Simulation of Business Systems
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Lecture - 02
Terminologies in Simulation

A very good morning again people and welcome to the next lecture second Installment of the Simulation of Business Systems course on NPTLE MOOCS and in the previous lecture what we have gone through our learning agenda.

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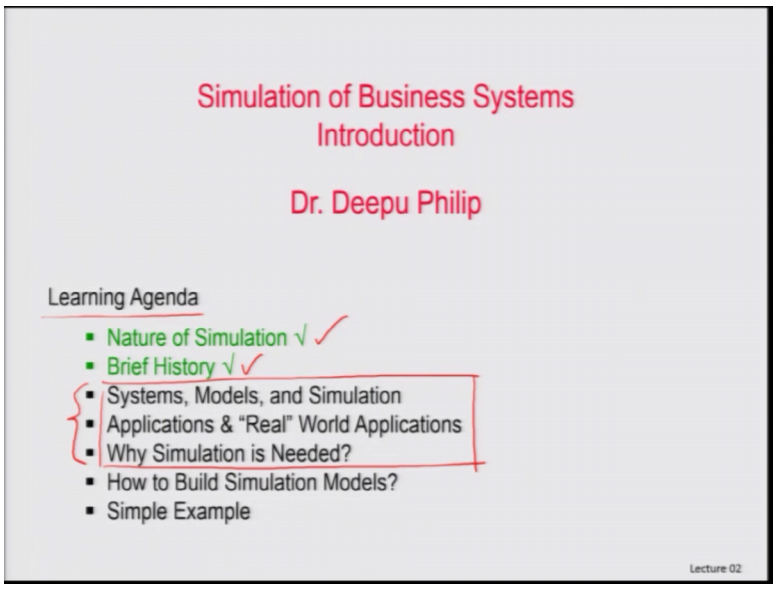

The main topics was listed and of which we covered the nature of the simulation and the brief history of simulation. And we will look into new concepts today. Mostly we will try to the focus ourselves on these 3: what is systems models, and the simulation, then application, and the real world applications and why simulation is needed. We will try to address these 3 aspects in the today's class ok.

Probably will be little long, because we are covering quite a lot of concepts in this. So, we will try to break it appropriately so that you would not have any problem in you know going through the concepts.

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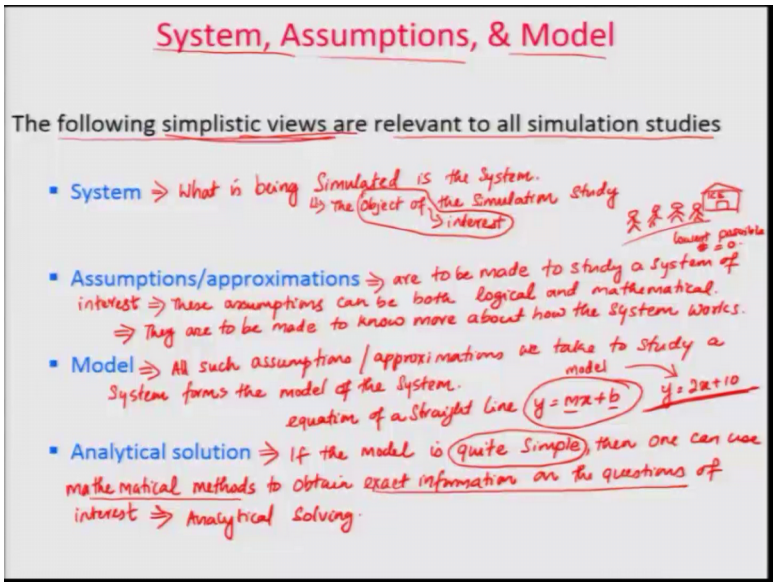

So, the first thing that we are going to look into is the concept of system assumptions and model ok. This is a people use these words in every colloquial way in most of the time, but in simulation they do have very specific meaning. So, these following simplistic views the simplistic views that I am going to provide are relevant to all simulation studies. It does not matter whether you are doing computational fluid dynamics so anywhere, but these approaches this view points that we are going to study now has it is applications relevant to all simulation studies.

So, the first phrase that we need to know is system. People talk about system. So, what is a system? In the simulation it is not the systems engineering system, in the simulation what is being simulated is the system ok. So, the system is the stuff that is being simulated, whatever is being simulator or in a way the object of the simulation study, object of what? The object of interest whatever you are interested in study that or what is being simulated that becomes the system that part I had believe it is clear.

Then we talk about assumptions and approximations we say oh while building the model we have to take so many assumptions, so many approximations. This assumption determine that assumption determine those kind of things. So, what are they? Ok so, assumptions and approximations are to be made to study a system to study a system of interest. To study a system of interest you have to make of assumptions and approximations. These assumptions or approximations can be both logical and

mathematical. So, some of the aspects can be logical some of them can be mathematical right and.

Why are these assumptions is to be made? Ok, they are to be made to know more about how the system work, how the system works ok. So, an example of this is that if you are thinking about people standing in a line. So, let us say here is a shop ok, this is a ice cream shop and people are standing in line, here to buy ice creams or getting the ice creams like this and buy one by one they will buy a ice creams and they will get out. So, one of the assumption that he can make a logical assumption into that can he make is that the lowest possible number lowest possible number of people is equal to 0, he cannot have negative people there. So, that is a logical assumption ok.

And he can always say that the number that the values the number of people who are waiting to get the ice cream is always an integer value, you cannot have 2.5 people. You can have an average, but realistically if you think about is this is will be the 2 people, 3 people, 4 people, 10 people, 200 people waiting in the queue depending upon how popular the ice cream area is. And then we can also write the same thing about the average waiting time to get the ice cream is 4 and a half minutes and that you can write as a mathematical expression which will become a mathematical assumption ok.

So, these types of assumptions and the approximations that we take to understand of study the system better ok. So, that is the main aim of taking the assumptions and approximations. So, then what is a model? All such assumptions or approximations we take to study a system forms the model of the system ok. Hope now you understand; what is a model, these assumptions or approximations that we take to understand the system better results in the model of the system ok.

So, your object of interest or object of interest of study is your system or whatever is being studied is a system and you take assumptions and approximations to better understand how the system works. And these assumptions and approximations that way translated to what we call as the model of the system.

So, then many a type people talk about analytical solution, people say is that equation of a straight line. So, like for example is, equation of a straight line is given by y equal to mx plus b, where m is a slope and b is the intercept, but this is a model. But when you say y equal to 2 x plus 10 then thus equation of a particular line which is 10 units

intercept and then the slope is 2; that means, the slope is the rate of change of y over rate of change of x delta y by delta x. So, then that means, for every 2 units of raise in y we can see that how it works of right. So, I am not going to explain that, but this becomes a model and this is a particular you know line that a person's that derived from that model.

For here there are certain assumptions that we assume that both x and y are the condition coordination co ordinate system. And there also like you know no imaginary values there all real numbers and those kinds of things we assume as part of this. So, that is how this equation of line was derived ideally speaking. So, in analytical solution when people talk about what is an analytical solution, if the model is quite simple is quite simple then one can use mathematical methods to obtain exact information exact information on the questions of interest.

So, if we use mathematical methods or mathematical approach to obtain exact information on those questions that you have of interest then that type of an approach is called as analytical solution. So, modeling a system using a mathematical equation, modeling a system using a mathematical approach or using a mathematical method to obtain the exact information to the questions for a simple system; their important aspect is it is system is simple then you will result in analytical solving or analytical solution ok.

So now, you know what is a system assumptions and approach model and what we also called as an analytical solution. So, when do we not do analytical solution obviously the answer is when system is very complex, is too hard to use mathematical methods to come up with the solution to the problem.

So, let us study little bit more on the systems and models and simulation.

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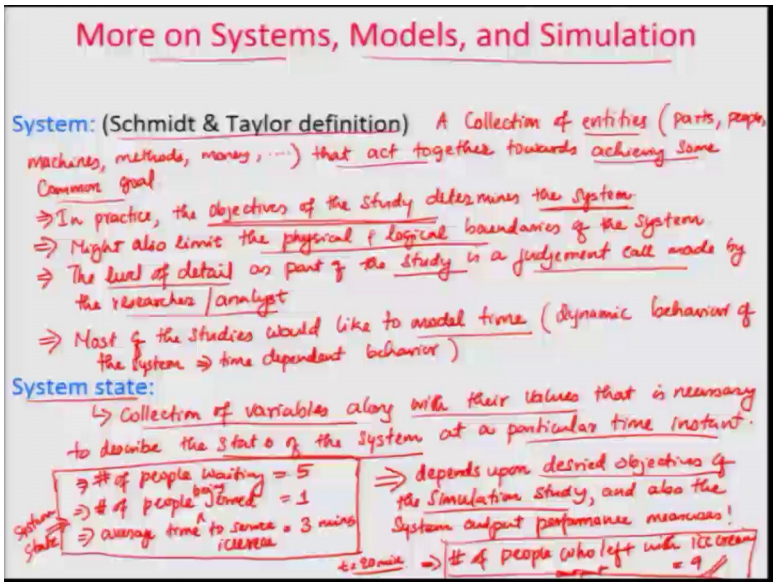

So let us see; what are the other definitions that are part of this. So, the system the Schmidt and Taylor definition which is very popular among many of the people ok, then definition says go something like this a collection of entities ok, what are those entities? Entities can be parts, people, machines, methods, money like this ok. A collection of entities that act together towards achieving some common goal that is what we call as the definition of Schmidt and Taylor definition. Is a collection of entities that act together towards achieving some common goal such kind of a collection is that collection of entities what we call as a system ok.

So, in practice the objectives of the study of the study determines the system. For example, you might be in a automotive factory automotive manufacturing facility. And then you are more interested in the time taken for completing a work at each workstation. Then you might be more interested in studying the conveyor aspects of the system rather than looking into rather other aspects. So, realistically the objectives of the study whatever you wanting to study that determines the system.

So, you would actually be in a big factory and you would just probably focusing on the overhead cranes, you will be looking only at the material transportation system at that point ok. Other aspect is in practice also it might also limit the physical and logical boundaries of the system. So, you are study objectives might also limit the physical and logical boundaries of the system. So, if we are more interested in how long it takes the

crane to move over head in the factory from one end to another, then you are study objective limits only the focus to the overhead crane. It does not care about what happens, what is the electric supply, how much is a nomination the factory, what is the rate at which the water is flowing through the taps, how much a material is being removed.

We do not study those aspects because, there is outside the habit of your objective of the study. The level of detail as part of the study the study is a judgment call is a judgment call made by the researcher, researcher or analyst.

So, how much detail you want to study? Ok how much detail you want to go into this study is a judgment called the modular or the researcher decides how much of details you want to be included. So, if you are studying about that rate the time taken for the crane to move from one end to another carrying different weights. You are not interested in what kind of color it is being painted, what is the color of the crane. You may not be interested you may not be interested whether the crane the driver cabin the operator cabin is air conditioned or not. You may not be interested too much on what is the power horsepower of the motor that is driving the wheels of that crane; you may not be interested in any of those.

So, hence the level of detail are that is part of the study is a judgment called depending upon your objectives of the study. Your study object is determined how much detail you also need to go into and that way it also determines the physical and logical boundaries of the system ok. And the last part is most of the studies would like to model time ok. So, in a system typical definition of the system the definition of that system the time is kind of left out. So, the way is dynamic behavior of the system or what we call as the time dependent behavior.

How does the system behaves overtime? That is one important aspect that is that many of the modulus would like to do. And in study of the system when there is a collection of entity is attacked with or not. But, in realistically the objectives of the study limits the system and as well as the physical and logical boundaries of the system are also determined by the objectives of the study.

And the researcher and analyst depending upon the objectives limits the level of detail to an appropriate level so that unwanted things are removed out that is why you make the

assumptions to remove unwanted things and also one other aspect is an aspect time, the time dependent behavior as a dynamic behavior the system also need to be added into the study. Because, many of the researchers would like to know how the system would behave.

Then we talk about another thing is called as a system state ok. So, what is a system state? So, by definition system state is a collection of variables collection of variables along with their values their values that is necessary to describe the state the state of the system at a particular time. Instant at a particular time instant at a particular time given time instant you would like to know the state of the system ok. So, it is a collection of variables a particular variables along with their values, that is necessary to describe the state of the system at a particular instant.

So, if you think about the ice cream example that we talked earlier, if I say that number of people waiting number of people waiting is equal to 5. Number of people served or being served being served equals 1 and average time to serve ice cream is 3 minutes.

If I say something like this these variables put together and if I say this happened at this is what is this status at t is equal to 20 minutes. So, after 20 minutes this is the state of the system then. So, this state of the system that we just described now gives us a snapshot of the system how the system is at a particular time which is at the twentieth minute of the system. So, this kind of the system state it always depends upon depends upon desired objective desired objectives of the simulation study of the simulation study and also the system output performance measures.

So, at this point what is the desired objective of the simulation study? Let us say if the desired objective in this particular case is find out that how many people were served then you do not get a answer here. So, if I add is the number of people completed, number of people who left with ice cream ice cream is 9 if I say that.

So, then; that means, at the time t equal to 20 minutes, 9 people are already brought the ice cream, 1 is being served, 5 are waiting in the queue and average time of service is 3 minutes ok, whether this numbers are right make sense or so that we will talk about it later. But, approximately this is what the idea is about ok. So, this aspect that we just added here this is more of a performance measures system performance measures how many people you have already sold ice cream.

Because, if you did not sell your ice cream then you would not really get money, if you do not get money then your system would not work. So, this is more of an output parameter and where as this is more about the system state parameter and this is more of a output or a performance measure ok. I hope you guys understand this much concept in a way and what we will do is we will continue now to extend this concepts.

But, be sure that you guys and when somebody says what is a system, when somebody says what is a system state, when somebody says what is a model, when somebody says what is an assumption, when somebody says what is an analytical solution, you should be able to be very clear in your mind about the concept that we just discuss now, so that you can understand what that person is talking about ok. This language is simulation is new to you and hence it is very important that you guys understand this language.

So, we have been seeing the basic definitions of system state assumptions and other aspects. And we also talked about why it is important to understand these state values of the state variables to describe a system. So now, let us get into the next concept which is as related to this is called as a complexity or system complexity ok.

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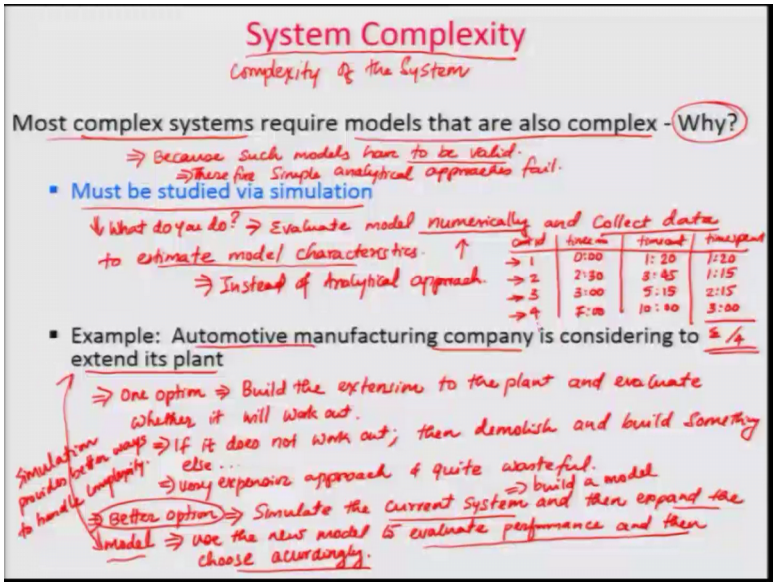

Some people also called this as the complexity of the system of the system. We call this as system complexity ok. So, the general rule of thumb is this, complex systems require models that are also complex ok. So, complex system models are usually complex why?

The most important question is why? Ok. This answer to this is because such models how to be valid ok.

So, to ensure the validity of the model you have to build complex models in this regard. So, hence complex systems will require complex models. So, then simple therefore, simple analytical approach approaches fail ok, you cannot use those simple analytical approaches. So, hence you have to study these things using simulation ok. So, what you do? What do you do then? Ok. Answer is evaluate model numerically, the most important word is this numerically numerical evaluation not analytically, numerically and collect data collect data to estimate to estimate model characteristics ok.

So, what we are talking here is instead of the analytical approach. So, this is the instead of analytical approach instead of analytical approach what you do is you model numerically, you study the model numerically, evaluated numerically then you collect data and then from that you estimate the characteristics of the model ok. So, a simple example of that is if you think about the ice cream. So, when I say thing about you have a data collection where is call at the customer id like this and then time in and time out let us say you have collect data like that. So, customer id 1, 2, 3, 4 like this the customer id is going on.

And the first person comes in a 0:0 and leaves at 1:20, the other person comes in at 2:30 and leaves at 3:45 and this person comes at 3:00 and leaves at 5:15 and this person comes at 7:00 and leaves at 10:00 or something like this. So, when you numerically study this so, this is where your simulator the arrival of people into the ice cream shop, individual people come into the system. The first person came in when the ice cream shop opened and stayed in the shop for 1 minute 30 seconds. So, the time spend you can calculate here will be 1 minute 20 seconds.

This person came in at about 2:30 and left at 3:45. So, this person spend close to 1 minute 15 seconds on this place this person spend 2 minute 15 seconds, this person spend 3 minutes on the shop something like this. So, then using this you can find the average of this, if you some this and divide by 4 then you will be able to get what is average time spent in the shop and stuff like this. So, this type of an analysis is what we call as a numerical analysis instead of a mathematical model.

So, let us think about a simple example an automotive manufacturing company a car manufacture company is considering to extend it is plant ok. So, the one option is one option is built the factory, built the extension to the plant and evaluate whether it will work out ok.

This is one approach, but let us say you built the factory built it and then you evaluate whether it works out, if it does not work out then demolish and build something else. This process continues, what is the major issue with this approach? The problem is it is very expensive approach and quiet wasteful ok. You keep on building and destroy that is what you are trying to do in this case. So, instead the other option better option what is a better option? Is to simulate the current system simulate the current system and then expanse then expand the model. Use the new model to evaluate performance and then choose accordingly ok.

So, the simulation approach would be simulate the current system. So, build this is build a model of the current system and then expand the model to include whatever is the extension of the plant. So, this expansion and this extension mirrors one another and then use this model to evaluate the performance and decide whether you should do this extension or not. So, this is one other approach of how do you deal with the complex systems. So, simulation in other way to do it is simulation provides better ways to handle complexity ok.

So, you can study complexity in a better way using simulation, you can model complex systems using simulation better. Now, let us look into the next concept.

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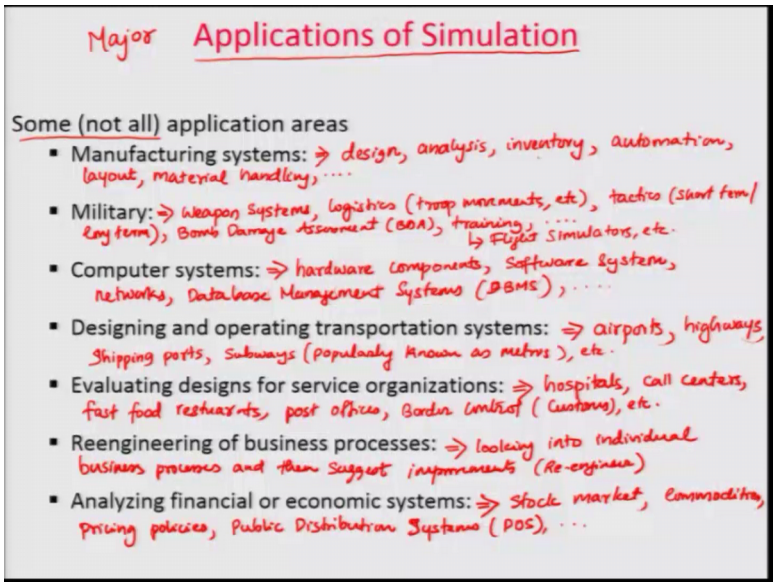

Which is the applications of simulation and what we are going to do is we are also going to look at the; I will just add the facer here saying that major applications of simulations. We are only going to study some major applications not all applications. Do not think that these are the only areas to with simulation is applicable these are some of the majority of the areas.

So, that first one is the manufacturing systems, in manufacturing systems the main aspects were simulation is involved is design of manufacturing systems, analysis of manufacturing systems like analyzing the tag time, tag time or what you call a cycle time, the throughput rate, work in process inventory etcetera. Then inventory, how much of stock is there automation that is another aspect you study, layout ok, material handling etcetera.

So, these aspects of manufacturing systems design, the analysis, inventory, automation, layout, material handling etcetera are all study are all studied as part of the simulation. Similarly, in military simulation also find a lot of applications as you say mention to you guys simulation actually came from military only Monte Carlo simulation. So, in this case what we are major studying is weapon systems, then logistics ok, military logistics this is includes troop movements etcetera ok. Then tactics, tactics is you know short term long term ok. Then what we call as bomb damage assessment ok, it is popularly known

as BDA, a bomb damage assessment; then training providing training to the troops these are all aspects that you can use simulation too.

So, the training very important thing is you can you might have studied something called as flight simulators and all flight simulations etcetera it teaches a pilot how to fly a new aircraft. So, because if you give them a new aircraft fly then they crash it then the cause will be very extensive or extraordinary. So, instead you make a simulation model on it and train the pilot to fly the simulation model. So, that when the pilot actually gets into the real aircraft then the chances of error are very minimal ok.

Similarly, in computer systems we can talk about modeling of hardware components ok, what would be an optimal hardware components ok, hardware components. Then software systems when you design a particular software system how will it actually behave, what is the speed of it. Then modeling and analysis of networks the traffic congestion that aspect of it, database management systems or what popularly known as DBMS etcetera alright these are all aspects of computer systems. Then designing an operation of transportation systems this includes airports ok. Then also includes highways, highways or freeways, then shipping ports ok. It also includes subways or what is popularly known as popularly known as metros and so, on etcetera.

So like for example, in an airport you want to study like for example, in a big airport like in Delhi you, simulation is heavily used to determine which gate should be assigned to which aircraft. And you can see is sometimes the aircraft will get delayed then the entire gate assignment will go for a toss and immediately simulation can provide you a alternate solution quickly.

So, that you can minimize the taxing time of the aircraft from the runway to the gate and also as well as the travel time from the gate to the runway; so that quick take off and quick landing and quick moment of the aircraft, the time to which an aircraft that remains in an airport can be minimized because the job of the aircraft is to fly not to stay in an airport. So, that can be taken care of by so, that is a performance measures that can be built in and you can you simulation to study to make the operations of the airport better.

Similarly, evaluating the design for service of organizations like a hospitals ok, deciding where to put the operation theatres and stuff like that, call centers ok, how many people

are necessary for call centers. You know how to do things like that, then you can study about fast food restaurants. McDonalds is an example where they depend heavily on simulation to study how many counters are to be opened etcetera like that. Post office then border control etcetera control or another common term of this is called customs etcetera alright.

So, these are the aspects of how do we do service organizations. Then business process reengineering, this is like looking into individual business processes, business processes and then suggest improvements or reengineer. So, these studies when you come when you model this. These business processes can be complex business processes can be easily modeled with the help of simulation, and then study the possible improvements and you can quantify those improvements before actually implementing the changes to the actual process ok.

Similarly, the last part is the analyzing the financial this is not the last part some of the major applications in which financial and economical and systems. So, you can study stock market using simulation is very popular tools available now. Then commodities, commodities is includes gold iron silver petrol those kind of things. Various pricing policies ok, then also you can think about studying is you know public distribution systems which we call popularly in India's ration shops ok. The PDS, those kinds of systems can be very well studied and improved with the help of simulation which will. So, by doing that you we will be able to come up with a better approach or better performance measure that would satisfy the objective of the system ok.

So, now, let us talk about the popularity of the simulation.

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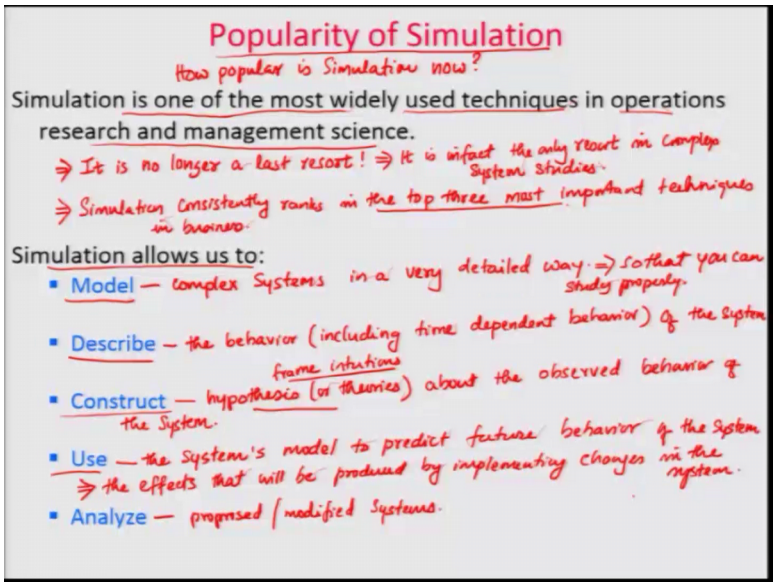

How much popular? So, the question we are going to ask is how popular is simulation is simulation now ok. So, the answer to this question is simulation is one of the answer is very simple, is one of the most widely used techniques in operations research and management science. So, in the over field this is one of the most widely used technique, the main reason is it is no longer a last resort.

Contrary to the earlier belief that people had that when everything fails approach simulation, now it is no longer a last resort. It is actually it is in fact, the only resort in complex system studies complex system studies ok. Now, also just give you some statistics, simulation consistently ranks in the top 3 most important techniques in business. So, we can see that is one of the top 3 most important techniques almost all the time because people are been dependent on it quite heavily for doing better things.

So, what does simulation allows us to do? Why is this technique? So, popular because simulation allows us to model means it allows us to model complex systems in a very detailed way ok. It allows us to model the complex system in a very detailed way, it also allows us to describe the system ok. Describe what? Describe the behavior including time dependent behavior, time dependent behavior describe the behavior of the system that is one other aspect.

Then is the construct ok, it allows us to construct, construct what? Construct hypotheses theses or theories hypothesis about the observed behavior of the system ok. So, it allows

us to frame intuitions why is it like this? Ok, why is it actually do? Why is the system doing this? It allows us to come up with an explanation on the exhibited behavior of the system. It also allows us to use allows us to use what use the system model systems model to predict future behavior of the system, allows us to predict the future behavior of the system, which implies the effects that will be produced by implementing changes in the system.

So, if you build a for example, if you are build a model of a car manufacturer and you say fine as of now I am using the factory and I am producing 200 cars in a day. What would happen if I increase the car production to 250 cars a day? Well we can say that that is it will give leads us to come up with additional raw materials and some more money and some more capabilities. Might not be true, you might when you start do the simulation you will find out the well the current fire suppression system that is created safety system that is created is not sufficient or not capable of handling any issues that happened due to the production of 250 cars.

So, it is not just straight forward you will have to now come up with a new mechanism. And a classic example of this is the Brandenburg airport in the Berlin, where you can know that the when the airport is now being built and when it is completed they are in a situation where the fire suppression system is formed completely inadequate. So, they have to now come up with a option of redoing then their fire system or demolish the terminal building and build the entire thing new which might be cheaper at the end of the day.

So, such kind of really drastic or failure systems can be avoided because if we build a model and use it and study what will happen in future when something is changed in the system. And when you have a reasonably good believable answer that gives you the confidence to go forward and implement the change accordingly. And finally, it also allows us to analyze it allows us to analyze proposed or modified systems ok. So, simulation allows us to model the system, model complex systems in a very detailed fashion. So, that you can study those system why do you model the system? So, that you can study you can study properly ok.

You do not want to experiment with the real system. You want to experiment with a model. You can describe the behavior of the system time dependent. Including the time

dependent behavior of the system you can construct various hypothesis or intuitions about the absurd behavior the system. Why is a system doing? What it is been doing now?

And you can use these systems model that you are developed to predict the future behavior of the system or the effects that will be produced in the system due to some proposed the change in the system. And once you can quantify that then you can go ahead and decide whether to use it implement the change or not. And also it allows you to analyze the proposed or modified systems once you analyze and you can come up with the rational suggestion whether this analysis this proposed change or the modified system is better or worse.

So, now we will get into the next concept which is called as the advantages of the simulation.

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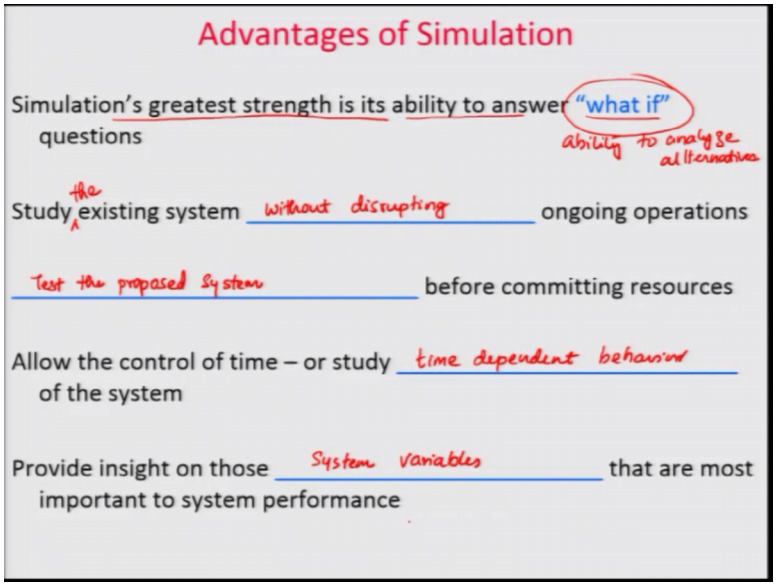

And the biggest thing that we should understand is a simulations greatest strength, why it is one of the one of the top 3 most popular tool. Is it is ability to answer the what if questions what if what if we increase the production from, what will happen if we increase the production from 200 cars to 250 cars? What happen if we change the fire suppression mechanism from the existing one to something else? What happen if we change the current lathe machine which is running at 200 parts an hour to a lathe which can make 400 parts per hour? Will bring profit? Will it improve productivity? That kind

of thing; so this what if questions because if the minute you can answer this that is what is called as alternate analysis ok, ability to analyze alternative ok.

So, these 4 points are kind of important, the following 4 points are important to you guys. Because, once you understand this then it will help you realizing why do we need to do simulation studies. So, the first part it is the study the existing system study the given existing system without disrupting. This is the biggest advantage of simulation without disrupting ongoing operations. Or what you are trying to do is you can study the existing system the existing product system will continue to do the production and then we will we can go from there ok.

And the second part is the second major aspect is you can test the proposed system test the proposed system before committing the resources. So, before committing money before committing people before committing materials you can actually test the proposed the system ok. The third aspect of the simulation is allow the control of time or study the time dependent behavior, these I said earlier also this time dependent behavior of the system.

So, you can study how the system will behave as time progresses and then the last part is provide inside to those system variables. System variables are they describe the state of the system, that are most important to the system performance ok. So, these 4 aspects are one are the advantages of simulation that are so, unique to simulation other than compared to all other studies that are available ok.

So, we will get into the last line and we will kind of conclude today's lecture here.

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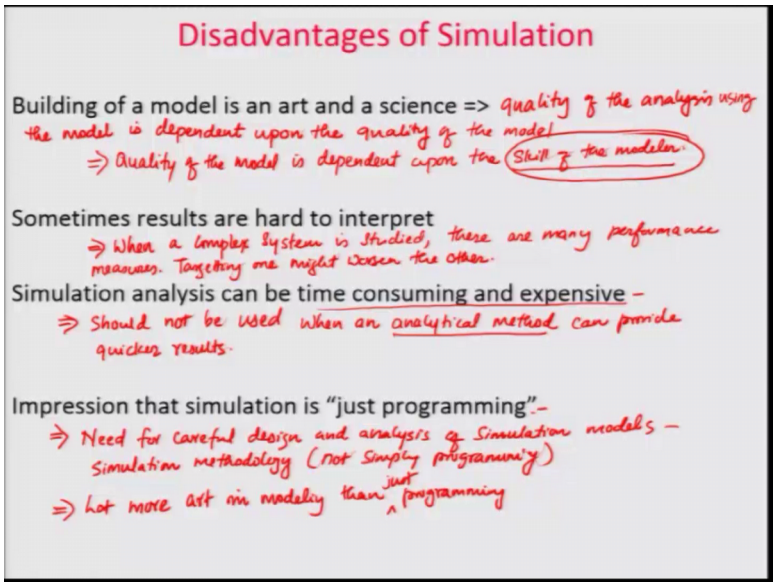

Well obviously, any system that has an advantage it will also have a disadvantage ok. So, the simulation is also not without it is disadvantages and there is there are some disadvantages and let us we will take a look into it. Building of a model or systems model is an art and a science that people make the statement. What does it means? It implies that quality of the analysis quality analysis using the model is dependent upon the quality of the model alright. So, which implies quality of the model of the model is dependent is dependent upon the skill of the modeler the modeler ok.

So, the success of the simulation study or success of building the model is dependent on the skill of the modeler. Skill of the modeler is something so, better skill the modeler is better the model will be so, that is an issue. So, the modeler plays a very important part in the simulation study ok. So, the study is dependent on the skill of the modeler. Sometimes the results are hard to interpret, reason being is when a complex system is studied is studied, there are many performance measures targeting one might worsen the other.

So, an example of this is if you say that I want to minimize the scenario where the machine and the worker should not be idle. So, I want as much as work pieces right next to them so, that they can continue to work. Well, that would ensure that the worker and the machine keeps on working or they are utilize heavily, but then it will also create a disadvantage that the work in process inventory on the shop floor will increase also. The

third fact is that if because you are continuously overworking the worker and the machine, if anything fails then your system will come to a standstill. So, you putting the focus on one particular aspect of a complex system sometimes deteriorates some other someplace else.

So, especially when you are studying very complex large systems, it is very hard to look a to have a holistic view in identifying what is the best thing to do ok. So, that is one of the reasons why sometimes simulation results become quite hard for a individual to interpret and sometimes you require a panel of experts to interpret the results ok. Simulation analysis can be sometimes time consuming and expensive ok.

So, another way is that should not be used, this is a simple rule should not be used when an analytical method analytical method can provide quicker results. So, if you can build a simple model an analytical model or a mathematical model and that can provide quicker results then please go ahead and build the analytical model and use it to get quick results. Do not get in the simulation because it can be time consuming and it can be expensive. That still simulation is time consuming and expensive process, it is compared to analytical method, it is way too time consuming and expensive. So, you should not use it when the models are simple ok.

And there is also an impression that simulation is just programming the lot of people think about it that way. So, trick here is the aspect is there is a need for careful design and analysis of simulation models. There is a careful need for design and analysis of simulation models or what we call as the simulation methodology. So, this is not simply programming ok. So, you need to carefully design and analysis simulation models not just do the program and then call it good in that never works ok.

And there is a lot more art in modeling than programming than just programming ok. So, you have to decide what all things to be kept, what all things to be removed. That kind of aspects are also an important aspect of the of the developmental simulation model that is why I earlier said the skill of the modeler is one of the most important aspect. And it is always a good thing in the simulation and it is also a big disadvantage because, if you have a law in the modular then the model that come out might not be of the sufficient detail and accuracy the. So, if you have a bad model then you get a better result. So, garbage in garbage out is really applicable for simulation as far.

So, I hope now with this overview you guys would have a clear picture of why simulation is an important tool and why simulation is an important. Or one of the three top important tools for people in operation research in management field for managing complex systems, studying complex systems, identifying ways to improve complex systems, Complex systems you will study the system even before it is implemented training provide training to people to operate the system better all these aspects which are very very valuable aspects can be provided by the simulation.

And also I said earlier is an expensive and as well as a process which is dependent upon the skill of the modular. So, any good system will also have it is disadvantages and once you can cover up for the disadvantages by becoming a very skilled and capable modeler then building a complex system will not be a tough thing to do.

So, from the next lecture onwards we will focus on how to build such models, what are the major aspect we need to consider, we will try to learn what is Monte Carlo simulation and then we will go from there. Thank you for your patient learning and continue to read the assigned readings and text books for more information.

Thank you.