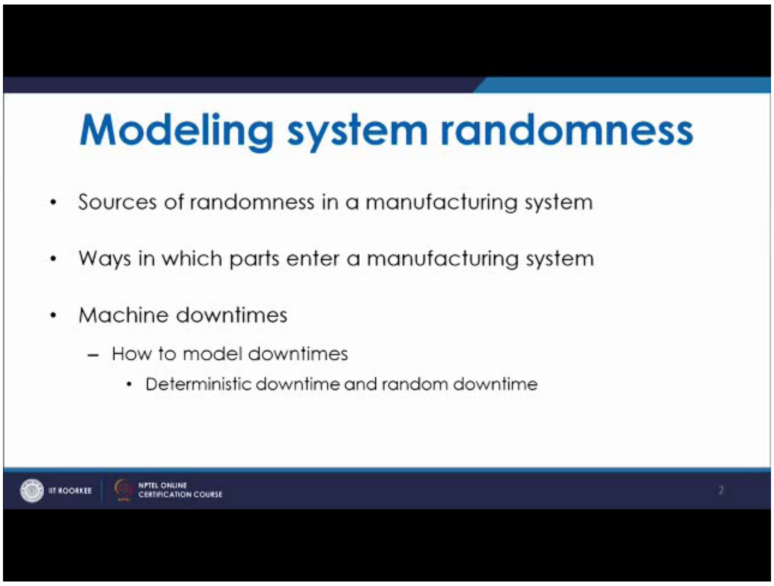
Modeling & Simulation of Discrete Event Systems
Dr. Pradeep K Jha
Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee

Lecture – 33
Modeling of System Randomness: Machine Downtime

Welcome to the lecture on Modelling of System Randomness. So, in this lecture we will discuss about the machine downtimes. So, in the previous class we had discussed about the system randomness and what are the sources of system randomness.

(Refer Slide Time: 00:38)



So, as we know that in the case of manufacturing system you have the inter arrival time, service time whichever parameters are there mostly they are basically random. So, you have the time when the failure will occur, the time when there will be downtime, when the machine will be idle, when it will be busy, what will be the waiting time for the machine to repair, because many a times you have the machine which is not available for the repair.

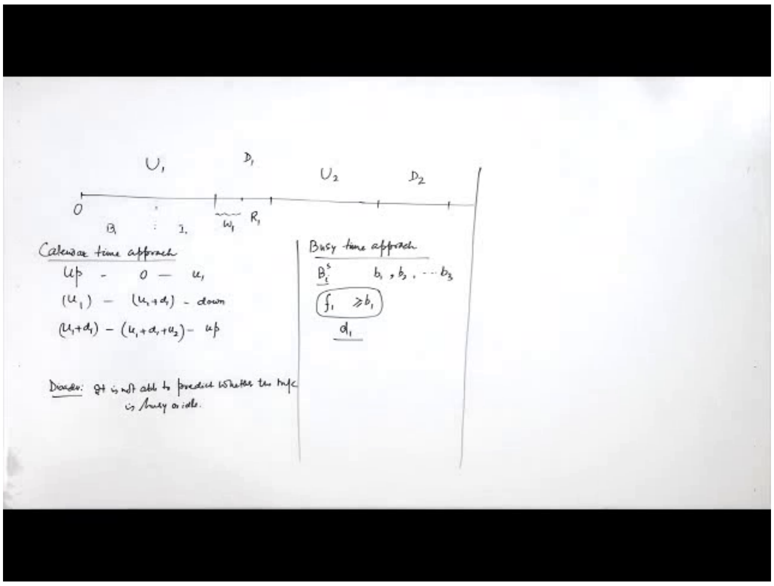
So, what happens that you have 2 approaches in which the parts will enter a system, the one thing is that when you have the accumulation of parts in front of the machine, there is ample of part which is available to you and in that case the service rate will be basically the rate at which the machine will be serving that only will govern that how you are getting the products out.

So, there is always the machine is always busy and whenever it will be you know failing whenever there is a failure, then the service will stop, otherwise the way it will serve that will be the way the products will be coming out. So, in that case you have the downtime of the machine in that case now one thing is that another is that you predict these times that when there will be downtime what time will be the uptime and what time will be the downtime.

So, basically in the case of manufacturing system this machine downtimes are very important because you have the machines and the products will be coming up, jobs will be coming up and you have to see that they come and they are attended. So, that is how you have to see that how to model these downtimes.

So, the thing is, that whenever a machine goes, a machine is approached by the, you know, product or the product goes for the work on the machine, basically you have some up time for the machine and some downtime for the machine. So, up time means you have that time the machine is working. In the uptime, the machine will be busy and or it may be idle also in that case, but then there will be the time when it will fail. So, that time the machine is said to be down.

(Refer Slide Time: 03:57)



So, basically, what happens if you look at the system it goes like that you have this way. If we start from time 0 then in that case you have the uptime. This is U 1, this is the uptime and then you have the downtime, there will be downtime D 1. So, in a cycle of operation you have some time as the uptime and some time as the downtime. Now, in the uptime you may have certain part which is busy. So, this will be B 1 that is the machine was busy and sometime the machine was idle.

So, because, many a times it happens that there is a break, there is shift break is there, that time machine is not working. There is a break people have gone for short breaks or there is changing of all of the tool. So, these are the times when the machine is not busy, but, then it cannot be said that it is down. This uptime is consisting of 2 parts; a part where the machine is said to be busy, that will be B 1 and then this part I 1 that is the machine is idle at that time. So, B 1 plus I 1 will make the time uptime. So, during that portion of time the machine is up.

Then comes the downtime. Now machine has failed. So, once it has failed there is a need to repair it, but then whether it will be repaired, how much time it will be taken to be approached. So, once it is down means the repair person has to be informed and the repair person has to come; before that, the condition is also that, he has to be available. So, in the downtime stage, when the machine is said to be down, in that case some part is that, it may have to wait, so it will be W 1. Then once this W 1 is over, now this W 1 may be 0 or it may be 1, it may be I mean it may be some value or it may be very large value, in certain cases catastrophic failure or failure of the machine itself or there is no availability of the service person. So, it will be quite high, but normally it is. So, you have to see you have to give that consideration that what should be the value of this W normally.

Then once this waiting is over means waiting is there because once the machine is down as we discussed that you have to inform the repair person at a place the repair persons are available. So, you have to tell them, then they will be showing their availability and depending upon the availability, if they are available in that case, they will be coming. They will take some time to come and if they are not available in that case the machine will go it will be waiting in the queue for to be attended. So, this way W 1 is there and once the W 1 is over once the waiting time is over then it has to be attended for the repair.

So, once the waiting time is over, repair person comes, then he will repair it. So, what we see, that you have normally U 1, D 1. U 1 is comprising of 2 parts, D 1 is also comprising of 2 parts. Now, the thing is that this is very much unpredictable to say because they are at separated point of time. The machine is up, but it is very difficult to calculate the I 1 and B 1 together. So, when the, because the machine is busy, in between it is idle, in between then again it is busy. So, normally we take these together and this is basically represented by one random variable that is U 1. So, that U 1 will talk about the machine uptime.

Then you have another random variable that will be D 1, depending upon what is the value of W 1, another random variable will be there. Now, we have already discussed about different kinds of you know distribution functions and we know that typically in the cases of these machine failure rate or the time to repair, you have typical distribution functions like we use exponential, gamma, Poisson, all that we have discussed about different kinds of distribution functions which are basically used typically for such applications. So, from there you will get these data. So, certainly that probability distribution will tell it will have certain mean value and then in future you can predict those values.

So, once you have. So, what we see that you see that here it will be U 1 and then it will be D 1. Similarly, you will have another cycle, will be U 2 and then it will be followed by D 2. So, what we see is, that U i's or D i's they can be predicted. You can have these from certain typical distribution functions or you may have the data also from the past, but the data when you have that may follow certain typical or standard distribution function or if not then that may follow certain empirical type of distribution function. We have to see that how it follows. So, this is how machines uptime and downtime is recorded.

Now, what we see that you have you have to model this machine up segments or down segments. So, how to model it? For modelling this uptimes, you have the approaches which are followed how to model these up times. One of the approach is the calendar time approach. So, the calendar time approach will talk about the time of the occurrences of this uptime and the downtime.

In the calendar time approach, once you have these data available from the distribution functions, you know that the machine is up for the period of here U 1 time and from U 1 to D 1. So, it will take the value of U 1 from the system and it is up during that system.

Now, this time, at that time basically the machine will fail. It is expected that the machine will be down. So, machine will be down. Machine is up during the period 0 to u 1. Once you have the u 1 value, you will see that from the 0 value to u 1 value, the machine is up. Now, from there at u 1, from u 1 to u 1 plus d 1, the machine will be down machine will be down.

Once again it is expected that once this time is over, then machine has to further be up. So, from u 1 plus d 1 to u 1 plus d 1 plus u 2, machine will be again up. So, this way the up and down data will be coming and basically it is calendar time because it will talk about the times it has that time it has designated as the source, as the time where the machine was basically supposed to be down. Now the thing is that although this is good because in the industries you have these uptimes and downtimes, these data can be available. So, if you ask for the data from the industries they can readily give you that for how much time the machine was down. So, this data D I or U I how much time it was up. This data are available. So, from there, this is the advantage of this approach that the data is available and you can model these random downtimes and you can accordingly talk about the effectiveness of the process and other process parameters or other performance measures can be calculated.

Since, it depends upon the time of the occurrence of the event that is what is the U i's or what is the D i's and D i's will again be depending upon W I and R I and normally W I may be taken as 0 or you are putting certain values. So, in those cases you are able to predict the performance measures. The thing is that, in this case there is one advantage I mean disadvantage and the disadvantage is that if you suppose the U 1 value is predicted, you predict that at the time of U 1 the machine will be down or machine needs the repair. Now, this U 1 at this time it may be so, that the machine was in idle state, because, it does not talk about the time I mean at that time what was the situation of the machine whether it was busy or whether it was idle.

So, basically, its disadvantage is that, it is not able to predict whether the machine was busy or idle. Now, the thing is, that nobody can predict whether it was busy or idle because we have taken combinedly this value as B 1and I 1 because, they happen at separated space of time so, we are taking it together, B 1 and I 1 together we take U 1. Now, the thing is that it's very unrealistic. It looks very unrealistic to see, that you are telling the machine to be down at a time when the machine itself is in the idle stage. So, in the idle stage a machine cannot be under the down position. You have to be careful about it, that whether the machine was down or what. So, for that you have to have the consideration.

While going for these values we wish also to mention that it may so happen that when you are doing the calculations, the downtime may occur at a point when some operation is going on. So, in those cases you will have to have that provision also because if the machine fails at the time of processing of any particular piece then in that case that is not completed. When the machine gets ready, in that case you have to see that the processing which was going on which was half done or which was not done, it has to be completed. That also has to be incorporated, but the thing is that we are talking about the calendar time approach. So, this is known as calendar time approach, this is the disadvantage of this calendar time approach.

The next approach is though, what we see, that calendar time approach works well and normally used by most of the manufacturing systems. But, certainly, there is one disadvantage with this calendar time approach and that is a disadvantage we have to keep because for that either you have to keep the model trained in such a way that it takes into account this factor.

Now, the thing is that the remedy to this is that there is another approach that is known as busy time approach. So, the next approach is busy time approach. In this busy time approach, now we are not talking about the U i's that when the machine was up we talked about B i's. We are basically interpreting this U i's in terms of B i's that is, what is a busy time of the machine. So, in actual, the machine fails depending upon how much it was busy. It cannot fail only on the basis of calendar time. So, that is very realistic consideration which tells that, more the machine will be busy, more will be the chances of failing that machine.

So, once you have B i's, we have b 1, b 2 or b 3 value, in this way you have to see that the whenever this b 1 time is reached; suppose a machine has to fail, this f 1 time has come, so more than or equal to b 1, the first fail will occur. So, whenever this time comes then you must know you must go for the random you know I mean the random number will talk about the time when it is going to fail.

So, once this time has come more than this busy time of the machine which is a specified because in the industries you have many a times some machines are over used, some machines are underutilized, so when this time comes then in spite of this use of U I you use the busy time. Because, there are lot of many a times the handling takes a lot of time the part itself has to move through different routes, so it takes time, at that time the machine was idle. So, that is what the consideration was there in the calendar time approach that in the calendar time we are taking that U 1, we are not considering how much time it was busy and how much time it was idle and that is why there was probability that the time when you predict that there will be failing of the machine and it may so happen that the machine does not fail, machine is an idle state. So, that is not a realistic assumption or so.

Now, in this case whenever this time comes, when the machine has failed then what to do is, you start the down time. So, that again then you can go for further the d 1. The machine will be down from that particular time to another d 1 time when the machine will be again you know occupied for its repair, in that again you have machine either to wait or you have to go directly for repair. So, this is the advantage of the busy time approach, that it realistically tells that when the machine will fail. It will talk more realistic about; it is based on the realistic assumptions. So, that is the advantage of this busy time approach.

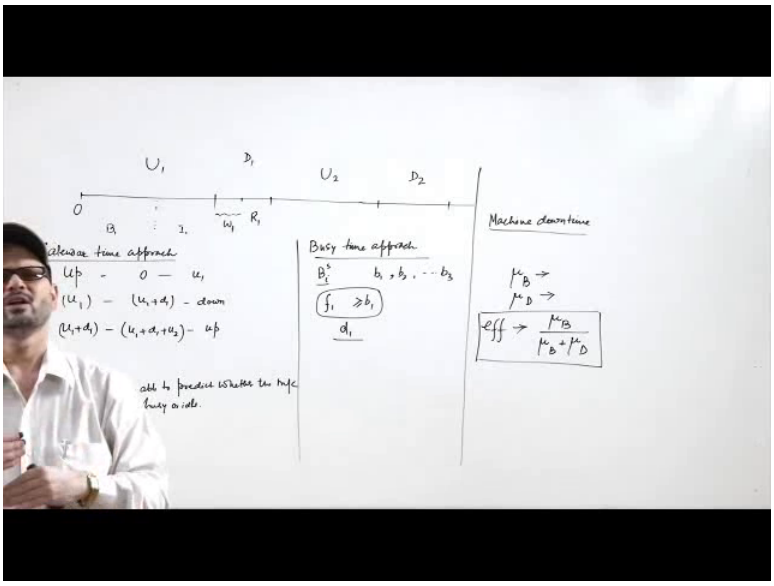
But, there is disadvantage also with this approach. The disadvantage with this approach is that, busy time is normally not available very easily in the plants; they are not normally talking about the busy times. Most of the time you will have the time of up and time of down available, so somebody can say that, yes, it was the machine was working for so much of time and then it was, you know, not working for some time, it was down for that much of time.

So, in the industries, in practical situations the availability of data is there with you in terms of U i's not B i's. So, although being a realistic assumption you cannot it has that modelling difficulty you cannot get the b 1. In the extreme case when there is no delay at all and when the part is always available in those cases this b 1, this busy time that will be basically U I. There is no idleness involved, there is no point so always you have the every conditions are favourable in those cases this B I becomes U I, because, that there is this part will be nothing. So, in that extreme case this B i's become equal to U i's.

So, what we see is that while modelling these machine uptimes and downtimes, this is about the downtime or uptime. So, for uptime we have seen that how to model it, how to model this uptime for that we have seen that you the calendar and approach or you have the busy time approach and by looking at the different you know conditions you can go for any method to do the modelling.

Now, the next thing what remains is that how to model this machine downtime.

(Refer Slide Time: 23:45)



So, machine downtime. So, this is about, how to model this downtime part. So, we have seen that in this case we have 2 approaches. Now, in the downtime what we see is that you have 2 components; one is the waiting component and another is the repair component. Now, both are basically probabilistic and you may have the distribution function which will be representing these 2 functions. Now, the thing is that either this W 1, will be significant or it will be insignificant.

So, in the case of insignificant values of W 1, you have to be pointing more towards the R i's that is repair time. So, what happens that you just because W 1, will vary upon the cases, whether the repair persons are available, if they are available in those cases this W 1 will be 0 and then you can just have these R i’s and if not, once you have those values then you can just put this downtimes. Now, the thing is that for these uptimes or downtimes you have basically different type of distribution functions and what we see is that normally gamma function well describes about this kind of times that what time it is going to be failing.

So, now the thing is, that if you have the repair person as we discussed if it is they are available then it is 0 and otherwise you will have to wait. You have to give some time or the machine. So, either you give some time or if they cannot come then it will go again for under queue for waiting for the repair. We select any kind of distribution functions and as we discussed that this distribution function like gamma seems appropriate or we can take exponential, we can take even Weibull, but gamma looks to be more appropriate which talks about this, because in case of beta I mean in case of the Weibull distribution finding the mean or that is basically cumbersome, but in this case you can get it from the table. So, you can get it and if you have the shape parameter and scale parameter known in those cases you can find the mean time.

So, once you have the distribution function, if suppose you have from the distribution function you have the values and you get the mean value of the busy time and the downtime, once you get that, in that case you can find the effectiveness of the system, of the machine. So, once you get these values because you have to compute these values, you have the data, you take the data from the particular distribution function and normally this data which you get, they are following the suppose gamma distribution function or be it any distribution function and you get the mean value of the busy time and mean value of the downtime, then in that case you can find the efficiency of this machine; how much it is being used and that you can get by this statement mu B upon mu B plus mu D. So, this talks about the effectiveness of this process and I mean the machine that how much effectively the machine has been used against the busy time and the downtime.

So, you must have the proper knowledge of the different kind of distribution functions and you must know that if this data follows certain standard distribution function then you have to use the techniques for finding the mean values I mean you have to find estimates the parameter so, you know many statistical ways to find the mean values for that. Once you find the mean for the busy time, as well as the downtime in those cases you can get this efficiency of these machines. Apart from these approaches, there also certain other ways by which you can model these downtimes like many a times you have the approach like you are either to neglect them, you can neglect these downtimes because you assume that it is very small. So, you can neglect and you can go.

So, basically that is also suggested when it is very small time, that you can suggest, but then that is not very advisable kind of situation. Except for certain those catastrophic situations where you know that nothing is in the control, anyway every system has to come to halt like you have something like break down of complete machine or you have the complete power failure. So, in those cases you know that you can do nothing, at that time in those cases you can think of removing those portions. In those situations you can neglect it, but otherwise you cannot neglect it.

So, these are the ways by which, but then the better way is that you must have the proper you know distribution function from where you have to get the I mean data that when the machine has failed and accordingly you can have the proper values of the downtime. So, as we say that we have seen that wall clock time or calendar time. Calendar time is also suitable, but many a times it fails, then you have to use the statistical distributions and finding those times when there will be busy or idle or there will be waiting for the repair and then further repair. So, there are many ways by which you can go for modelling.

Thank you very much.