Rapid Manufacturing
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Lecture – 43
Rapid Product Development, Technomatix (Part 3 of 3)

Good morning, welcome back to the course I am Dr. Amandeep Singh and I will take the plant simulation Technomatix in this lecture.

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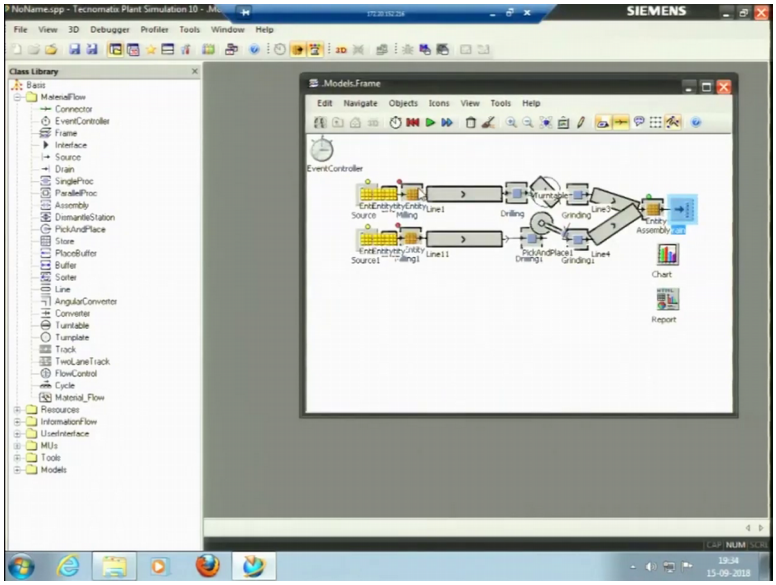

I like to talk about the distributions I have just opened this milling process, the processing time is 1 minute. If a put uniform distribution uniform distribution you know that is also known as rectangular distribution. So, where we have just this start and stop we have the minimum and the maximum value and we know that the value would lie between these two values we do not have much information.

So, a uniform distribution and triangular distribution and beta distribution these are sometimes known as the lack of information or lack of knowledge distributions. Because we do not have much past knowledge we just have 2 or 3 or 5 or a very few number of observations and we do not know what a distribution would it follow. We have just a

minimum value and maximum value we do not know what is happening in between. So, we just pick this rectangular distribution.

If you remember if you know the rectangular distribution is just we have a value and b value that is all. So, it is showing if we have to put it in it this way stream, start and stop. So, I will just put start and stop let me say the minimum time is 2 minutes and the maximum time is 3 minutes ok. So, this is there now I have just put start and stop I have not put any stream. What is stream? If we know about random numbers stream is the seed of the random numbers.

So, when we talk about a simulation what is simulation? Simulation we are trying to imitate the reality and what is representing the reality? What is representing our actual real objects or subjects it is the random numbers. Random numbers which you are working on. So, where does our random numbers start from for the specific so that is a stream.

So, if we instance for there are 2 processes I put the same stream here same stream means the random number would start from the same seed and the successive random numbers would be same. For instance if I put the seed value 2 here in one process and seed value 2 here in another process so, the 9th random number that is selected in this process and the 9th random number that is selected in this process that would be same 9th 5th because a seed is same. So, the successor random numbers would be same. So, it is recommended to pick a random seed not I would say random same at least a different seed for different processes to have the good simulation process.

So, if we do not put any stream value here, the software would pick a stream value by itself ok. So, I am not picking any putting any stream value, that I have just put uniform distribution. So, we know that the minimum time would be 2 or let me say the time varies from 2 minutes 50 seconds to 3 minutes. We know that this is the minimum this is maximum ok. First I will talk about triangle distribution. Triangle distribution is actually sum of 2 uniform distributions, 2 uniform distributions are there, 2 uniform distributions means uniform distributions means, but this does have this smallest value and the largest value we do not know what would happen, but in triangle distribution we have 3 values we have the smallest value, we have the largest value.

But we have the one value that is in between, but repeating for the maximum number of times it is repeating from maximum number of times that the value is mode what is mode? Like mean, median, mode is their mean is the central value median mean is actually the average of the values, median is the central location value; mode is the value that is a maximum frequency ok. So, here we can put if I pick the triangle distribution it is showing stream c, a, b. Here a is the smallest value, b is the largest value, c is the mode value that is that is the repeating for maximum amount of time when it is repeating I am talking about the past data in the past data I have 5 or 6 observations I know this is the minimum value this is the maximum value, but there is one value which is which is trying to repeat maximum number of times.

So, I can pick the triangle distribution. Based upon the past data if I have a lot of observations in the past I can pick normal distribution if that fits good here. In normal distribution is asking for its parameters the normal distribution. I would say normal distribution statistic it is asking it asking for stream not is asking from mu and sigma. Mu is the mean or average sigma is the standardization also it is calling for the lower bound and upper bound; lower bound is the minimum value and the upper bound is the maximum value within which our distribution would lie.

So, we should have the knowledge of the distribution as I said the softwares are GIGO Garbage In Garbage Out. So, if you put the right distribution and you have the right numbers and we having the results of the simulation very close to the realistic conditions. So, this is the work of a systems engineer to design it in a proper way. So, if I change this time you can see I do I do not apply because it is because it is showing you know if I do not put it in a proper way, this is stream mu sigma I am showing the value of stream it as aspect, I was showing the value there is 250 and 3. The value of mean was smaller than sigma so, that is why it said it is showing the negative value it is not accepting would not accept any other format than is required.

So, let me pick just constant time here and it was just to make you understand the properly, it was 1 minute I will apply. So, let me see if I run it for an 8 hour day and try to see the throughput open you try to see throughput if the throughput part it is 1167 per hour is 48, and the total throughput is 389 for an 8 hour day for 8 hours ok. Now, if I change the processing times open, if I change this processing time to let me take 2 minutes and I change this processing time also to 2 minutes. In actual conditions we

cannot change the processing time the processing that is has to take it would take the milling it has to if it has to take 2 minutes unless, we change the tools we change the machine or we have the CNC machines or advanced machines we cannot, but work on more on the processing times.

So, processing times are fixed yes in the plant simulation or in the manufacturing simulation here we can think of working on the bottlenecks the processing times are fixed. We can think of designing the layout in a way that the material flow is minimum; and that the total time taken is minimum total time taken would be minimum; that means, the total throughput would be the larger ok. So, if I change this time now I have increased the time to 2 minutes, now I run the process and let me try to see the throughput here. You can see the throughput was larger before. So, it has reduced now because the processing time is increased ok. It is 582 pieces per day 194 pieces in a 8 hour day ok.

So, also we can have this setup time as well for instance a work piece is to be manufactured it will take 2 minutes for processing and 1 minute for setup. 1 minute for setup means for instance some milling is happening if you are milling process and what do we do? We just rotate the tool and remove the material.

So, it is removing the material from one work piece, this is 2 minute process after 2 minutes the machine stops this work piece is taken off and a new work piece is brought in here that is the raw 1 and it will start process on this. Now this setup the setup takes 1 minutes here. So, this is setup time this is setup time this is processing time if I induce such a setup time as well and apply let us see what happens too much throughput now. Only in one line I have put some setup time. So, the throughput is further reduced here it was 97 pieces. So, it is 194 pieces now ok.

Because the set up time is there now another 1 minute is being taken. So, total time taken in the milling process in the line 1 is 3 minutes now ok. So, this was a brief introduction about the software the major or the main objects that we can use, now I will pick some examples I have some examples for you to show you different layouts. And also the experiment manager will use we will try to see to see the simulation that we can do in the software. So, this is continuous material flow I will select 2 lane track here. So, traffic circle or segment table traffic circle pick and open the model ok.

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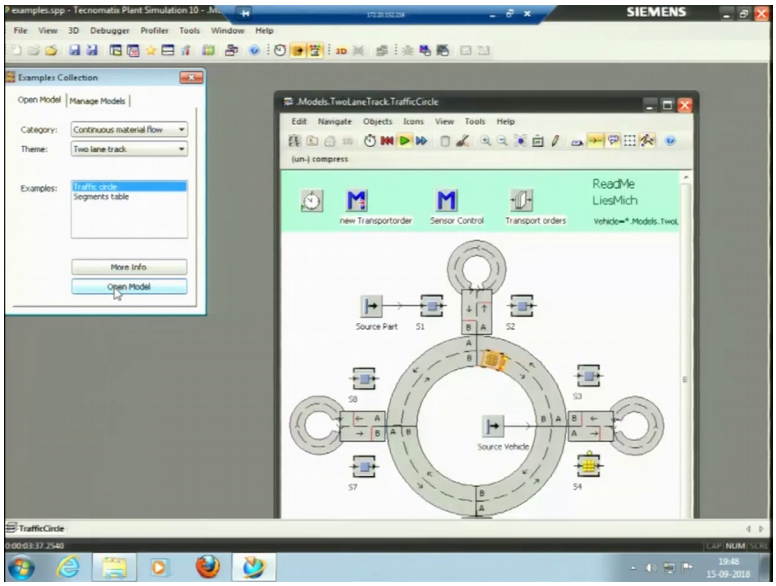

So, this is the model it is already running. So, I will just run the model you can see this is the trolley that can pick our material from. So, this is source part some processing is being done here, I can see what is the time of the processing here the times is constant 1 minute. So, you can see it is happening I will make it a little faster. Control panel I will make it a little faster and then run ok. This trolley is running; trolley is continuously running through the tracks this is actually about 20 times faster.

So, the processing is happening it has happened for the 9 minutes, it is not stopping. So, what is the setting? So, there is no end time. So, it will continue for the infinite time. So, this is a kind of a just a cell in O cell ok. So, cancel stop. So, segment table open model. This is the saying a track how the track is built? So, let me pick you choose user interface dynamic statistics, display panel or chart open.

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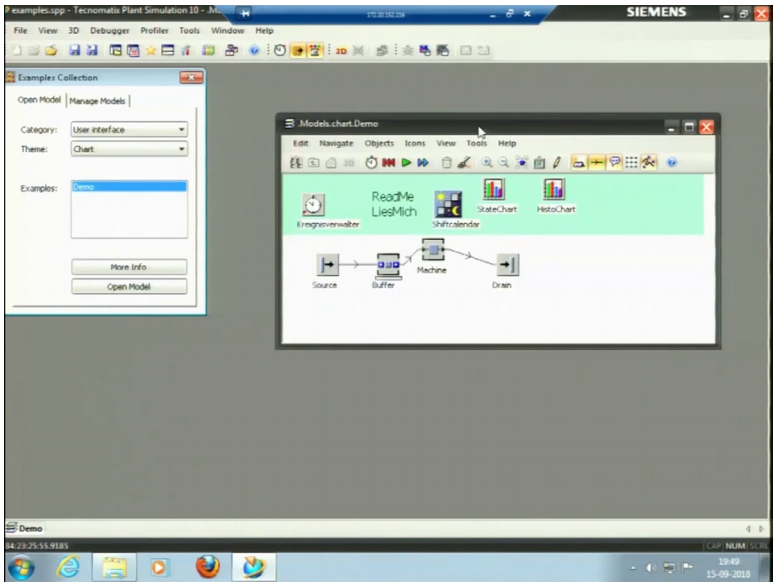

So, it is model we can see the chart, what is setting there is no end time I will put the end time here 08 00 00 apply, let me try to run this model. So, it has run for one day. So, entity buffer is there, entity machine is there this is similar to that. So, we can see the charts here show chart.

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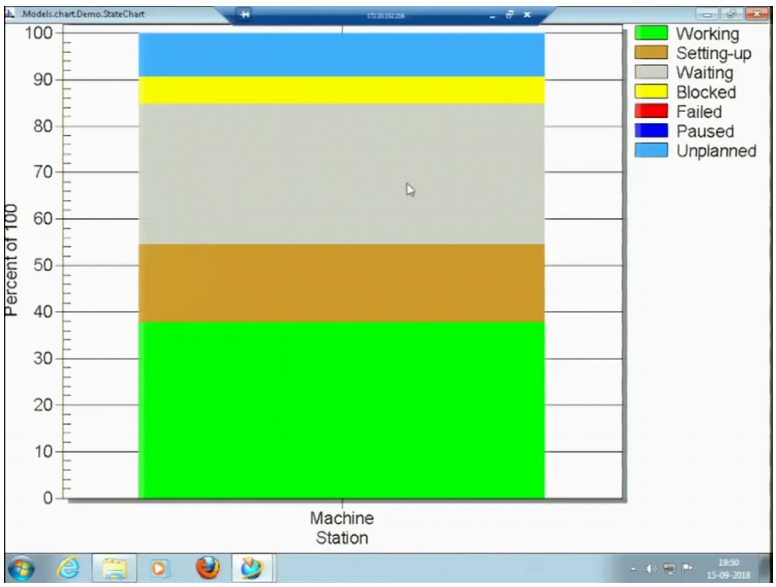

So, for only one machine, it is showing the charge that this is something unplanned blue color is unplanned then we have blocked then have we do not have any failure here we have this waiting time for the about 37 percent of private has been working. So, this is

another example ok. Then tools and optimization the important is experiment manager, I will just pick the buffer line optimization this is line comparison open model.

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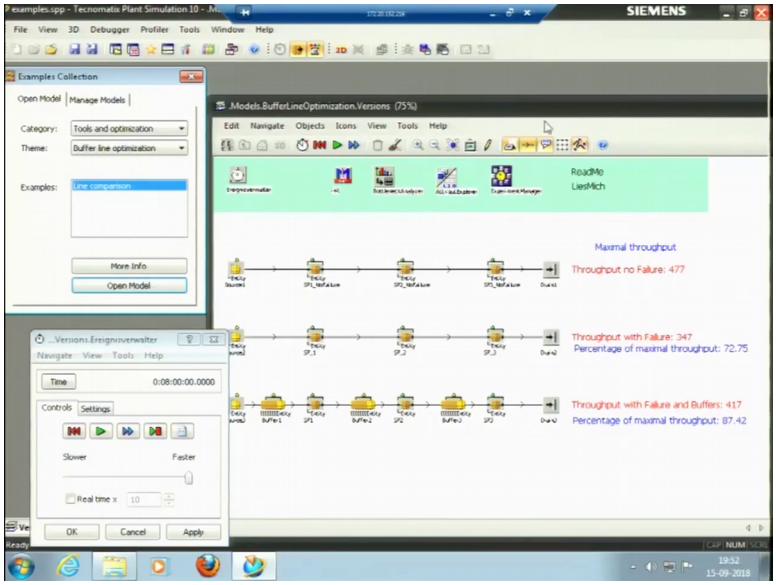

So, in this model what we have? We have 3 lines in this line their throughput with no failure this is throughput with failure with throughput with failure and buffers. So, there is a their buffers kept in between, if I enlarge it this is buffer, this is another buffer. So, a backup buffers in between, this is throughput we need to see throughput with no failure another line is throughput we have put some failure rates here ok. If I see the failures it has 90 percent failure; 90 percent availability it is 10 percent failure, in this case there is no in the first case there is no failure ok. So, let me try to run this model yes. This model has run for an 8 hour day.

So, for with no failure, the PC's those was produced in a day or 477, with failure it is 347, but because failure is there we have put the buffers in between that can store some of the material. So, it is about 417. So, also it is giving the percentage of the maximum throughput; maximal throughput is 477. So, it is with failure we have 72 percent and with failure and, but with buffers we have 87 percent of the throughput of the maximal value ok. Then I can then in resources, I can see broker and animation. So, shift calendar worker I will show you a worker introduction worker introduction model.

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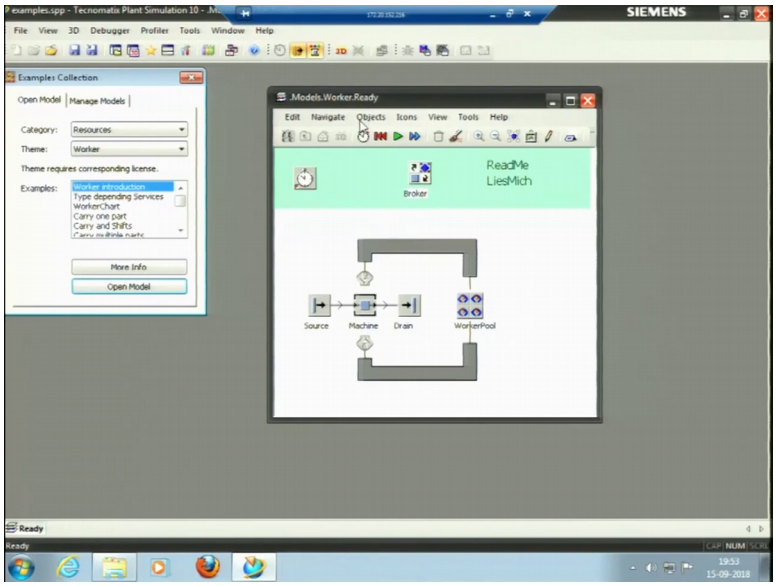

So, this is the worker introduction model. So, in this case you can see the workers are just introduced into machine and if we run this let me try to make it as a little slower, apply now run you can see the workers who are running it. So, I can see the number of workers are 2 here and work pool is there and the broker is there, broker is trying to distrib.ute the work to different workers ok. So, this is one of the example then ok. Let me come to the major simulation thing, that is the experiment manager to the optimization experiment manager.

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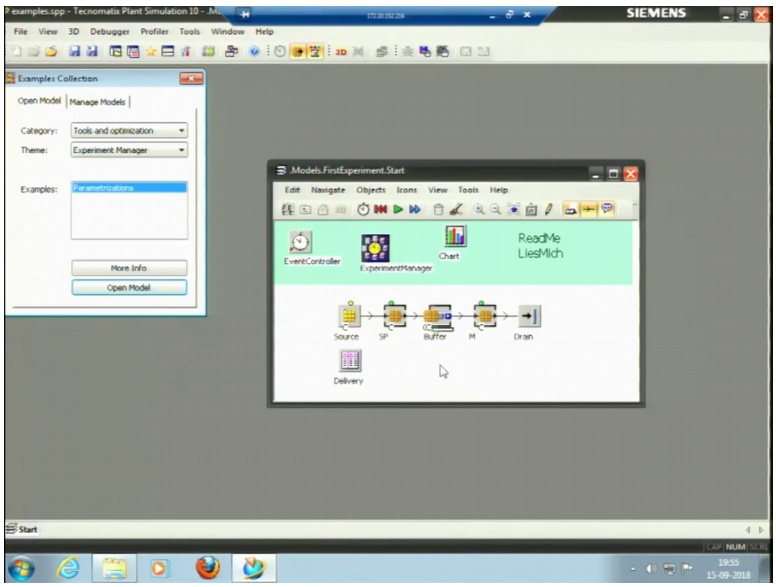

This is the one of the models where we have experiment manager; this experiment manager can show the simulation ok. If I run this model for it let me open this experiment manager first it said definition and evaluation. In definition we have defined the output values; output value of the workstation portion start field portion it is working and failed. So, what output do we need and what inputs do we have? Input is the route delivery and mean time to repair ok.

So, if I run this model. So, also I can define the experiments that is for number of 100 number of parts mean ten to repair is this much 5. 10. 15 then 5, 10, 15 this is 400 parts, it is for 200 parts again. So, this number of experiments would run if I run this experiment manager. Let me try to run it is it has run for 8 hours.

Now, let me try to see experiment manager now, I need to see the results. It has shown the results that the mean time to failure if it is kept 5. So, it is working for this much number failed for this much number of time. So, for the simulation of 100 parts for the simulation of 100 parts again this is for 200 parts. So, it has taken 8 experiments. So, I can see the report as well here ok. In the report it is telling that they are number of experiments; in experiment 1 this happened in experiment 2 this happened this is the total failure this is what blocked time, then gray color is waiting time all these things it is telling in the report.

So, in experiments what is what is it taken? It has taken different random numbers an experiment number 1 different numbers random numbers are taken; experiment number 2 different numbers have taken what is experiment number 1? It was given here the inputs that we gave output values sorry output values are here in these results. Experiment number 1 is 100 parts with mean time to failure as mean time to repair mean time to repair as 5 minutes; experiment number 2 is 100 parts with mean time to repair as 10 minutes ok. So, it is showing these experiments here.

So, we can have all different kinds of designs, then rule we have not defined any rule make setting can also be done, this is in like if we go to the detail of the simulation these things are possible.

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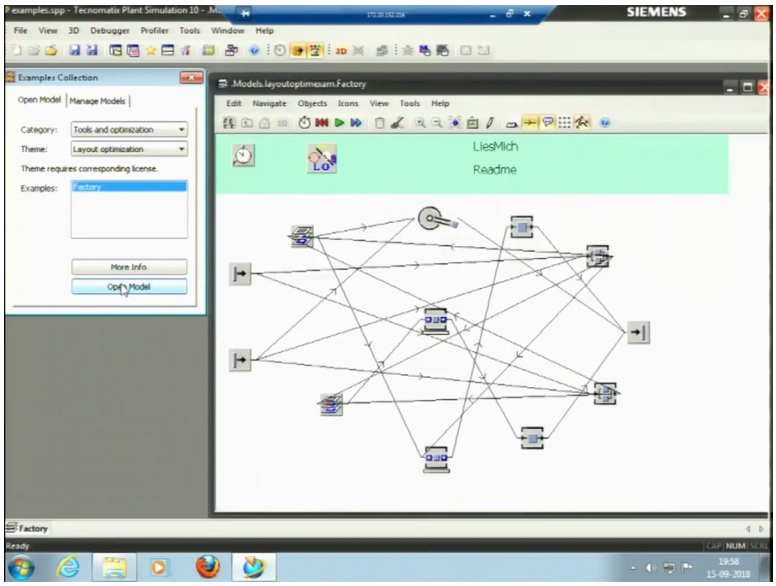

So, now a layout optimization factory optimization; factory layout is there, this is the factory and we have made weird kind of connections here. So, factory layered optimization can be done. For where to keep what machine then what would be the overall what would their maximum throughput if you do that. So, this can these models can be also we can prove through these things to find the optimization here.

So, another model I can pick here is from continuous material flow 2 lane track distance control sensors; sensors are like if we need to for instance if we need to accelerate at some point or we need to put brakes or we need to put the occur, this is a light and like we can do anything let me open this model ok.

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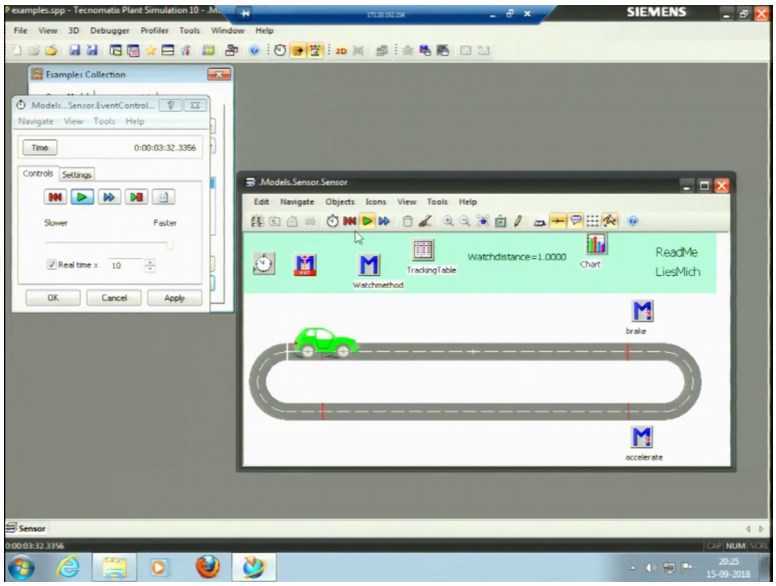

Yes, this is an brake and accelerate model. So, I have defined the method here wash method, the method here is brake and accelerate. So, if I try to run this model first let me see the even simulator, it is n time nothing, but just to see whether how it runs, you can see this is brake after brake it will just slow down, after accelerate this is feeding the speed. So, at this point brake would apply, it is accelerate now the brake would apply it will take a turn accelerate it will accelerate from this point ok. So, this is a kind of an entity, this car here we had just one kind of entity, this is another entity which is in the form of car, the name is auto sorter.

So, this was my sensor, it continued continuous material flow there are many models in this ok. So, I will just pick randomly something some tools and optimization, I can pick experiment manager then I have I try to explain to experimental in more detail I pick an example. So, before that let me pick something with a transfer station ok.

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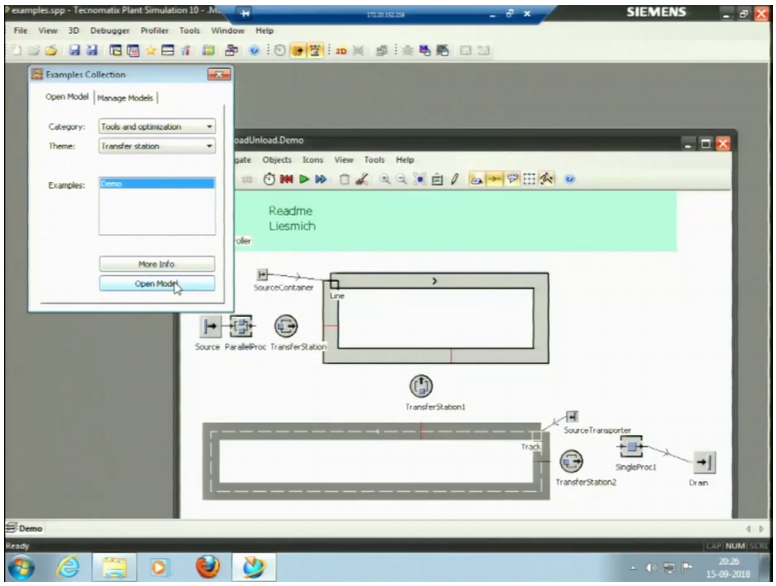

Transfer station I have a demonstration model here, transfer station is this is one cell this is one cell, this O is one cell this is another track here 2 way track ok. Transfer station it will just transfer the material from this cell to this track. Let me try to see the event simulator here, you can see the trolley or the container came here the container is coming this some machining is happening here, some machining is happening at this parallel process ok.

Let us first see what are the process parameters here, this is a parallel process in which 2 into 2 4 processes are there the times is again the default time 1 minute. So, it is from source it comes and transfer station is here, we need not to connect transportation. Transportation when we see the transportation. So, it will transfer it will load it will just load the process, it is corrected correct path from the parallel process we just need to put the name if the of the process from which process it will pick the part from parallel process then it will target or the transfer the parts to line.

So, there is no connector required in between; we need to just mention the predecessors and the successor process is here. So, sensor position is this one. So, all these ah so we can select load, unload, reload, move it is loading the parts. So, all these attributes availability is 100 percent we can select this ok. I would not change anything and let me try to run the simulation. So, these containers are running some processing is happening here it will taking 1 minute.

So, transfer station is then transferring the part to this container. So, this container is just coming here and this transfer station which is connecting the part from this line 1, 2, 3; 2 way track ok. If I see its properties it is from line through a track the name of this track is track only. So, again from this there is another transfer station this source transporter as well. The source transporter that is a source is there that is trying to transport material form some other frame or some other using some inter other interface it is trying to do that. So, this is one of the objects that can be used. So, this is just a transfer station now apply.

So, there is certain examples which are available for us to see how these things happen. As now you know what is factor simulation, what is technomatix, what plan simulation ten some of the objects we have discussed in that and some of the libraries we have discussed now let us talk about rapid manufacturing. As I discussed the factory for rapid manufacturing could be like this.

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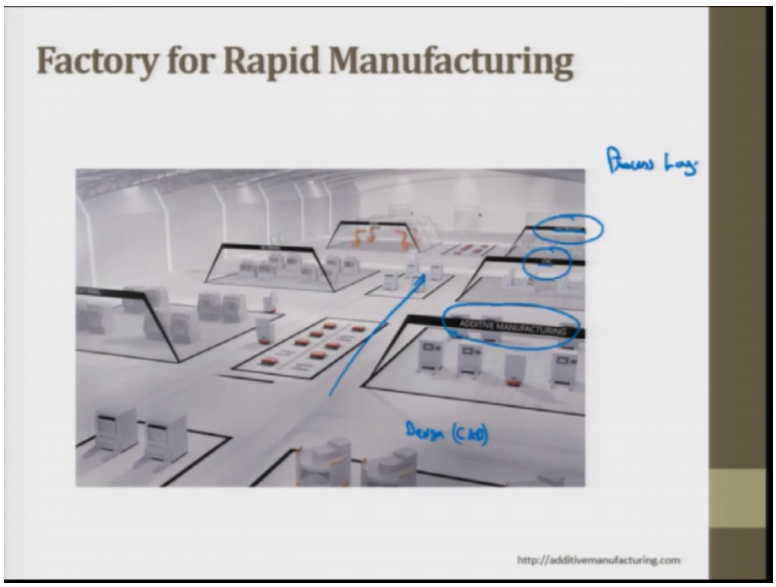

This is a factory for rapid manufacturing; in this we have different sections. This is specifically additive manufacturing section, this is CNC, this is heat treatment right. Before additive manufacturing it can be some may be design here or CAD that can be in the factory or maybe it is control auto factory. So, this all setups are there this is a kind of a process layout again.

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Now, one of the factories is this is additive manufacturing, you can see this pool here that is 3D printers are working and only one worker is trying to set the machines than the machines as an automated work by themselves, or workers is just spending some time on this set up. So, this is the factory that is given by Siemens.

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So, also as I said these are the workers those are working on different machines here and some of the machines the CAD model is controlled directly from outside. This is again as I said closed based manufacturing may be Wi-Fi is working.

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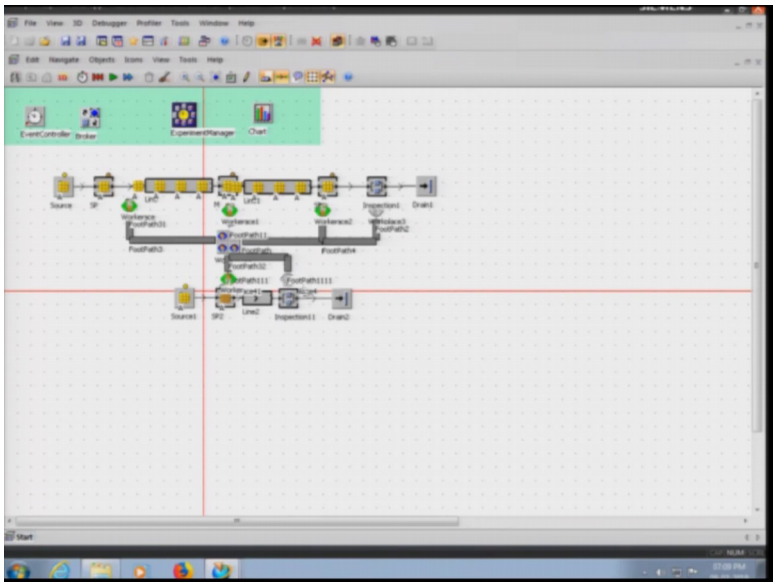

So, I have a factory for you this is a hypothetical factory, in which you have different processes here these are single processes if I put the names on this is single process 1, single process 2, single process 3 right and then we have instruction and packaging. Also we have a second line which you have a single process and inspection and testing. So, what are these processes those I have put? This is selective laser sintering. So, first what happens let us think it is a sintering of the metal products or metal additive manufacturing. So, this is selective laser centering here, and the second process here is CNC process that is post processing that is taking place here, after that this is heat treatment after that inspection and packaging.

So, we are talking after the CAD model received the STL file is received from the CAD model and SLS a Selective Laser Sintering has happened. So, this is one line this is something I have put a flow line that has a kind of a big batch to work on. So, the machines are automated they have workers who are working this is work pool where the workers are being controlled this is the second line in which this is fused deposition modeling or 3D printing. And this second line is put as something customized products or specifically ordered based products or jobs or production I can say. In jobs or production only one job come we do not know what will be the size and what will be the time that would be taken. So, variability would be high for the second process.

So, let us try to demonstrate how does experiment manager works here. In experiment manager will conduct 25 experiments each having 50 observations. So, what are input variables here? Input variables are this selective laser sintering processing time, selected a sintering setup time then CNC processing time, CNC setup time then the third process that is heat treatment processing time and setup time then packaging is just the processing time and then is the second line of 8, 9, 10 points are for the second line which is fused deposition modeling or 3D printing, this is the processing time, setup time and packaging time. So, these are inputs.

What are these times let us see those are put here. These times the distribution is kept constant here, it is constant dissimulate takes this time this much time here and setup time is this much. These times are generally observed before putting into simulation, a few pilot experiments are conducted and those times are put in here. And those times are then used to conduct simulation for having the feel of the realistic environment when we will have a long run. So, these are the times for the single process one that is selective laser sintering, let me see this is FBM.

So, time is around 70 minutes and this is setup time is this is constant the distributions are taken constant, the distributions can be selected in a way depending upon the process that we have chosen as I have said in case of the selective laser sintering because I have taken first line as a big badge. So, we might be knowing that what is the time. So, that can be taken normal distribution. So, those distributions are put here now. Those is after putting those distribution these are the input variables, that I just showed these are the experiments.

Experiments different experiments 25 experiments would be conducted. Total 25 experiments times for selective laser, sintering setup and processing time for this setting and processing time for CNC, all these times are put here. So, 25 experiments and for each experiment we have put observation per experiment; that means, each experiment would be repeated 50 times and that would give a result for one experiment I can consider one day. So, I have put this time as an 8 hour day here ok.

So, one experiment would run for 50 times for 8 hours; that means, total experiments that would be conducted would be 25 into 50 that is 1250 experiments. So, 25 experiments for a single day would be conducted. So, let us try to run this simulation and see what are

the results those are coming. You can see this is current experiment, this 6th experiment 7th experiment observation for 8th experiment these are observation 50 observation would be conducted would be taken. It will also show how much time has it taken for conducting this simulation. This is a very small and hypothesized simulation. When we conduct actual simulation the whole factory the number of parameters those are set, but this is finished the total running time was 38 seconds for this simulation.

So, they have shown the results here. I have put it in a default that we need to produce a report here; though this is the report that they have produced the model is this one. So, these are the units those are moving ok. So, this is the overview of the timing that we have put here, these are the values for the experiments. So, the output values of interest you can see this is the output for line 2 throughput line 2 output. So, let us first show you the output for line ones. So, in this window you can see, we can publish the results what variable do we need to produce? Let us say throughput line 1 first throughput line 1 and report is show throughput line 1 is like this..

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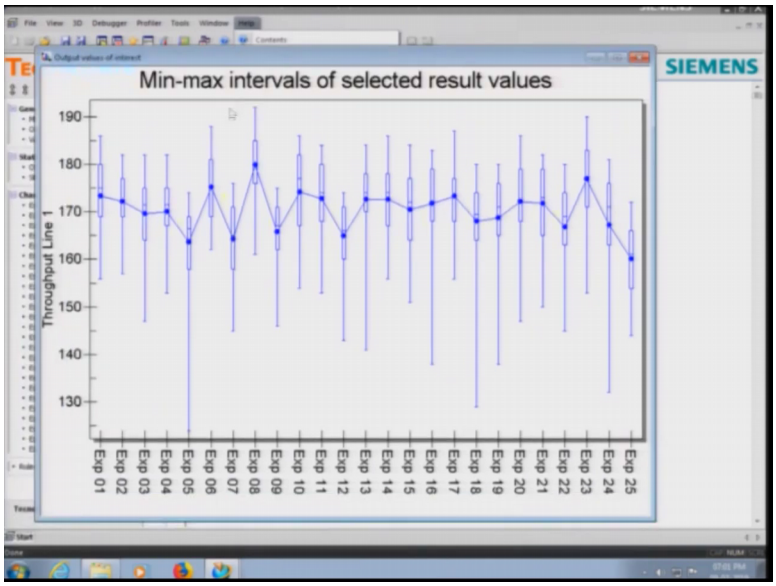

You can see as I said in throughput line 1 we did not put variability very high, the average value here is around 170 and the standard deviation is around 4.5 or 5. So, which is around 2 to 2.5 percent of the mean value. So, this is stable variability in case of line 1 we have different machines. You can say in the case of experiment number of 5 this is the box plots those are produced. So, in this box plot, you can see the lower whisker is

coming this low. The box plot is something in which we have this point as median, this is median this is quartile 1 and this is quartile 2 and this is quartile 3 here.

So, this is trying to replicate the realistic situation. So, in realistic situations sometimes it might take may produce very less number of units in a day in day 5 maybe experiment number 5. In this one box plot means 50 observations total 25 days, but 25 experiments are conducted one blocks plot is 50 observation. Out of the 50 observations this is the median, this is of maximum value and this is the minimum value, this is line 1.

Now, let us try to produce the report for the line 2. So, detailed results can also be produced now let just pick the variable line 2, and tell them to show. Now this is line 2 you can see the variability is quite high. The reason for this is that number one is the number of units those are produced is only 14 is the average here. It is only 14 maybe from a 10 to 19 pieces are produced. From 10 to 19 pieces are produced and average is around 14, out of these 14 units the standard deviation is 1.5 around 1.5.

So, 1.5 out of 14 units is around 10 or 11 percent. So, this is a little higher variability than we observed in line 1. So, this is something that we have job shop production as I said. The products are coming if we do not know: what is the specific product that we are going to produce, what time it would take. So, that is why that variability is quite high. So, this is simulating the job shop and the batch productions here.

The starting point for this simulation was is selection of number of workers you can see there are 4 workers those were selected finally, the starting point was actually 6 workers. 6 workers means one process has one worker corresponding one worker they total 6 processes you can see 1, 2, 3, 4, 5, 6. It was assumed that each worker has equivalent skill set, they can work on any machine post processing, pre processing, selective laser, sintering fused deposition modeling this is not the actual case generally when we talk about additive manufacturing. The workers might have different skill sets, but to simplify the simulation for you this is done here.

And the workers strolling speed or walking speed is kept as 80 meters per minute which is the standard that is given by International Labour Organization: ILO that is one of the things that is taken into consideration here, also the variability that is the total availability is taken as 95 percent for each of the processes here that I can show you here. Let me show you the failures you can see 95 percent is availability here 95 percent availability.

So, those things we have put here and we have tried to obtain a factory that is producing the goods and the total throughput is shown in the report as we have seen. So, for the workers the starting scenario was one worker productivity as I said total 6 workers and it was found similar throughput that is possible for 4 workers as well. Similar it was not exactly same for 5 and 6 workers the throughput was completely similar, but for 4 workers it was a little lesser than 5, but that was acceptable it for the line 1 it was something like this.

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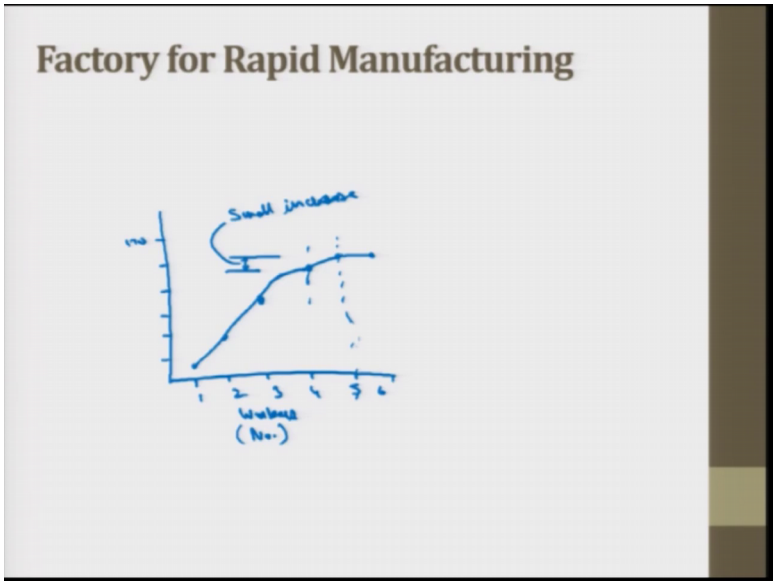

If I say worker 1, 2, 3, 4, 5 and 6 and this is a throughput it is let me say 170 here, and it is coming down like this. So, this is workers or number of workers 1, 2, 3, 4, 5, 6. So, this plot came something like this till 4 workers 1, 2, 3, 4 it was even from 4 to 5 throughput was like this and from 5 to 6 it was exactly same.

So, selecting 5 workers was the first option ok, but there was a little variation only this little variation this little variation this small increase or small improvement in the number of units as those are produced, but this is there is always a tradeoff there whether the worker the paid at we are going to worker is that high or the number of units those were producing the profit that we get from them is that higher.

So, depending upon these, we can see whether to select four or five workers, but yes out of 5 and 6, 5 workers were selected. So, this was for the selection of workers and for the

throughput, I have told you how the variability was shown and also I will have to show how the charts look like the utilization let me say show chart.

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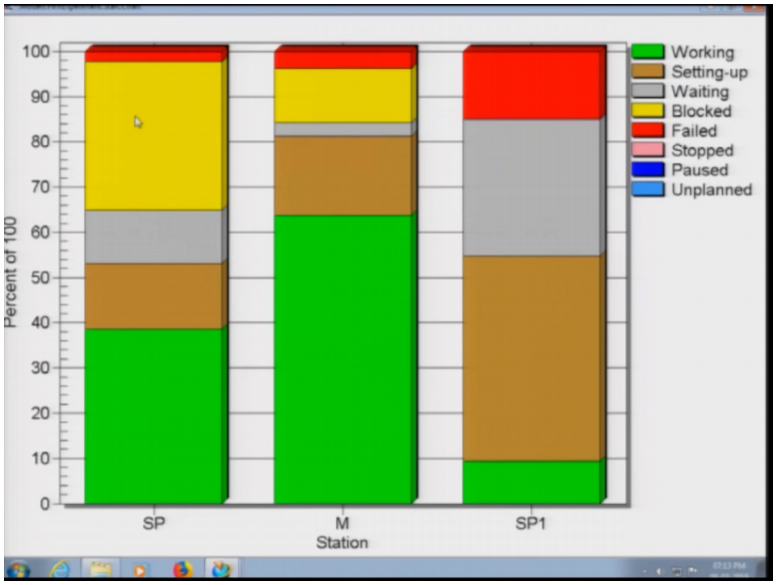

So, this is a chart that is 12 only the green color here shows the working time. Just is the blocks time or setting time setting time we cannot ignore working time is when the machine is actually working, and block time yes that can be worked on waiting time can be worked on.

Now, blocking here means this is blocked for this much of time we say this is percentage of time from 65 to 97 something for 22 percent of the time the single process 1 that is selective laser sintering is blocked. That means, the successive machine that is post processing is taking longer time and this machine is waiting for its on the pieces that is mesh vector to shift to the next machine, but what we can do?

We can put a buffer in between to store the pieces or we can had one more post processing machine that a CNC machine, would had it all depend what do we need to what is the total investment we need to make. We need to just maximize the throughput; number 1 based upon throughput and the cost incurred we get the total profit the overall aim is to maximize the profit. This I have discussed in costing as well, this is breakeven point whatever criteria gives us the earlier breakeven point and we get the better profit that is taken into account.

So, this is plant simulation 10; that we have discussed and how factory design can be simulated using any of the softwares those are capable to do this. One of the softwares we have discussed and with this my part in the course is over. Professor Ramkumar will take one more lecture in which he will take the case studies on rapid manufacturing the 3 specific case studies on different fields 3; fields those are taken our medical sciences, number 2 is automobile in aerospace and then we will conclude the course.

Thank you, for being in the course you are welcome to ask any questions, prepare well for the exam, just follow the notes those we have given and also try to read the books those are given in the reference in the different presentations and the course home page.

Thank you so much.