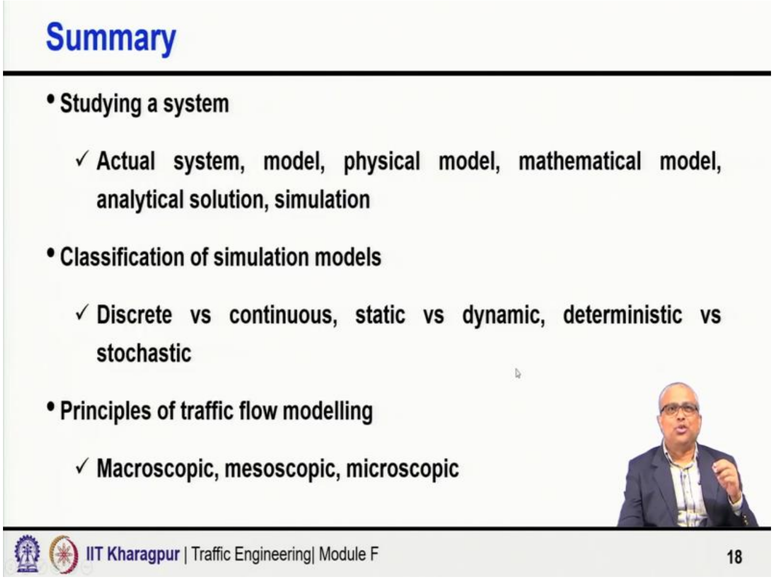

So, what we discussed here is how to study, how one can study a system. What could be the classification of simulation model? What are the different ways we can classify? And some principles of traffic flow modelling that this is also a decision whether we want to do analysis at a macroscopic level or mesoscopic level or at microscopic level. So, with this background and overview, I close this lecture. We shall continue in the next lecture. Thank you so much.