Traffic Engineering
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Lecture 50
Traffic Simulation - III

Welcome to Module F lecture 7. In this lecture also, we shall continue our discussion about Traffic Simulation. And this will be the last part of the discussion about Traffic Simulation.

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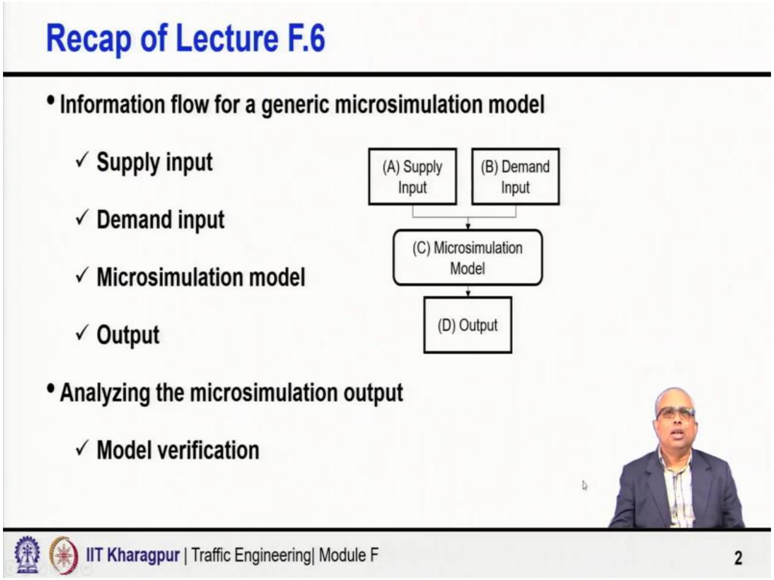

In lecture 6, I mentioned to about the information flow for a generic microsimulation model, talked about supply input, demand input, the microsimulation model itself and the outputs, in outputs I mentioned to you that model verification, model calibration, model validation all are extremely important. And we could discuss only the model verification part.

So, we shall continue our discussion grossly about the output this box component D or here the output component and we said that model verification part, model calibration and model validation all are important, discussed in lecture 6 about model verification part only. So, in continuation to the previous lecture today, we shall talk about model calibration and also model validation and then also a few other important aspects regarding traffic micro-simulation.

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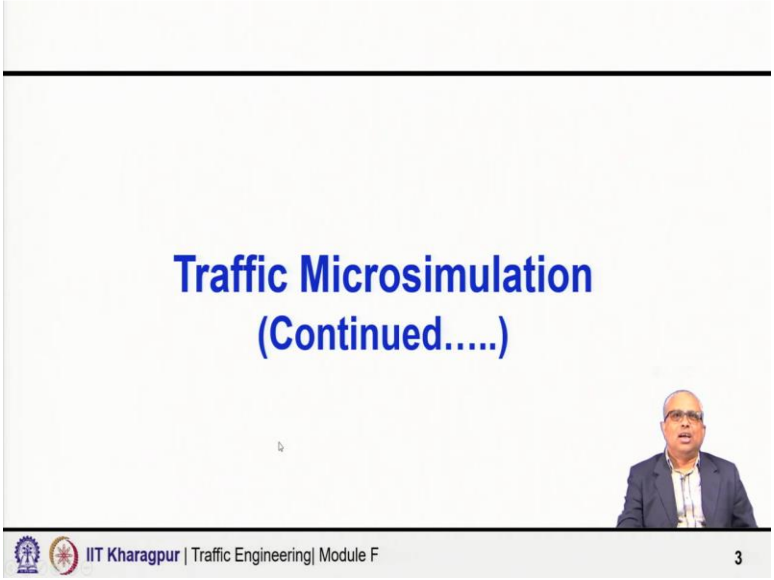

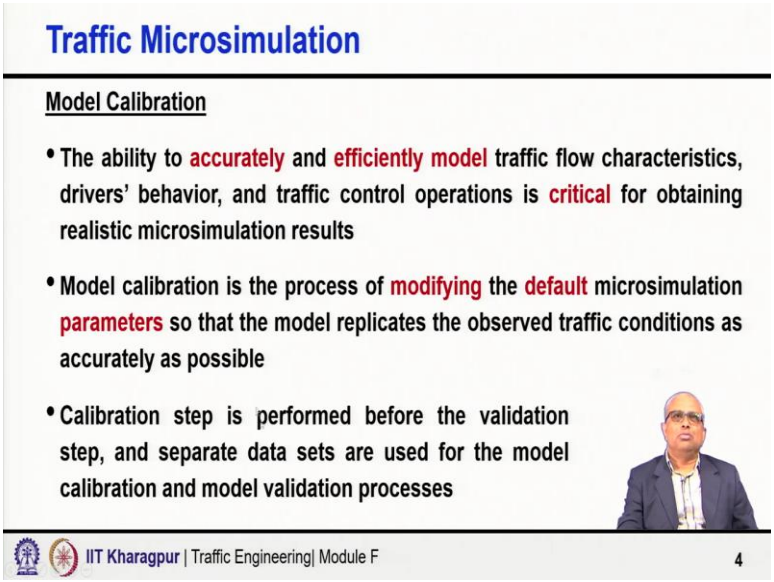

So, coming to model calibration, the ability to accurately and efficiently model traffic flow characteristics, driver behavior and traffic control operations is critical in order to obtain realistic microsimulation results or outputs, how accurately and how efficiently we are able to model all this. There are different components or entities in a traffic microsimulation model. So, how accurately and efficiently you were able to model all such components, traffic flow characteristics, driver behavior, traffic control operations and all this.

So, in order to judge that the model calibration is important or in that context the model calibration is important. Calibration is the process of modifying the default microsimulation parameters when you are doing a traffic microsimulation, so many inputs, so many parameters are involved. Some of the parameters you can measure from the field, some of the parameters you cannot measure directly from the field not so easy. So, how the default microsimulation parameters can be modified. So, that the model replicates the observed traffic condition as accurately as possible.

So, how to set the parameters, which will suit number one, the context and the geographical areas. The specific context may be why I am saying context because what I am why I am doing that developing the simulation model what is my end objective, if my end objective is to improve in traffic operation at an intersection, if my objective is to improve the corridor level traffic flow, if my objective is to reduce regular emission or number of conflict points. So, it depends on what, why we are doing this work at all, why microsimulation model we are developing, it depends on that and it depends on the specific geographical context.

That means, I am simulating an intersection but which intersection because every intersection the features may be different in terms of traffic flow, in terms of geometry, in terms of the vehicular composition, gradient to every parameter, every parameter will vary. So, how the microsimulation parameter can be selected in the best possible manner keeping in mind the objective of doing the simulation and keeping in mind the local context where I am going to apply it, so, that the model replicates the prevailing traffic condition in a given context as per our targets as accurately as possible.

Obviously, calibration step is performed before validation, because first you calibrate the model, and then you validate it separately. And therefore, also the separate data sets are used, we cannot use the same data set for calibration and validation purpose. So, if we are using a data set for calibration, we should not use that data set for validation, same data set. A different data set which has not gone inside the calibration should be used for validation.

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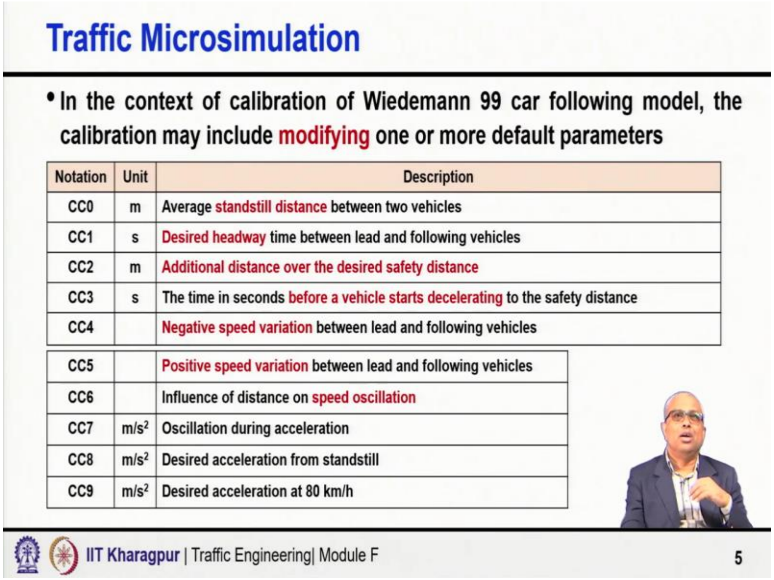

What it may mean calibration in the context of traffic microcirculation? It may mean setting the parameters properly microsimulation model parameters properly, say for example, if you are using Wiedemann 99 car following modules, then I have already mentioned this to you that the parameters CC0 to CC9. So, it may be all about what parameters values I use for all these parameters, sorry for each of the parameter. So, that my output closely match with the reality.

Now, when you are applying this Wiedemann car following model, the parameter values and when you are applying it maybe in any European city and if you are applying in any Asian cities or even India say in Calcutta or in Delhi or Chennai, the parameters will be same? No, because the whole traffic environment is very different. So, what may be good and appropriate for an European city may not be good for an Indian context. So, how to decide when you are developing a model for an Indian city or trying to apply for to in an Indian city, how best this parameter can be taken, so, that the output matches with our traffic condition, that is all about calibration.

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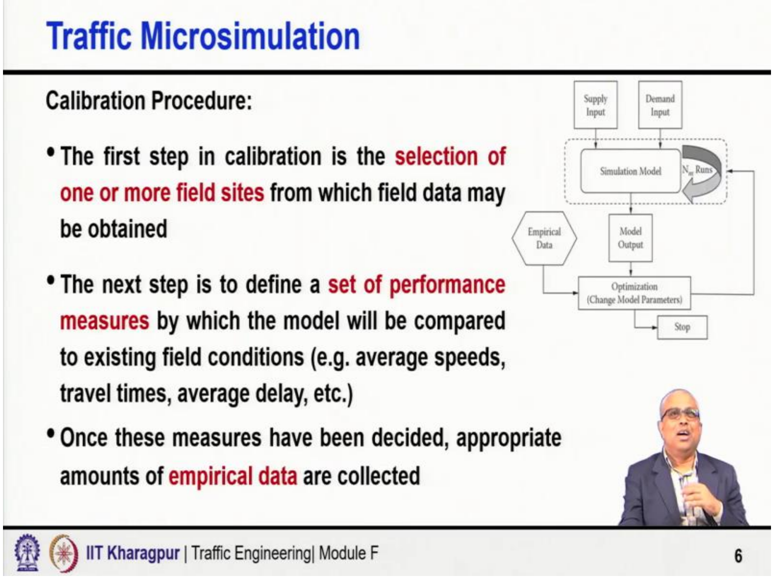

Now, calibration process, the first step is selection of one or more field sites as I say it is important where which intersection if you are going to take intersection, say for example, then which intersections or intersections you are going to take? So, you must select the one or more field sites first, where do you want this model to be applied. The next step is to define a set of performance measure this relates to the other respect what I said that what you are trying to do, why, why you are developing this model, what is your objective?

So, accordingly you decide what should be your performance measure, how you are going to evaluate the performance? So, the performance measure is also very much context specific means, what you are trying to achieve and then the other thing is site specific or location specific where I am trying to apply it for intersection improvement. So, for intersection improvement, what set of performance means that I should use that is one aspect that we are discussing here.

The other is once I say I want to improve intersections, are you going to improve intersections in an European city or in an Indian city? That is what you have to select appropriately then it is to be calibrated for the local condition and for the context. So, accordingly you decide what performance measures you want to take. It may be average speed, it may travel time, it may be control delay, it maybe average delay, so many ways you can select possible, so many performance measures are possible. So, you have to see what is an appropriate performance measures for the context. Once these measures have been identified then in all those selected field sites, you collect the data empirical data you need to collect.

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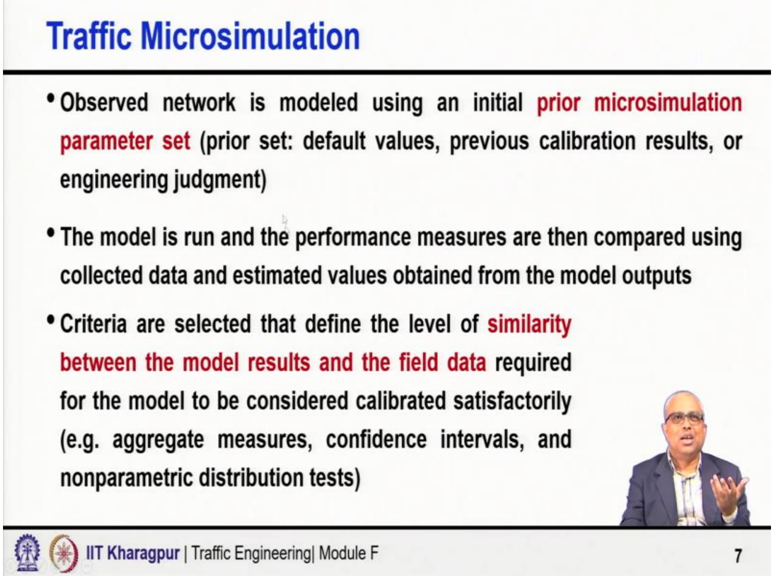

Now, observed network is model generally using an initial prior microsimulation parameter set. You have to start with some parameters set. You do not know what exactly set of parameters will be most appropriate. So, you start with a trial set and sometimes it may be the default values if the really the traffic environment based on which the micro simulator has been developed, if the traffic condition is very similar, as I said that many of the microsimulation platform has been developed considering the land based, more homogeneous, more disciplined traffic environment.

So, if you are applying it maybe in an European context or in Western countries context, you can start with the default parameter. But if you are going to do the same thing for an Indian context, you will know that anyhow those parameters are not going to work. So, if they are passed as these previous works have been done, and people have said that this for this parameter, this value is more suitable or appropriate, you can take those things. So, it may be default values, it may be based on previous calibration result or it may be based on some engineering judgment also.

Then, you run the model and you then compare the performance measures as you obtained from the model with the one you have obtained from the field data compared to. Now, to compare to decide need to decide criteria, because it will not exactly the same thing will match because by nature stochasticity will be there in the model output, stochasticity will be there in the real data. So, two things will not exactly match it is nearly impossible. So, you have to decide criteria.

So, criteria's are selected, criteria selected that define the level of similarity between the models results and the field data required what kind of similarity is required for the model to be considered calibrated satisfactorily. So, up to the level of similarity that you expect that criteria you have to say what level of similarity between model result and the field data, you expect, in order to say that your model is calibrated satisfactorily. So, it could be aggregate measures, it could be some confidence interval, nonparametric distribution test, number of things are possible.

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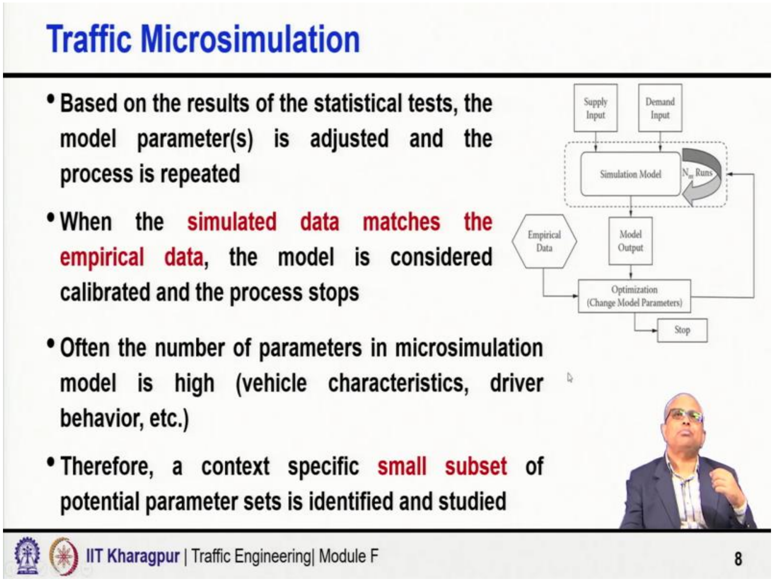

Then based on the results of the statistical test, you need to often carry out statistical test. The model parameters is adjusted if you find that no, my errors are statistically significantly different. Then, I need to further adjustment of the model parameters may be required. So, the model parameters are adjusted and the same process is repeated. Till the time you find your simulated data matches the empirical data within the permissible or acceptable limit as you have said, define the criteria within that it is matching. So, then you considered, yes now my model has been calibrated and you stop the process.

Now, remember that often the number of parameters and microsimulation model is very high, your vehicle characteristics related parameters, your driver behavior related parameters, so many inputs are there, it typically you take a good microsimulator maybe 30 parameters or more than 30 parameters you maybe required. Those parameters are actually controlling the overall simulation output. So, will you start changing everything it becomes gigantic task, most time may not be required. So, therefore context specific small subset of potential parameter sets is identified and then studied.

How I can do that? There are different ways of doing it, you can quickly further given context like the parameters every parameter for every measure of effectiveness, the sensitivity may not be same. So, if you take the control delay or generally the delay, the parameters which are really influencing the delay and the parameter which are influencing maybe another measures may not be same.

So, given your performance measure, you can do a quick sensitivity to check which are the model parameters which are actually highly sensitive given that performance measure. So, you create a small subset manageable parameters the subset, out of this whole set bigger set and then you ignore those because they are not really that sensitive, say most sensitive or highly sensitive parameters you take and then try to do some adjustment.

Maybe there are so many ways optimization has to be done, outside you can use different search algorithm, you can use genetic algorithm to give a trial and every time you give a trial set, you have to go inside the model and again take simulation run that do not want multiple simulation runs to be taken. And then you can compare again the simulation output with the observed field data and the process has to continue.

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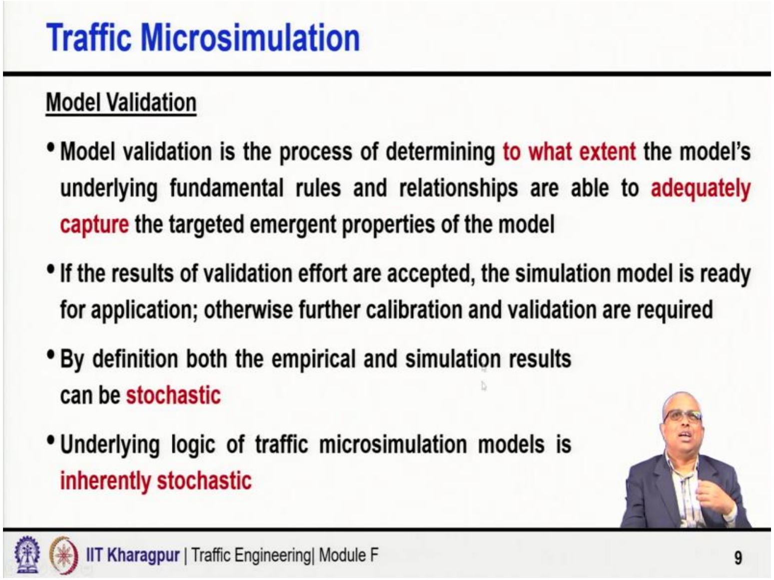

Now, coming to the model validation, validation is the process of determining to what extent the models underlying fundamental rules and relationships are able to adequately capture the targeted margin properties of the model. You have calibrated, calibrated mean your output is matching, but have you really captured the relationships properly or if simply you have gone with trials and multiple trials and somehow said the parameters and calculations are somehow matching that again need to be tested.

So, an unknown data set which has not gone inside during the calibration process and calibration step should be used. And there also the inputs unknown, the outputs or the performance methods are also known from the data set. And you see how well it is able to estimate the performance measures from the model and how closely that is also matching with that is will your output will field observations. And remember that this is the data set which has not gone inside during the calibration.

So, if here also a reasonable accuracy you are getting then you are confident that yes my model has actually captured the relationship very nicely. So, if the results of the validation are accepted, then the simulation model is ready for application. So, maybe you have calibrated an intersection and you want to validate it take very similar intersection adjacent to that which are comparable in terms of geometry, in terms of the traffic, in terms of all other parameters environment generally comparable or the same thing you have used some our data and similar another hour you try to fit the data and try to see. It has to be of course within that range. Because whenever you develop a model, you calibrate the model, you calibrate for a range of conditions.

So, within that, of course it has to be, so remember that by definition, both the empirical data and the simulation results can be stochastic. Actually, they are stochastic if you go to the field, simple measure, the traffic volume or take the composition you will not get exactly the same volume, same compensation for continuously every week day or working day between 9 to 10 you go and measure at the same location values are not going to be same. So, because of the inherent stochastic stochasticity.

So, once you have the field measurement like this you will get okay I have got data for a number of days. So, you will get a central tendency, will get a dispersion and if you have very good data, you will probably also be able to fit a distribution which distribution actually is describing this variation or the behavior in a proper way. You will say probably it is a normal distribution, it is some other kind of distribution depending on discrete or continuous what is the context. So, it is stochastic.

Similarly, the simulation run when you are taking it give different seed values and remember that there are pdfs, everywhere parameter is actually a pdf. So, the random numbers are actually generated. So, every time you are giving a different seed the generations are different. So, you cannot simply take one model run and compare it. So, both are actually stochastic. So, the underlying logic of simulation model is also inherently stochastic as I said.

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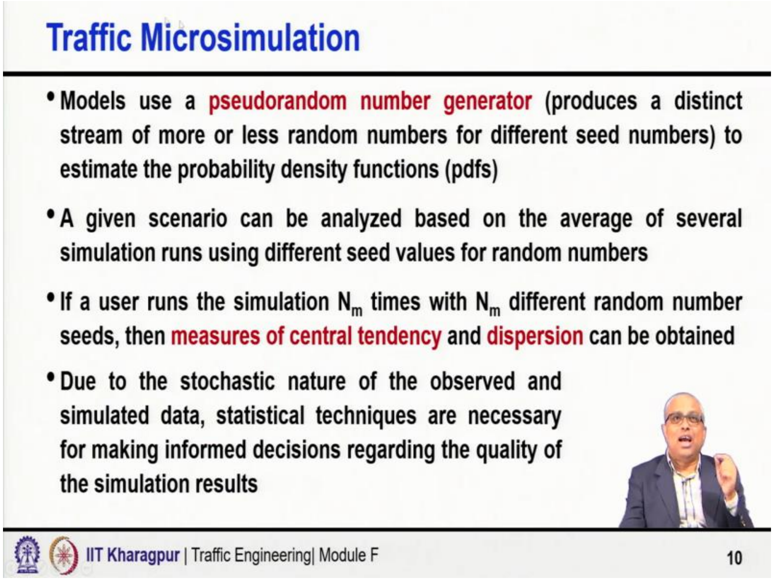

Because models use a pseudorandom number generator produces a distinct stream of more or less random numbers for different seed numbers to estimate the probability density function, so, pdfs are there. A given scenario can be analyzed based on average of several simulation run using different seed values for random numbers. So, for example, if you use a run simulation in m number of times with Nm different random number seeds, then the then measures the central tendency and dispersion that can be obtained.

So, you have Nm number of runs with Nm different random numbers seed outputs are there. Now, with all the outputs together taking them you can measure a central tendency, you can see a dispersion. Similarly, in the field also you measure have a central tendency whether have a dispersion, many statistical comparisons are possible. Due to the stochastic nature of the observed and simulated data statistical techniques are necessary for making informed decisions regarding the quality of the simulation results.

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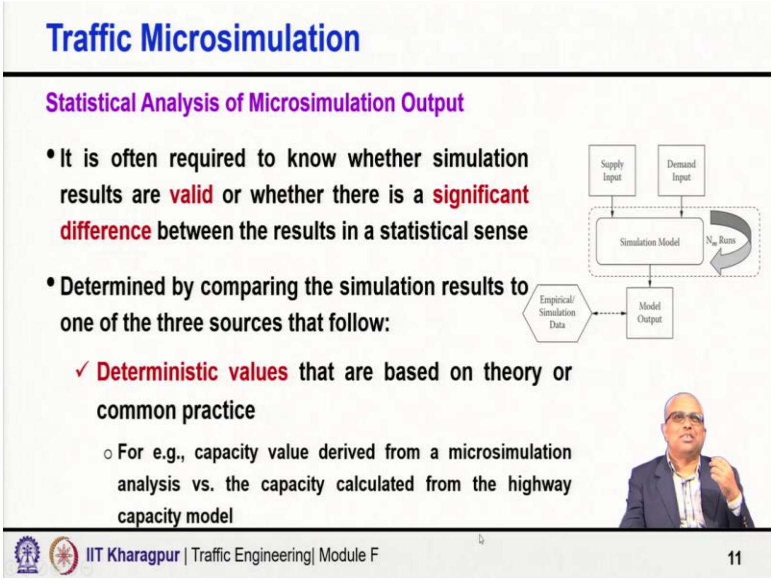

Coming to the statistical analysis of microsimulation output, it is often required to know whether the simulation results are valid or whether there is a significant difference between the results in a statistical sense. I say in a statistical sense, two numbers may be different to mean values or average or expected values may be different, but are statistically different, two things that dividend. So, this can be determined by comparing the simulation result to one of the three sources that follow. This is for your general understanding that all what you get output from simulation model, there could be the three kinds three ways or three sources could be there for comparison purpose or check purpose.

So, one is what all deterministic values you have got you can compare those based on theory or common practice, for example, the simulation results also may give you what is the capacity. Now, the capacity value different from a microsimulation analysis can be compared easily with the capacity calculated from the highway capacity manual or the country specific guideline or norms also. So, that this kind of road at this kind of facility or this kind of thing normally should have this value as capacity.

So, you can compare it for what you got from the model that can be compared with you do not need to go and measure it in the field that is good, that the manual capacity manual or the relevant guideline in our case, maybe the Indian Roads Congress guidelines, what the value is they are saying? So, I can match it. If there is a general agreement, then I can know that okay, it is reasonable and satisfactory performance it is given.

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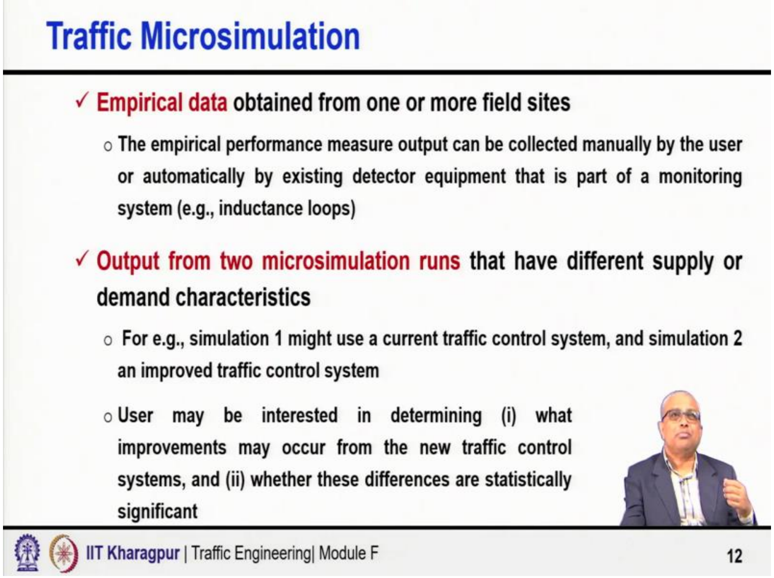

The other is empirical data, the simulation models outputs can be compared with the empirical data obtained from one or more field sites. You have actually gone to the site and measured the delay anywhere comparing. So, the empirical performance measures output can be collected manually by the users or even automatically by existing detector equipment, how you can calculate, how you collect the data is different ballgame, but you can collect it manually, you can collect it automatically, you can do videography and then do the data extraction. So, many things are possible.

But basically, compared that what you have collected from the field with the output. Another things is also possible. Output for two microsimulation runs that have different supply or demand characteristics. For example, you have taken simulation then for two different scenarios, say one and two, maybe for example, simulation, one might use a current traffic control system and simulation two an improved traffic control system then you compare. So, I can simply compare one and two, two outputs can be compared to see how the improvement is happening.

So, that is all for whatever output you are getting three different ways you can actually do the comparison. In this case, user might be interested in determining what improvements may occur from the new traffic control system. And also, further these differences to these again. These differences with that is a statistically significant you cannot say compared two number because they are all coming from different number of simulations ran with the central tendency with the dispersion probably with the distribution also. So, whether the things are different means whether they are statistically different or if they are different, then are they statistically significantly different, this also needs to be checked.

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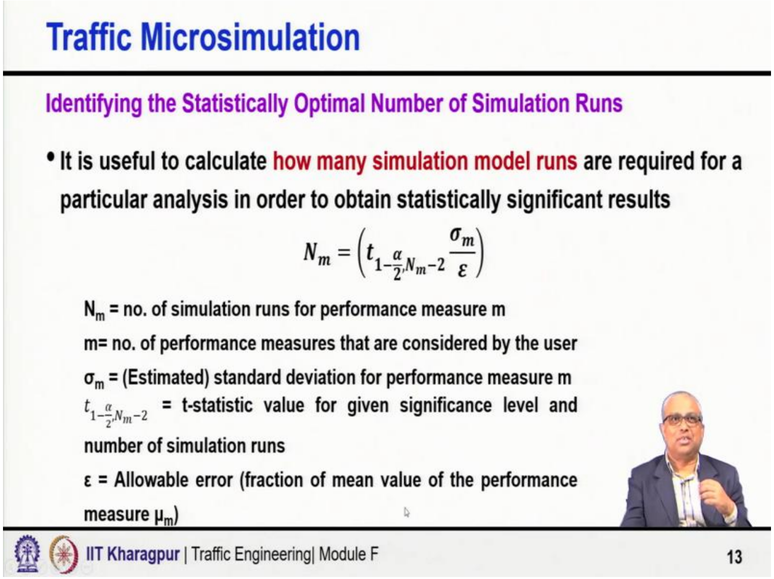

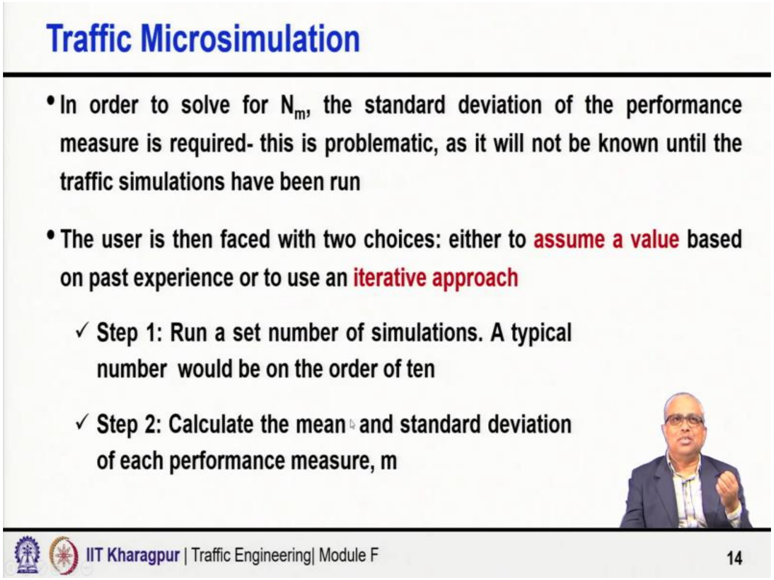

Then in this context, identifying the statistically optimal number of simulation run is important. I say by nature, the simulation outputs that is also stochasticity they are also. So, just in one simulation run you cannot compare. You have to take multiple simulation runs, how many simulation runs? So, it is useful to calculate how many simulation runs are required for a particular system in order to obtain statistically significant results. So, here is the formula that can be used.

Remember that this is based on the t statistics value for a given significance level and number of simulation run. Then the estimated standard deviation for the performance method and the

Allowable Error, what you accept. The problem here is other things could be fine assume but the in order to solve for Nm, the standard deviation of the performance method is required. Now, how do you get this problematic thing, how you get it? As it will not be known until the traffic simulation runs have been taken. How do you know?

So, one possibility of course, you can say that I will assume a value based on past experience. Because those who work with the traffic simulation, the extensive work many of them are doing. So, you were assuming value based on past experience or you can use an integrative approach. For example, step one, run a number of simulation runs just take some runs, field runs and a typical number would be in the order of 10, take runs then you got some output now. So, you calculate the mean and standard deviation of each performance measuring because there may be say five performance measures. So, for that m indicates five. So, all the five or each of these five performance measures, you calculate the mean and standard deviation for the number of runs you have taken.

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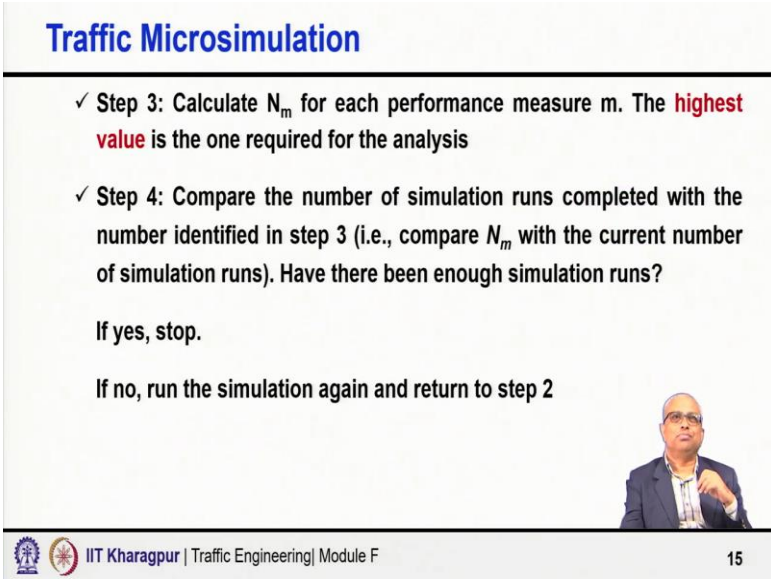

Now, calculate then Nm number of runs required for each performance m separately. Now, the number of whatever output you have got for each of the m performance measure, the standard deviations are not same. So, the required number of simulation run is not going to be unlikely to be same for every measure. So, take the highest value among those for all the considering all the performance measure and the highest value is the one required for that analysis then take it. So, compare the number of simulation runs completed with the number identified in step three.

So, compare Nm with the current number of simulation runs, because we have taken only a few trial runs. So, have there been enough simulation? If the answer is yes, then stop, if not, then take the additional runs. And you can also check once you have taken the additional runs again you can calculate the standard deviation or so, and then check again whether this number of runs what you have taken is adequate for all the performance measures.

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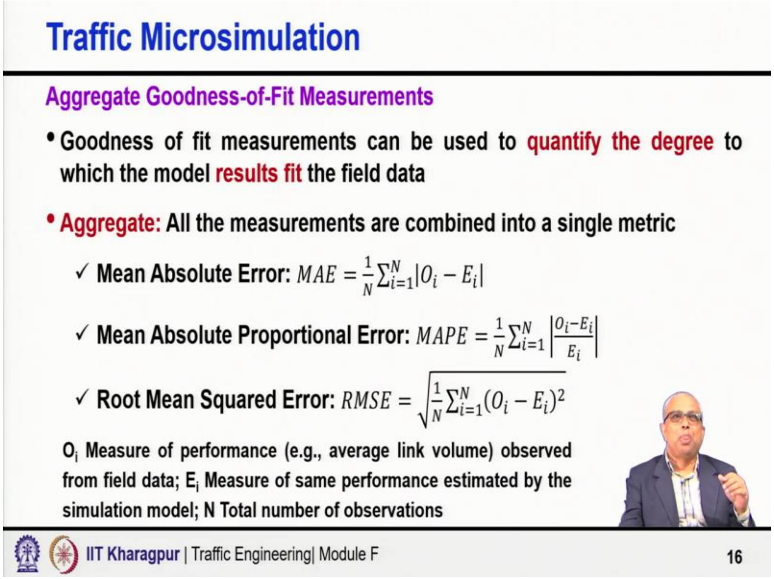

Now, the for-comparison purpose, often we use aggregate goodness of Fit measures. Goodness of measures can be used to quantify the degree to which the model results feel a fit the field data, why we are saying aggregate these methods are aggregate because all the measures can be combined into a single metric.

That is why we are calling them aggregate goodness of fit, why the word aggregate because all the measures are combined into a single metric, many possibilities for such measures. Say, for example, you can use mean absolute error y minus Ei, y is the measure of performance from field observed one and Ei is the measure of the same performance estimated by the simulation model.

So, y minus Ei absolute value, because it is mean absolute error and sum it over for all N divided by N. Total number of observation is N or it could be mean absolute proportional error, proportional means y minus Ei divided by Ei normalized proportional error and that submit over N again divided by 1 by N or it could be root mean squared error. So, y minus Ei square of that difference sum it over N, 1 by N. So, these are the possible thing.

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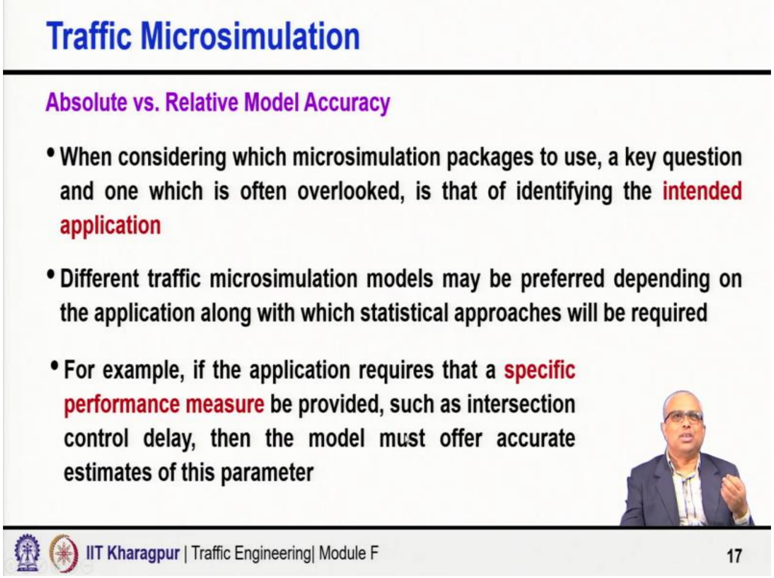

Now, one decision is whether we considered the absolute or relative model accuracy. Both will be meaningful, it all depends on again the context. When considering which microsimulation package to use this is another decision often within which microsimulation package to use. A key question and the key question which is often overlooked is that of identifying the intended application.

What I am trying to do, as I said I am trying to model an intersection or trying to see how intersections can be improved. Or I am modeling a corridor or I am trying to see that some other changes in the infrastructure or control system, how it is going to impact, what is the application, what is the kind of improvement or what I am trying to look for.

That intended application and whether the microsimulation platform has got this capability to satisfy my requirement that should be the first thing. Different microsimulation models therefore, may be preferred depending on the application along with which statistical approach will be required.

For example, if the application requires that a specific performance measure be provided, such as intersection control delay, then the model must offer accurate estimates of this parameter otherwise, there is no point in using that platform. So, what I am on to do, what measures I is required for me that the model should be able to estimate accurately. That is what is the first requirement and the most probably the most important requirement.

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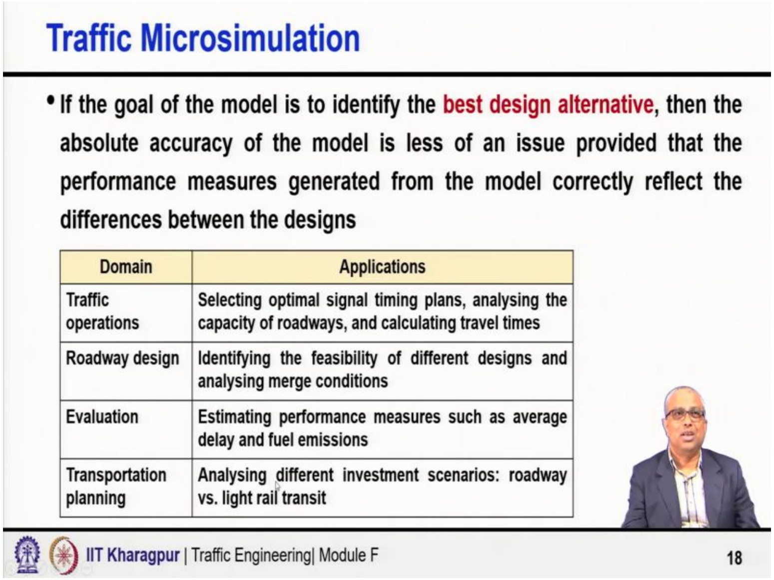

Now, on the contrary, if the goal is to model, so, here in this case, it is the absolute accuracy, which is important, I want the control delay to be measured accurately by the model. That is what is my requirement. So, here it is the question of absolute model accuracy, but it is not always so. For example, if the goal of the model is to identify the best design alternative, alternative designs you are there anyone to evaluate them, whatever maybe the purpose, again, the many purposes could be there for which we would like to have this that which design alternative is better.

Then here the absolute accuracy model of the model is less of an issue provided that the performance measure generated from the model correctly reflects the difference between the designs. So, all at what I want which is supposed to work better than others, which alternative is more desirable than others that is the reason why I am developing this model, I am testing it, I want to test that. So, as long as alternative to alternative, it can actually capture the difference properly.

My purpose is soft; it is good enough for me. So, I do not need here the absolute model accuracy, but it is the relative module accuracy that is important for me depending on the application context, and here I have mentioned some of the domains and the corresponding application. For example, if you are thinking of traffic operation, then setting optimal signal setting timing plan, analyzing the capacity of roadway and calculating travel time. If you are thinking of roadway design, then identifying the feasibility of different designs and analyzing merge conditions could be the applications which will be of interest to us, while doing the micro traffic microsimulation.

It could be evaluation, evaluation of performance measures such as average delay, fuel consumption, again very important or could be even transport planning application for analyzing different investments scenario road versus light rail transit. So, these are the different domains and applications where we would be interested.

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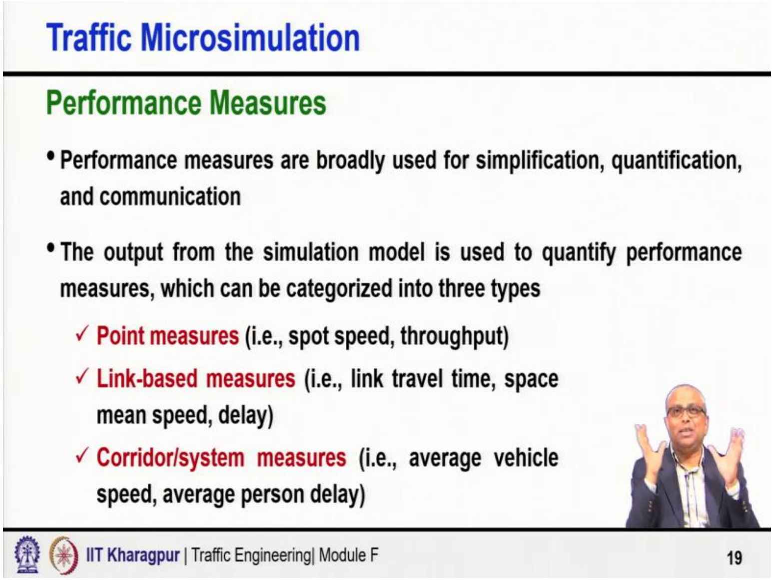

Coming to the performance measure, the performance measures are broadly used for simplification, quantification and communication, you want to communicate the results to maybe the policy makers, even the politicians, decision makers. So, it has to be simple, if you take the performance where to go and simply can tell present, it is like this future it is going to be like this, if you do the sector differential, it is easy, they do not need to understand how the traffic interacts and the vehicle interact with another vehicle or what car following is happening, how the interaction is happening with other roadway and controlling elements they do not need. They need simply to understand is it going to solve my problem end of the day.

So, the performance measures are very useful. The output from the simulation model is used to quantify performance measure which can be categorized in three types. Sometimes it could be point measurements for example, the spot speed at a given location, throughput at a given location, these are all point measurement. It will be link-based measures for example, the link travel time, what is the specimen speed, what is the delay or it may be corridor or system measures overall average vehicle speed, average person delay and so on. So, you select performance measures appropriately as per the context and as per your requirement.

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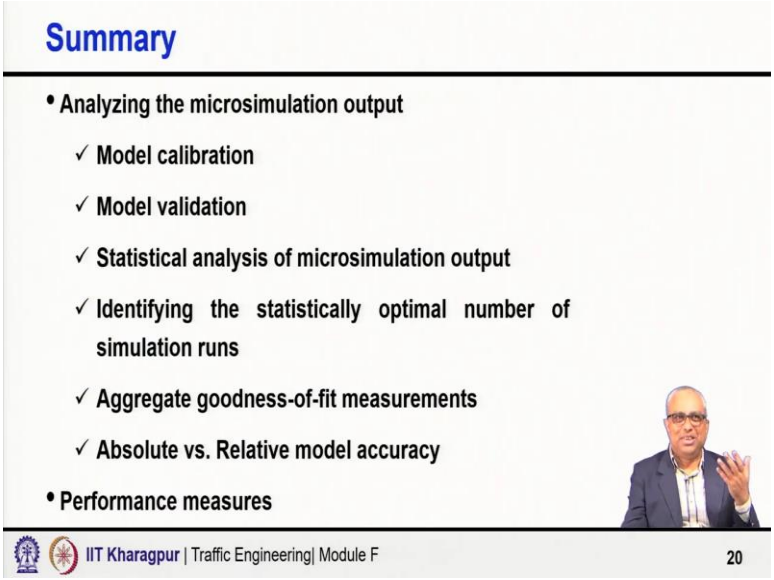

So, with this what we discussed today, how to do the analyze the microsimulation output. Particularly here we discussed about model calibration, model validation, also the statistical analysis of the microsimulation output, identifying the statistical optimal number of simulation runs, aggregate Goodness of Fit measurements and then absolute error vis-a-vis, the relative model accuracy, absolute accuracy vis-à-vis relative model accuracy and also what kind of Performance measures and point measures or as I said the link-based measurement, corridor based or system measures, how to choose the performance measure. So, with this I close this lecture and also close this module. Thank you so much.