Sustainability Through Green Manufacturing Systems: An Applied Approach

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Lecture – 04
Introduction to Simulation

Good afternoon. Welcome to the 4th lecture of Sustainable Manufacturing course on NPTEL and this course is about how do we; we will be able to convert a typical manufacturing system here to a sustainable manufacturing system or a green manufacturing system. And today we are going to discuss a very critical tools that is required to do that analysis it is the tool is called simulation and today’s lecture is about introducing the concept of simulation and later down the road we will be introducing more about simulation and other aspects, we hope that you have some basic understanding of simulation, but you not then we hope the during the discussions, we will be able to facilitate your learning in this regard.

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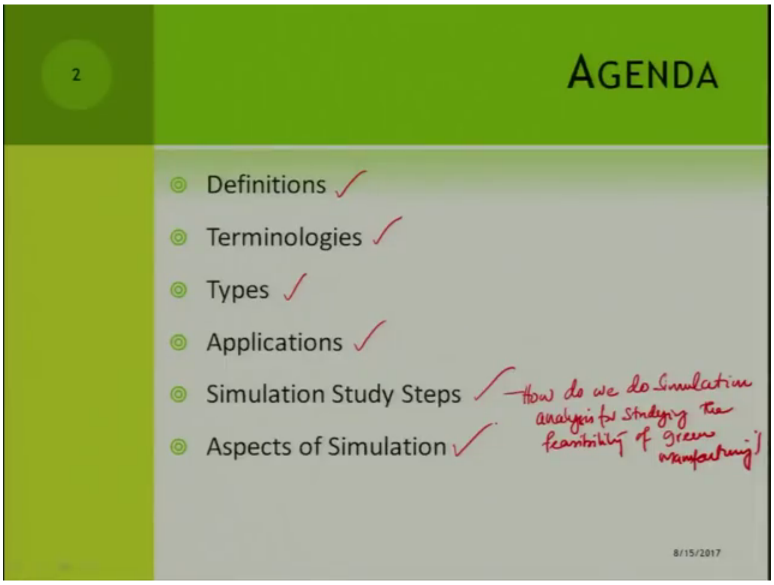

So, the major discussion points today will be include the definitions that are part of the simulation, what are the major terminologies that are used, then that are what are the types of simulation that we use, then we also talk about what the major applications of the simulation where are they applied and what are the steps the study steps or how the question here is how do we do simulation analysis for studying the feasibility of green manufacturing.

So, the this is not a simulations course, but here the emphasis is more on introducing you to the tools and tricks that are necessary to do simulation study tutorial screen manufacturing and certain aspects of simulation also we will study as part of this course.

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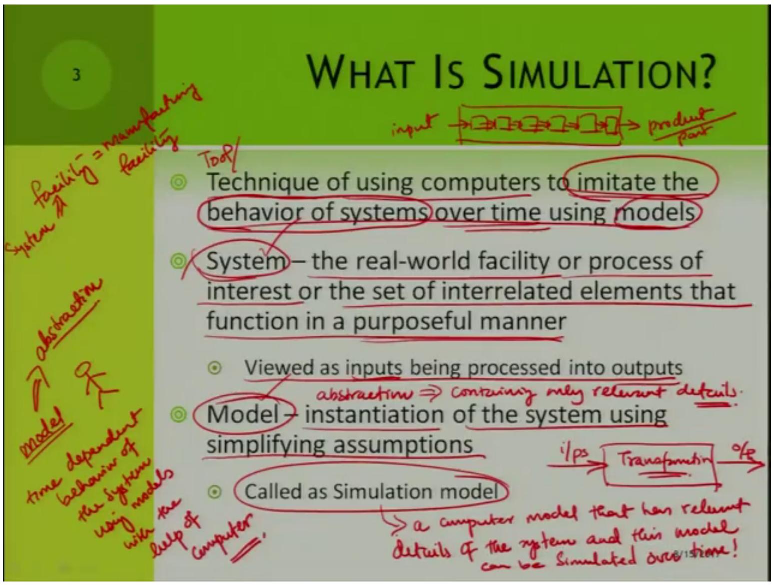

So, let us look into this major first question what is simulation and in the simplest sense this simulation is a technique it is a tool, I would like to use the word technique, but some people also a like to use the word tool. So, it can be a tool or technique tools slash technique of using computer. So, you are using computers to imitate the behavior of a system over time using models. So, the main important concept of this is the first word that you will look into is model. So, model is what is a model? So, typically if I said draw a model of a human being then people will draw like this is a model which says as a head also 2 hands 2 legs right. So, that kind of, but it only shows these are the major aspects it does not say whether it is a male or a female whether is wearing suit or it is wearing jeans or shoes or belt or was a young child all those details are avoided of it.

So, the model is anyway it is a representation or it is in a typical the right word for it is it is an abstraction. So, model is an abstraction of a system. So, when you say model to study the system, the behavior of the system. Then what you doing is you are abstracting the system you are using a model to abstract the system to study whatever is necessary for you and avoid that, but you in how are you studying this you are studying it using computers and how are you studying it you are imitating the behavior you are imitating or you are mimicking the behavior. So, how would the system behave as time progresses and over time? So, the time dependent behavior of the system using models with the help of computer this is what we can a call it as a simulation the technique of doing this or the tool that allows you to do this that is called simulation.

So, when we say system there lot of thing ways this word system is used people talk about systems engineering which is the course that I offered earlier, but here the system when we talk about in simulation specifically for this course we are talking about a real world facility or process of interest. So, when we talk about facility, we are talking here the facility word is synonymous to a manufacturing facility. So, what we are talking here is here is a manufacturing facility and or when we say the system which is of which is a real world facility.

So, the system is a real world facility, which is actually manufacturing facility or in other way to look at it is a set of interrelated elements that that function in a purposeful manner. So, you have lot of interrelated elements. So, when we draw the transformation process if you are remember this we had a diagram like this and we did different processes by rectangles and we connected them by lines and we said these are interrelated processes or these are processes that are connected in some logical fashion. So, that when you have the input from one side the form of raw material energy and etcetera you get a product, which is an output or a part which is what you required comes out of the other end.

So, this because these are interconnected in a purposeful manner the purpose is to produce a product or a part or it is viewed as inputs being processed into outputs. So, various inputs goes into the system and there gets processed into outputs. Hence this is why we earlier called it as transformation processes the inputs go in outputs come out, these are the inputs these are the outputs and here is a transformation process.

And in this course we are actually trying to study the transformation process using computer models and try to study the behavior of the this transformation process over time how it behaves as time progresses is what we are trying to do.

So, as I said earlier model is an abstraction of a system. So, model is in a instantiation; instantiation can also be called as an abstraction. So, in this case what we are talking about is you are studying a particular view point of the model, if you are talking about a factory you might not study the details of how the walls of the factories painted may not be of importance to you. So, you may not you may not study the floor the type of flooring that is used in the factory, but you definitely studies that type of machine that is used in the processing speed at which the machine operates is of paramount importance to you.

So, when you say an instantiation of subtraction abstraction which means containing only relevant details you only focus on the relevant details that is relevant to you for the study; so, the relevant details of the system using simplifying assumptions. So, you take a assumptions you are like I do not care about the color of the paint, I do not care about the type of the floor, I do not care about the type of the particular machine that is used.

So, the things that are that you do not consider that are important are eliminated and things that are considered important are kept like the processing speed of the machine, the amount of electricity that is used the type of coolant that is used all this aspects are considered as part of the model and when you create such a model then it is called as a simulation model. So, a simulation model is a computer model that has relevant details of the system and this model can be simulated over time; which means you can see how the model will behave you can use his computer program to study how the system will behave as time progresses or you can study the time dependent behavior of the system. How you guys are clear with the idea of simulation and the concept of simulation.

So, we studied that it is a technique of using computers to imitate the system behavior and we see what is a system and we see what is a model and why is this model called as simulation model compared to the typical model. We talked about the concept of abstraction which contains the; which means creating a model that as only the relevant details that are that are relevant to the pertaining study.

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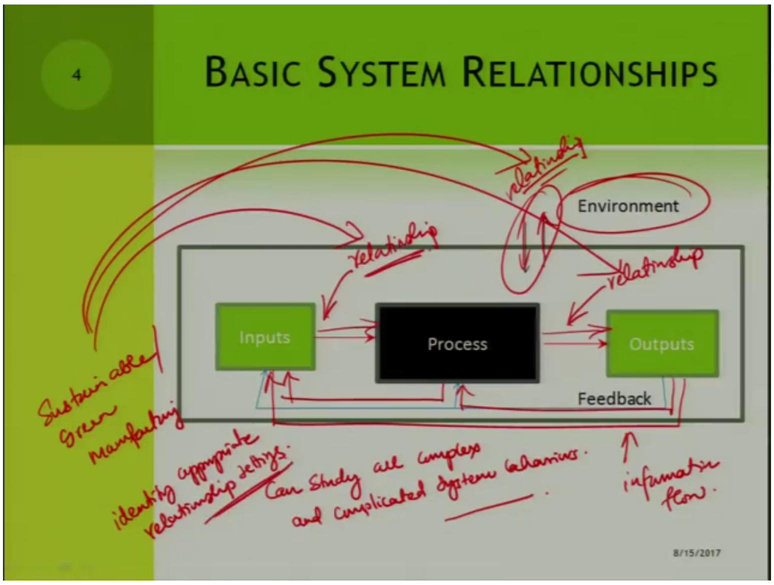

So, in a simulation system if you look into it the basic system can be represented in this 3 box sometimes people call it as a black box that is why we choose a black box here. So, the inputs are given into the system and then it the process is somehow manage the inputs and they translate this process is into outputs, within which you have feedback; sudden feedback will be going from the output to the process certain other feedbacks will go from the output to the inputs, sometimes their feedback that goes from the process to the inputs, these inputs process and outputs together along with the interaction of the environment the external environment put together. So, having such a capability to study all these things using one computer model is a phenomenally powerful tool their need is can study all complex and complicated system behaviors.

So, creating such a scenario allows us to study the system relationship. So, here we can study the relationships of input and the process, here is a relationship of the output and the process here is the information relationship. How is the information flow happens and how does a system deals with the environmental here is another relationship the environment how does it behaves, these type of different relationships can be studied very well using the simulation system. So, these and the aim of studying or aim of trying to make sustainable manufacturing is. So, when we say when you want to make it as a sustainable or green manufacturing, the aim is that you are able to study all these different relationships and set the relationship. So, identify appropriate relationship settings this can also be the study can also be thing through in a particular fashion like this.

So, as I said earlier we studied what is a system and there are different ways you can look into the system.

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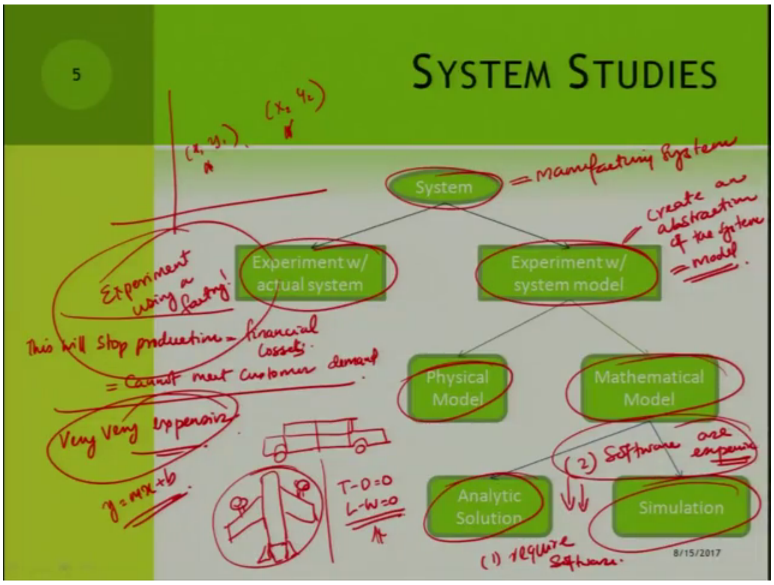

So, if you look at into this tree a system as I said earlier is any in our case it is any physical system, in this case we are actually focusing on a manufacturing system that is of important to us. So, in a manufacturing system you can do 2 studies in 2 ways, you can experiment with the actual system that is Experiment using a factory. Well there is nothing like it is actually a great tool to study what is in the point is when you doing the experiment you cannot on the production. So, the major disadvantage of this is this will stop production, which means financial losses or other way to talk about it is you cannot meet customer demand because of all these reasons doing experiment with the actual system.

Second part is it is very expensive very very expensive because of all these reasons experimenting with the actual system is not really a feasible solution. So, if you want to study about how to convert this particular automotive factory. So, you walk into Maruti Suzuki and says look I think I have a really good way to convert your factory to an sustainable or a green facility, please give me your factory for 2 months let me do experiment on your factory and I will tell you; what it is I do not think anybody will do that because the expense they because the underlying financial expenses that are associated with doing something is humongous.

So, experiment with the actual system is not really possible in this specific thing that we are talking about it is possible in many cases like for example, when people talk about developing missiles or bombs or something like that yes then you do actually experiment with a system you create a bomb and then you drop it and study the damage which is called as bomb damage assessment and see whether the bomb has sufficient efficiency to meet the requirements as a weapon and extra like that. But in manufacturing you can this cost prohibitive and the size of the system itself is huge that is prohibitive that you end up you never really do experiment with the actual system or early do it happens then what is other alternative.

The second option is experiment with the system model so; that means, you create an abstraction of the system this abstraction is called as a model and use this model then use it to do your studies this is. So, this process is actually this modelling and doing the experimentation with the model is to a large extent and when you study to our time then is where you actually become a simulation a simulation is a subset of this. So, when you say that I am going to build a model of this there are 2 ways you can actually build the model of that; one option is you can pick the Physical Model.

Physical Model means like for example, if you are saying that I am going to make a physical model of a car then; obviously, you can say that here is a physical model my car my look like a bus, but yes this is the idea you make a physical model and then you say I am going to take this and study at (Refer Time: 16:26) a run it in a (Refer Time: 16:27) study the a fuel efficiency and all those kind of things or they drack coefficient stuff like that that is one aspect of doing a physical model.

Another example is a mathematical model. So, when you can another example of a physical model is talk about is an airplane. So, if you look at an airplane from the top view. So, you have like a tail here is a tail and you have 2 wings like this and I am just talking about a fixed wing aircraft with 2 engines running here this is you are looking from the top this is a physical model, you can also talk about an any flying condition, you can study it as a system where in which you have a thrust minus drag equal to 0, lift minus weight equal to 0 and you say any system that fulfills this conditions will also fly.

So, this is a necessary condition for flying and here is a physical model that will achieve the same thing of flying. So, you can study the system both basic you can create a physical model or you can create a mathematical model and in a mathematical model you can create an analytic solution analytic solution means you can actually solve the problem using a, like for example, if you say y equal to mx plus b, then is a mathematical model and you can analytically solve this problem you can try to find out if some details given to you can find the slope and the intercept of this and then you can say this is the equation of the line.

So, if you are given a Cartesian coordinate system at you are given 1 point and another. So, this we call it as x 1, y 1 and you call it as x 2, y 2, then we know how to make the equation of the line using these 2 points, take any point in between x and y we studied this geography. So, that is and then you can solve the problem analytically or you can actually solve the problem using simulation and for simulation if you trying to solve with you require a specific software typically simulation softwares. The problem of using simulation is that it number 1 is it require software and second one is the software or software are expensive well; obviously, not as expensive as this is extremely very expensive they are expensive, but only a fraction compared to this particular expensive. So, this expense is very much lower compared to experimenting with the actual system.

So, I hope you understand how the simulation studies are; where would the simulation studies fall under the big schema of things.

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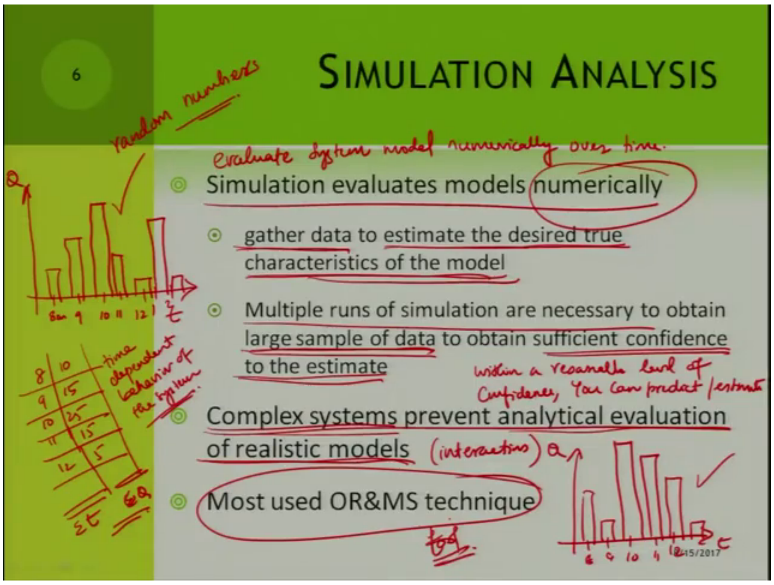

So, when we talk about simulation analysis. So, the simplest way to think about simulation is that simulation evaluates models numerically or we can say that numerical study of the system model. So, when you evaluate system model numerically over time then that is basically a simulation. So, what happens is when you do this numerical evaluation you collect data, you gather data, and you estimate the desired characteristics of the model. So, what happens is that if you think about a system and here is a time and here is the quantity that you are going to produce Q let say called as a quantity to be produced and ask time progresses in a day different hours at let say this is 8 a m 9 a m 10 a m 11 a m 12 noon 1 2 like this. At 8 a m you might be producing this much quantity, 9 you may produce this much, 10 you may produce this much, 11 you will only produce this much, 12 you will only produce this much let us say 1 ‘o’ clock you produce this much, 2 ‘o’ clock you produce this much like this.

So, you as the time varies your now quantity that you are producing also varies, but then if you want to find out what is the average throughput of the system then you basically can take all these times and then. So, if you say that I produced at 8 a m if you look at it you produced 10 units, 9 a m you produced 15 units, 10 a m you produced 25 units, 11 a m you produced 15 units, then 12 ‘o’ clock you produced 5 units something like this. So, if you look at this then if you sum this total time sigma t and here is your total quantity sigma Q and then you can easily estimate what is your average production and those kind of things.

So, this is the time dependent behavior of the system and when you study this and you find the time dependent average of the system. So, that you can estimate the characteristics estimate is an estimations not the true value, you can estimate that you can say to a reasonable degree of accuracy; I am confident that the system will behave this particular fashion that is what happens. So, you gather data and use the data to estimate the desired true characteristics of the model and another part is multiple runs of the simulation are necessary to obtain large samples of data for sufficient confidence to the estimate.

So, when do a computer study it one or the big aspects of simulation is it uses the concept of random number streams or random numbers. So, when you are dealing with the random stuff you cannot really say that here is one particular simulation run and here is how the system is going to behave, you create multiple runs you use the computer to create study the multiple random number numbers use or multiple streams of random numbers you use. So, next day when you look at the time dependent behavior of the system it might look like this here is your Q here is your t and here is your 8, 9, 10, 11, 12 etcetera and here you might have a 8 like this, 9 like this, 10 like this, 11 also like this, and then 12 also large 1 ‘o’ clock is small something like this that can also happen.

So, depending upon the way you look into the system the time dependent behavior can change. So, if you have multiple time dependent behaviors like this and you average them over, then you can actually create large sample of data or large different instances of data from their sufficient confidence can be given to the estimate or to you can say that within a reasonable level of confidence you can predict or you can estimate the characteristics of the system. So, that is the important aspect of this and why do we do this time dependent behavior the numerical estimation, why do not we do analytical because the issue is this the complex systems prevent analytical evaluation of realistic models.

So, like for example, in a factory the raw materials keep on arriving as time progresses, in a typical analytical solution you have seen that all the raw materials are available to you before we start the production in real life scenario rarely happens the raw materials keep on arriving throughout the entire day. So, that type of a phenomena to be studied can require simulation rather than the analytic model because the complex system has so many complexities the major complexity are the interactions of different contractions back and forth which are important to study and cannot be really study through analytical evaluation.

So, that is the reason why simulation is heavily used and it is also one of the most heavily used OR OM tool or a technique. So, one of the heaviest used operation research tool and technique is simulation which allows you which provides you a really good way of studying complex systems.

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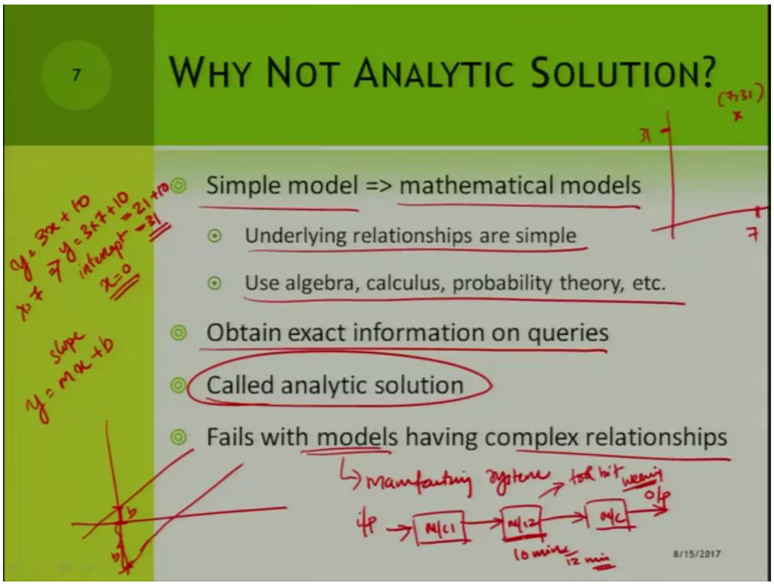

So, as I said earlier complex systems analytical solutions are difficult, why it is why not analytical solutions people will keep on asking this question what prevents from doing it is. So, the simple models usually if you think about it is mathematical models are can be thought about as simple models and mathematical model works very well in simple systems because it has underlying relationships are simple. So, if you say y equal to Mx plus b as a equation of a straight line, then it is y is dependent on 2 things actually dependent on the slope and the intercept the intercept is important because it tells you which way the where the line begins. So, if you think about this we can draw a line 2 different line with the same slope exactly same slope.

But both of them have 2 different intercepts here the y intercept y intercept is intercept is a place where x is equal to 0. So, here is your y intercept here is the value of b, in this case the value of b is this is your y intercept in this particular case. So, what I am trying to say is that for simple systems mathematical models work very well they do wonders actually and you can use algebra calculus probability theory etcetera to actually solve this kind of problems as well and you can obtain exact information or exact out, exact numbers, exact numerical values.

So, if I say y equal to 3 x plus 10, then I can exactly find the value of y for any given value of x if I say x equal to 7, then I can say that it is y equal to 3 time 7 plus 10, which is equal to 3 times 7 is 21 plus 10 that is equal to 31.

So, for the value of for a particular case when the value of y x is equal to 7, then y will be 31 and you can find out that is a particular point. So, we can take it in a Cartesian coordinate system and somewhere here this is 7 and here let say is 31 then you can say this is the particular point that we are talking about it is 731 something like this. So, that type of models actually work beautiful in the case of simple systems and such solutions are typically called as analytical solutions and these work in simple.

But with the complex systems or complicated models or like models like a manufacturing system where there are so many complex relationships are included then such study this is not really a efficient way of doing the analysis like for example, let say you have a factory in which you have 3 machines connected in series. Let us call this as machine 1, machine 2, and machine 3 and input comes from here and the output goes out of here and what happens is as time progresses let say this particular machine the tool bit wears. So, the tool bit wearing. So, as a tool bit sharpness reduces the rate at which the metal removal also reduces.

So, the rate of production of this machine might not be the same as time progresses it may reduce, if it says in the initially the first the fresh tool, it will take let say 10 minutes for a fresh part after some point of time it may take 12 minutes. So, then you are in trouble because of that because the in the mathematical model you assume to 10 minutes, but as time progresses it change to 12 minutes. So, that type of a complex relationships are quite difficult to model in a mathematical model and hence that is a reason why we use do not use analytic solution to study complex systems.

So, another aspect is also that is important about simulation is what we call as feedbacks because lot of the system especially in a manufacturing system it works on feedback.

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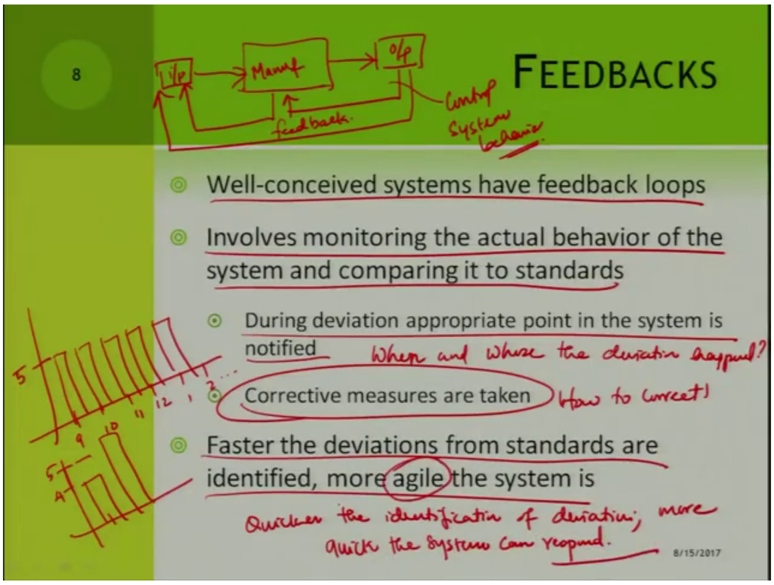

So, a manufacturing system or any well conceived system will have a feedback loop. So, if you remember the diagram earlier that we drew this is the if you think about this is the input, this is the output and if you call this as the manufacturing the inputs gets here, output goes here, and from output some feedback goes to this and some manufacturing some feedback goes to input and from some output some feedback goes to input we studied this. So, any good system will have a feedback loop because this feedback is important this feedback is used to control the system, control system behavior.

So, because of this why is this feedback important or what we call this as the feedback why is this important the feedback is important because it helps you it involves in monitoring the actual behavior of the system and comparing into the standards.

So, if you are saying that I want to produce 5 units in every hour, I want to produce 5 products every hour. So, ideally speaking your production should be like this 9 a m, 10 a m, 11 a m, 12 noon 1 2 like this as the time progresses and here is your 5 and the production should be like this 9 it is 5, 5, 5, 5, 5 like this consistently you should be producing 5, but rarely that happens certain times what happens is at 9 a m you are only able to produce this is 5, you only produced 4 so; that means, that 10 you have to actually produces 6 to make it to the average of 5. So, this kind of things so as happens is you it allows you to it this feedback tells you that fine you did not meet the mark of 5. So, you need to produce more. So, that is a feedback and that allows you to ensure that you maintain the standard or you achieve the desired output or throughput in this regard and by monitoring this you are able to identify appropriate point in the system when the deviation happens the question here is when and where the deviation happened and how do we correct it.

So, this question is important to this and the corrective measures how to correct this is important. So, if you say that I want to reduce them or minimize the usage of energy, then using simulation you can find out are you reducing the usage of energy or you are not; why is the energy is being increased and find out the reason and take corrective steps to do that. So, the most important thing is for a system the quicker you can identify the deviations. So, quickly quicker the identification of deviation more quicker, more quick the system can respond such a system is called as an agile system agile means it can quickly respond to any change in the system.

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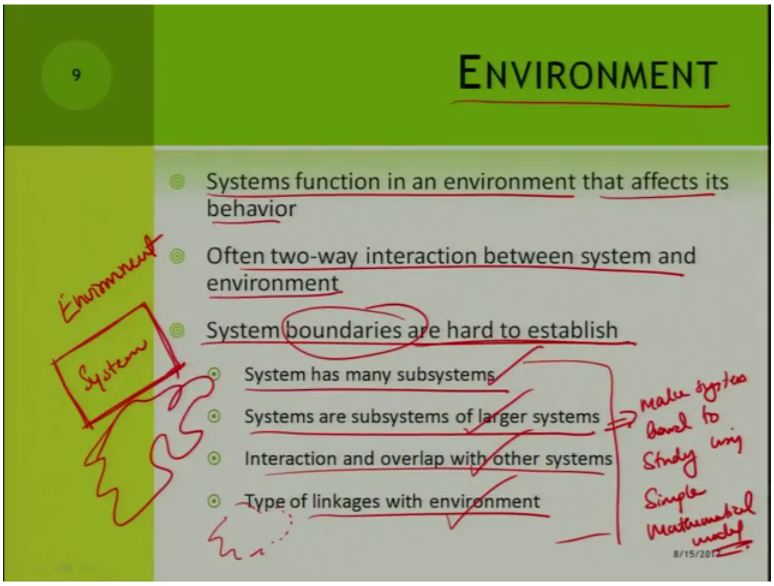

Third part that we talked about this the model when we drew the black box is the environment or environment whichever way we want to talk or call it. The important aspect of this is that any system that functions in an environment for any manufacturing system, you know the environment do affects it is behavior as we said earlier there are certain environmental drivers that actually force the manufacturing system to Upbre to accept the concept or you know bring in the concept of sustainability into them the earlier traditional model what city was about cost time and quality was the model and now the environmental factors are also been put into the system.

Typically the environmental are always to 2 way interaction between the system and the environment, there is a you are always taking in some information and you are also giving something back. So, like for example, you are taking raw materials from the environment to the system and then you might be giving the carbon dioxide out stuff like that. The reason are this environment if you want to study the environment mathematical models are hard because the first and foremost important issue is system boundary is hard to establish, in a cage you can actually draw a box and say this is the system and everything outside this is the environment or environment, but in reality it is easy to draw a box like this, but the real boundary of the system might be something like this it might be some place it could be something like this and some place it might be broken boundaries.

So, the boundary of a system is very hard to establish and once it is very hard to it is a because the reason is system typically has many subsystems as we remembered in the earlier lecture we had said that a factory can how multiple production lines inside it. So, there always many subsystems in there a factory will have something called as a heating and a cooling system, they will have now material movement system and an over can crane system, there is a safety system, there many subsystems are in a part of a system and systems are and always systems are subsystems of larger systems like your; the factory a of a big company there may be 5 factories of the same company.

So, then the; and that are 2 5 different geographical locations that is also another aspect and systems do overlap among each other there is no hard boundary a between systems sometimes boundaries do overlap and there is definitely linkages with the environment. So, all this kind of factors actually make systems hard to study using simple mathematical model. So, having many subsystems system being a subsystem of a larger system the interactions and overlaps with the neighboring systems and as well as subsystems and the linkages within the environment all these factors together contribute to the complexity of the system, because you cannot clearly establish the boundary of the system and since you cannot establish the boundary of system clearly or hard to establish it you cannot really come up with the closed form mathematical model to do this.

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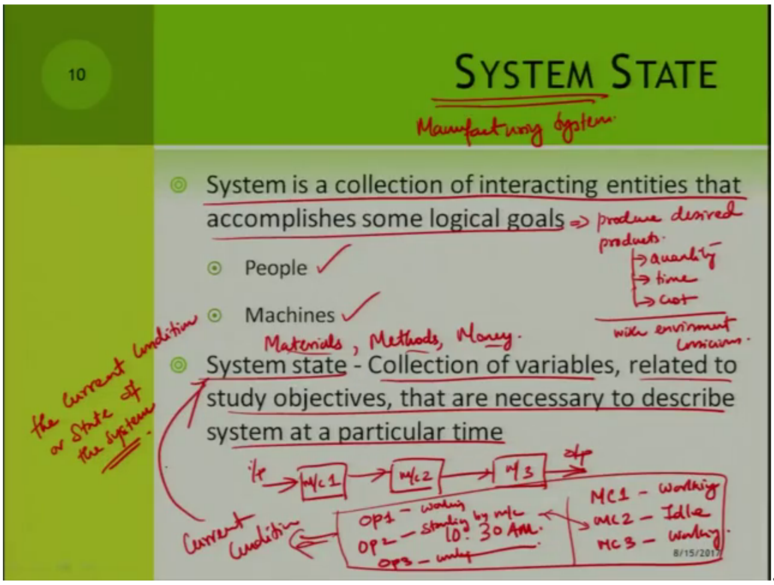

So, with that we will get into the next big concept of simulation which we what we call as the system state and as I said earlier in if you look at the a for us this system is a manufacturing system. So, it is a for us this manufacturing system is a collection of interacting in it is that accomplish some logical goals, in our logical goal is produce, desired, products, you have to produce it in the right quantity, produced at the right time, at the right cost, and now we add as with environment conscious that is the important the logical goal for us and to do this we have people we have machines and we have materials, we have methods, we have money etcetera. So, for the time being we are basically looking at people and machines to begin with and then we will look into materials methods and other aspects later down the road.

So, there are the many aspects to the system many interacting entities people machines materials methods money they are all interacting entities. So, when you are looking into a complex system like this, when you say price call system state, what are you mentioning is that you are trying to study the current condition or state of the system current state or condition of the system? So, when you say the current state or the condition of the system then you are basically it is a collection of variables related to the study object is that are necessary to describe the state system stated a particular time.

So, if you let say you think about a system in which you have 3 machines. Machine 1, machine 2, machine 3, and parts flow through the system you have your input you have your output something like this and that 10: 30 AM. If somebody says what is a state of the system and I say that machine 1 working, machine 2 idle, machine 3 working. If I say that then what happens is machine 1 is doing some job, machine 3 is doing some job, machine 2 is idle, or it is not doing anything why is it not doing anything machine 2 could be broke down it is going through preventive maintenance or it is waiting for a part or the operator has gone for a bio brake there could be so many other aspects of it.

So, then you need another variable call operator status. So, the operator 1, operator 2, operator 3; so, when you say that operator 1 working, operator 2 standing by machine, operator 3 working. So, then the operator 2 is bright by the machine the machine is still idle. So, then you may it might be either broken down or it could be a situation where the parts are it is waiting for parts to be arriving there something like that and so such kind of a study when we talk about these where you would require.

So, then you would require many more variables to completely describe the state of the system. So, such variables all of these variables put together they together describe current condition and this current condition is called as the system state, and system state is an important thing in any simulation because you always study the system at different time intervals at different time points that discrete time points and that system state is averaged over the time to come up with an average behavior of the system and you repeat the study many times and once you repeat the study you are able to achieve what we call as very good estimate where highly confident estimate about the behavior of the system.

So, I hope that with this you have a fairly average reasonably idea about simulation the beginning the concepts of the simulation we will continue this lecture in the next class. So, this is the part one of the simulation lecture. So, we will take this up in the next class.

Thank you very much.