Manufacturing Systems Management
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Lecture - 36
Drum Buffer Rope System

In this lecture, we look at the principles of drum buffer rope, which act as a controlled mechanism in synchronous manufacturing. We explain the ideas of drum buffer rope system through an example.

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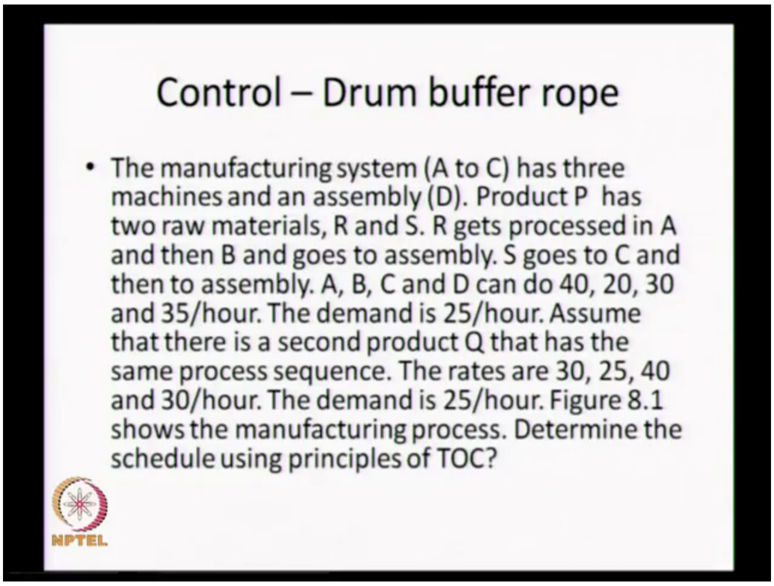

So, we have a manufacturing system A to C has three machines which are A to C and an assembly D. So, it makes two products which are P and Q. So, it makes two products which are P and Q.

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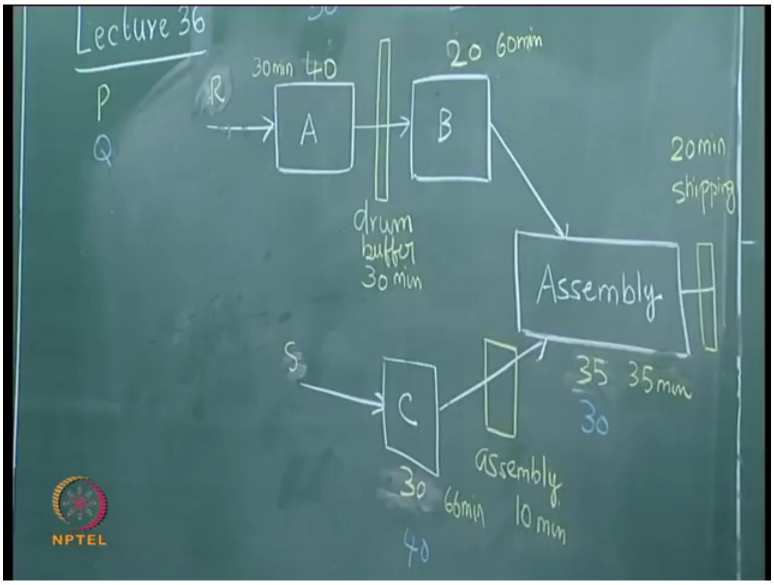

P has two raw materials R and S, R gets processed in A and B and goes to assembly. So, we will have 1 machine which is A, we have another machine B and then we have the assembly here we have a third machine C.

So, this is the manufacturing system. So, as you look at product P it has two raw materials R and S. So, R will come here, S will come here. So, R will go through this go to assembly, S will go through this and then go to assembly. A, B, C and D can do 40 20 30 and 35 per hour. So, this is 40, 30, 20 and 35 per hour. Assume that 40, 20, 30 and 35 40, 20 B is 20 C is 30 and D is 35. Assume that there is a second product Q that has the same process sequence rates are 30 25 40 and 30. So, this is for P. So, 40, 20, 35 and 30.

So, there is another product Q which again has the same raw material R and S the rates are 30, 25, 40 and 30. This is for Q 30, 25, 40 and 30 for Q determine the schedule using principles of t o c. So, let us assume that we are going to make P first. So, P is going to have an R and S. So, let us write the R and S in this way. So, that it represents product p. So, we look at product P this is this all these are per hour. So, this is the bottleneck. So, this is the bottleneck. So, everybody will produce at the rate of 20 per hour. So, there is extra time here, there is extra time here this is this will be the bottleneck. So, since the demand is 25 per hour.

So, let us look at the demands demand is 25 per hour and the demand is 25 per hour for Q also.

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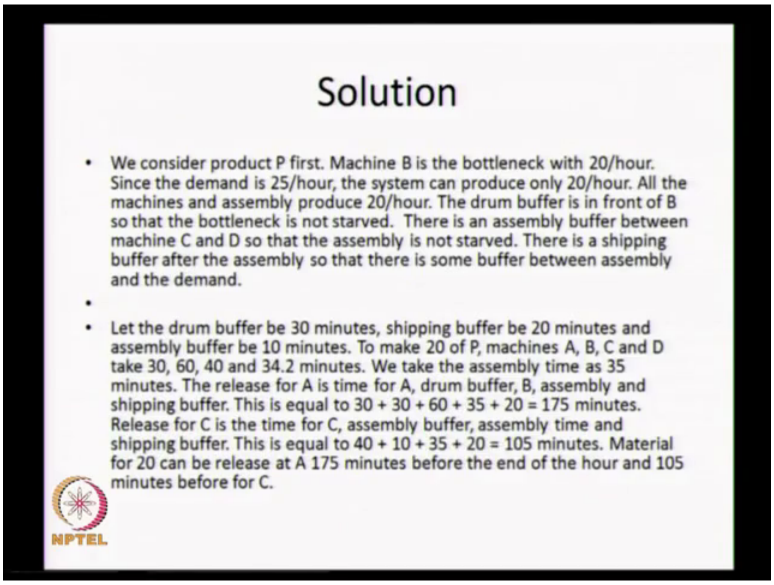

So, demand is 25 per hour, the system will produce only 20 per hour. So, this is the bottleneck. So, in front of the bottleneck there will have to be a buffer. Now why should there be a buffer in front of the bottleneck. So, whenever there is a bottleneck the bottleneck has to be utilized fully. So, when the bottleneck has to be utilized fully the bottleneck machine in principle should not be starved, it should not be waiting for material to arrive. Therefore, it is good to have a small amount of inventory before the bottleneck machine. So, synchronous manufacturing allows and permits inventory in front of the bottleneck machine. So, this buffer which is in front of the bottleneck is called the drum buffer now this colour represents P.

So, it is a drum buffer the bottleneck is called the drum. So, you will have some buffer in terms in front of this we will later see that this inventory actually need not be units, but it is time. So, there is a drum buffer in front of the bottleneck machine which is B there is an assembly buffer between machine C and the assembly, and there is some shipping buffer after the assembly. So, there are three types of buffers, now this is called assembly buffer. Now if there are multiple routes the bottleneck is in 1 of the routes, the rest of the routes to the assembly will have assembly buffers. Now here there are only two routes. So, there is an assembly buffer here and there is a shipping buffer which is here after the assembly before it reaches the customer.

So, there is shipping buffer after the assembly. So, that there is some buffer between assembly and the demand let the drum buffer be 30 minutes shipping buffer be 20 minutes and assembly buffer be 10 minutes. So, this is 10 minutes, let the drum buffer be 30 minutes and the shipping buffer be 20 minutes to make 20 of P the 4 resources let us look at the time it is needed. So, this can do 40 per hour. So, in order to do 20 this needs 30 minutes. Now this can do at 20 per hour in order to do 20, it requires 60 minutes.

Now, this can do 30 per hour in order to do 20, it requires 20 by 30 hours which is 66 minutes this can do 35 per hour. So, this would require in order to do 20. So, this will become 20 by 35 which is 4 by 7. So, this is point 4 by 7 into 60, to 40 by 7. 7 3 sar 21 37 4 sar 28 27 2 sar 14 30 4.2 let us keep this as 35 minutes. Let us keep this as 35 minutes. So, 30 60 40 and 34.2 minutes, 30 minutes 60 minutes let us look at this again I have said 66 minutes.

So, it can do at the rate of 30 per hour which means per unit it takes 2 minutes so.

In order to do 20 units this will take 40 minutes.

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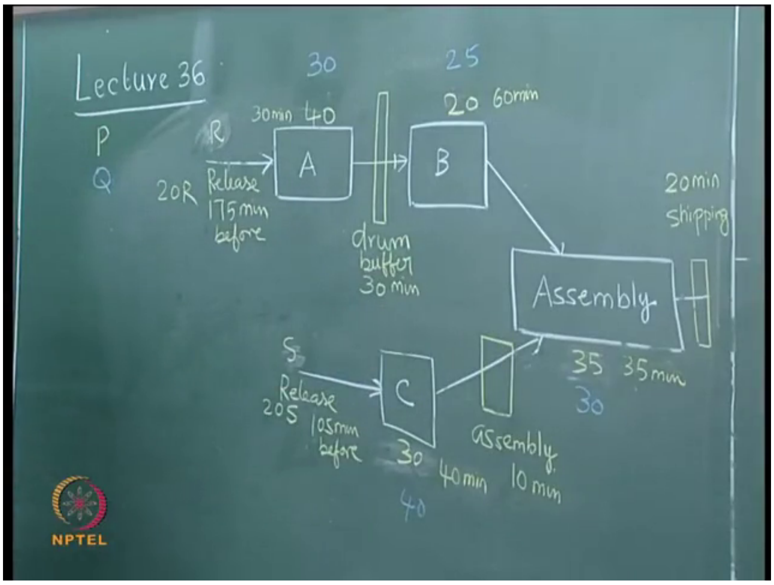

So, now what happens is if this is required at a certain time here, this should be done 20 minutes before that we should reach here now. 20 minutes before that we reach here 55 minutes before, we should reach here so that this does the extra 35 minutes. So, this is 65 minutes before I should reach here 105 minutes before I should be here. So, release S 105 minutes you release S.

Now, let us go back to this 20 minutes before we should be here, 55 minutes before we should be here 55 plus 60 115 minutes we should be here 145 minutes we should be here, 175 minutes we should be here. So, release 175 minutes before it is due. Now let us look at a few things at the actual processing time from here is 40 plus 20 is 60 plus 35 is I am sorry 30 plus 60 90; 90 plus 35 is 125. 125 the 50 minutes come here. So, 175. So, for a 125 minutes processing time required we are releasing it 175 minutes before giving an inventory or a cushion of 50 minutes.

Now, we are not releasing excess material. So, release 20 of R and release 20 of S. So, the inventory is not excess inventory in terms of items, inventory is excess inventory in terms of time. So, what happens is these 30 plus 20 minutes will provide the cushion. So, essentially when 20 minute this is released at 175 minutes before, it takes only 30 minutes to produce this 20 pieces, it takes 30 minutes to produce. So, 145 minutes before it will come here. Actually speaking at this point it is enough if we reach if you leave out the shipping buffer, 35 minutes plus 30 95 minutes it is enough if this reaches the entire batch reaches 95 minutes before it is actually enough, but it is reaching 145 minutes before.

So, the 50 cushion is actually available here. It also takes care of a little bit that even if this is getting slightly delayed the processes before the bottleneck there is still some cushion in the before the bottleneck machine. So, even if there is a slight delay here it is absorbed by this. Now we have to make sure that this works complete because if there is a delay here, there will be a further delay here because the only cushion we have is this 20 minutes afterwards. That is the reason why we give a little bit of a cushion at the end of the shipping. So, similarly here for 40 minutes plus 30 minutes 75 minutes processing time we are giving 105 minutes before it is released.

So, the 30 minutes is the cushion where there is 10 here and the shipping 20 is here. So, why are we giving an assembly buffer? For the shipping buffer helps in adjusting it provides some more cushion here, but why are we giving the assembly buffer we are giving the assembly buffer to make sure to ensure that, this is not a bottleneck and does not become a bottleneck. If we had said that for example, 20 minutes 30 by 55 minutes this is here plus 40 95 minutes if we kept here and we had not kept a 10 minute thing then the cushion available is only this 20 and this will just have enough time to start feeding into the assembly when this is feeding and the assembly will start working.

So, this will behave like has to behave like a bottleneck, but actually there is more time available on this. So, we do not make it bottleneck by forcing this 40 minutes on it therefore, you give extra time just before the assembly.

So, that there is some amount of cushion for these non-bottleneck processes, which come. So, this will be the typical release of these.

Now, this release can be made slightly better, if we do a few things. Now so far we have done a backward flow calculation. So, we have to do it little carefully the backward flow calculation and then we go back and try and do this again, understanding this 175 minutes, we are yet to come for Q. So, we keep this as it is we move to we draw the figure again, and try some more computation on this and then we will come back to this.

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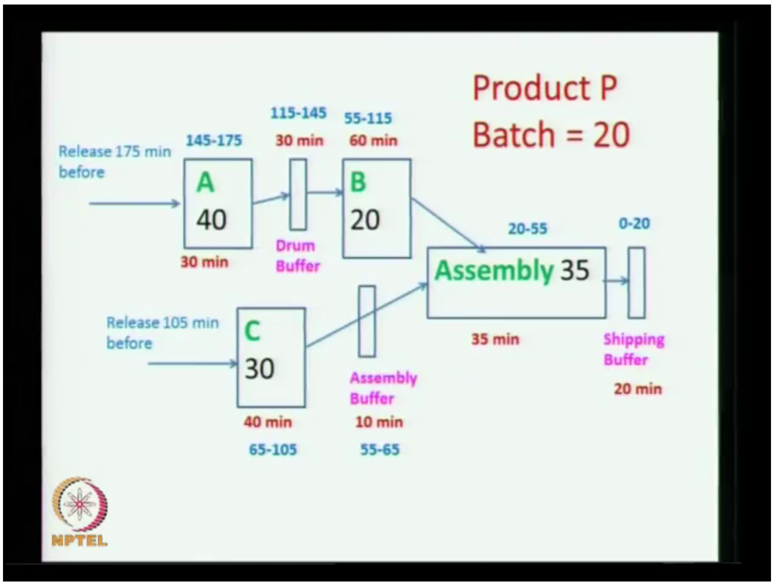

We show the same picture in this slide. So, the same three machines A,B and C are shown here the assembly is shown here and we have just now seen that material R which goes into A and then B and then assembly has to be released 175 minutes before it is due or the point before it should be given.

So, we started by having a 0 here and then we gave 20 minutes for the shipping buffer and then another 35 minutes for the assembly, 60 minutes on B which is the bottleneck the bottleneck can do 20 per hour, the batch size is also 20. So, it takes 60 minutes and then there is a drum buffer of 30, and then machine A can do 40 per hour. So, it takes 30 minutes to do a batch of 20.

Similarly, from this side we said the second raw material which is S is now released 105 minutes before it is due doing the calculation starting from 0 here again 20 to 55 and then assembly buffer of 10 minutes which is 55 to 65 and then this does 30 per hour, it takes 40 minutes to do a batch of 20.

There are two aspects that have to be mentioned in this picture one is we actually have two products there is another product Q and we have not yet superimposed Q on this picture, to understand how much time it takes or when the raw material for product Q has to be released. We will do that in due course second part is that we have a batch of 20 which means, all these machines as well as assembly they process a batch of 20 of P and the transportation happens after the entire batch is completed and all the 20 are transported, which means from time 145 to 175 or 175 to 145 in the reverse direction it is done in A and then all the 20 are transported here and the processing is done between 115 and 55.

So, in this picture the process batch is 20, the transfer batch is also 20. Now we have also seen that the transfer batch can be different from the process batch and we will try and incorporate that into this picture, to see what happens to these start times 175 minutes and 105 minutes what happens to these, if we have a process batch of 20 and a transfer batch of 10 we show that in the next slide.

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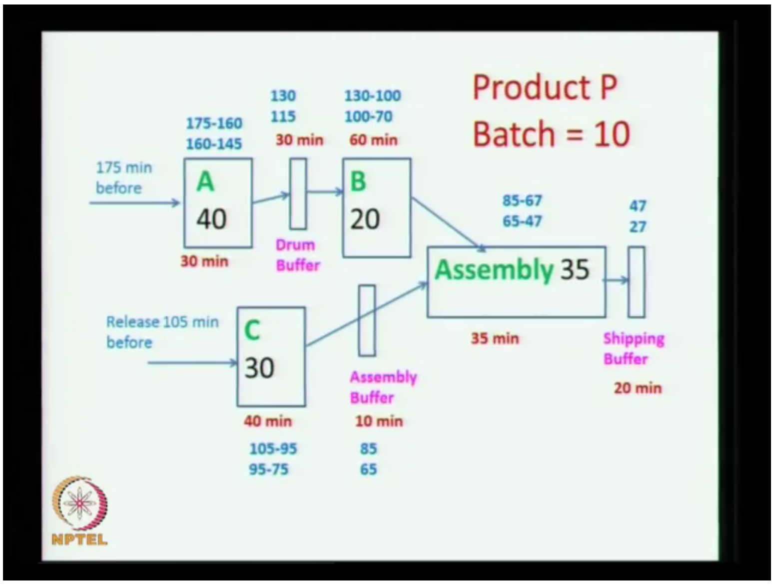

Now, this is how the next slide will look like. Now there are two ways of doing this computations, one is to start at 0 here at the end of the shipping buffer and then move backwards like we did in the previous slide. The other way is to start with 175 and 105 which were the numbers that we computed in the previous slide, and then move from left to right in the forward direction and see whether we are able to finish at 0 or whether we are able to finish before 0.

So, we will follow this option of starting at 175 minutes before from here and 105 minutes before from here, to see where exactly the two batches finish do they finish before 0 or do they finish after 0. So, the batch of 20 is released 175 minutes before at this point, now this batch of 20 is processed as a batch, but then 10 each are done. So, if it takes 30 minutes to do the processing of the 20 pieces, we assume that it is going to take 15 minutes to do the first 10 and another 15 minutes to do the next 10.

So, in machine number A we will begin with 175 to 160 for the first transportation batch of 10 and 160 to 145 for the next transportation batch of 10. Actually the processing happens between 175 and 145 continuously for the batch of 20, but when the tenth piece comes out at time equal 160 a batch of 10 is ready for transportation.

So, the first batch of 10 moves from here to the drum buffer. So, the drum buffer we give the same 30 minutes for this batch. So, 160 to 130 will be for the drum buffer and then it moves to B, and B requires 1 hour to do 20 pieces. So, the first batch of 10 that arrives at time equal 130 takes 30 more minutes. So, from 130 to 100 the first batch of 10 is processed. Meanwhile at 145 the second batch of 10 is completed and we should note that the process batch is actually 20, but the second batch transportation batch of 10 moves to the drum buffer from 145 to 115 30 minutes are given and at 115 it is ready to come here, but then this b is busy till 100.

So, at 100 it will start the processing, and take another 30 time units or 30 minutes to finish at 70. So, as far as B is concerned there is still a production batch of 20 or a process batch of 20, but the computations are shown for two transportation batch of 10 each from 130 100. And from 100 to 70 from there it comes to the assembly at this point meanwhile we are now going to look at the other one, where we are releasing 105 minutes before at c we are going to release. Now it comes to C 105 minutes before C requires 40 minutes to do a process batch of 20, once again we are assuming that this process batch of 20 is being split into two transportation batches of 10 each

So, each of this transportation batch of 10 would take 20 minutes therefore, from 105 to 95 the first 10 are processed and from 95 to 75 the second 10 are processed, but if we look at machine C we can also say that from 105 to 75 for 40 continuous minutes the process batch of 20 is entirely processed. So, the first 10 comes out at 95 and transported. So, we give an assembly buffer of 10 minutes. So, it becomes 85 here and at 85 it is available to the assembly. Now here the first batch is available at time equal to 100. So, based on this calculation assembly will begin at 85 because assembly requires both this part as well as this part.

So, the assembly starts at time equal to 85 and goes on for the first 10 transport batch of 10, the time required is 30 minutes for 20. So, we approximate it to 18 for 10 17.5 is approximated to 18 for 10. So, the first 10 get assembled between 85 and 67 and the next the next 10 will they are available at time equal to 65. So, there is a gap of 2 minutes here because the next batch of 10 is available only at 65, from here it is available at 70 from here. So, the next batch of 10 will start at 65 from the assembly, there will be a two minute delay in the assembly and it will start at 65 and finish at 47 taking 18 time units.

So, as far as the assembly is concerned, it does a process batch of 20 from time units 85 to 47 with a small gap of two time units, where the assembly is idle right now between 85 and 47 it is idle for a period of two time units and at 47 it finishes all the 20, then the shipping buffer of 20 minutes is given. So, the first batch comes out 47 at time equal to 47 and the second batch of 10, will come out at time equal to 27 from this picture.

So, if we release 175 minutes before the due time the first part that is r a batch of 20 and release s the second part, 105 minutes before the due time a batch of 20 here and a batch of 20 here. If the product production batch is 20 and the transportation batch is 10 as shown here, we are able to get these two things out at 47 and 27 respectively whereas, the same thing when we had a production batch of 20 and a transportation batch of 20, we said that if we release 175 minutes before at this point and 105 minutes before at this point we got the entire 20 out of the assembly at time equal to 20, and there is a shipping buffer of 20. So, at time equal to 0 these are available to be consumed.

So, what we understand through these two pictures or these two slides is that, for the same production batch if we are able to reduce the transportation batch, we are able to get these two transport batch of 10 each at 47 and 27 well ahead of the due time of 0. So, the next thing that we have to do is; how do we adjust this 175 and 105 such that these two are closer to 0 not beyond 0 of course, closer to 0. So, the simplest thing to do is to reduce this by 27 and reduce this by 27 to see what happens.

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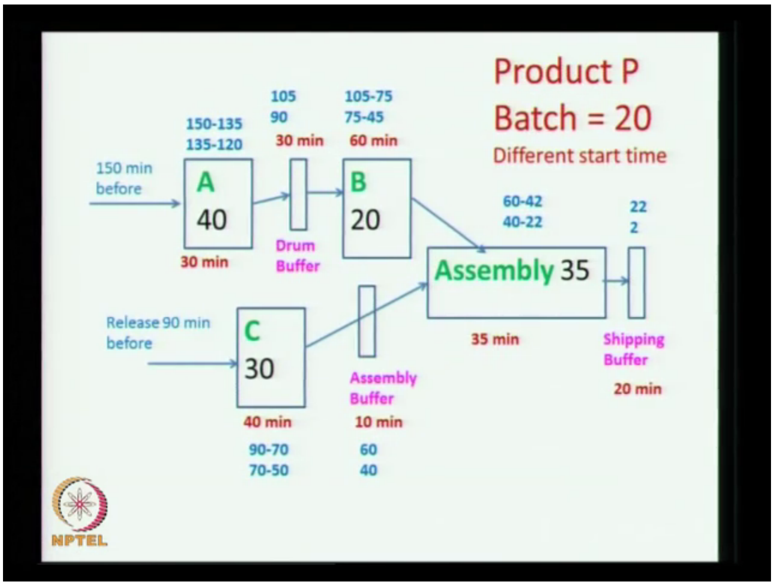

So, what we are showing here in this picture is, we have not reduced each by 27, but we have reduced them by a smaller number or a certain number.

So, 175 gets reduced to 150 here and 105 gets reduced to 90 here. So, we realize that the reduction that we have shown here is 25 time units, and while the reduction that we have shown here is 15 time units, and not 25 time units. So, 175 here is reduced to 150 and 90 time units at this point. Now here what i have shown is product P batch equal to 20 is the production batch, the transportation batch is 10 here I have shown two numbers here one each for the transportation batch of 10.

So, let me repeat that though we have shown a 20 here, this 20 means the production batch is 20 and for this example the transportation batch is 10 the different start time, start time is different from 175 and 105.

Now, we show these computations for 150 here and 90 here. So, 150 again comes to a at 150, A requires 30 minutes between 150 and 120, but as done before it is split into two time slabs of 150 to 135 for the first 10 and 135 to 120 for the second 10. So, this 135 there is a 30 minute drum buffer. So, 135 becomes 105 120 becomes 90. So, machine B starts at 105, it takes 1 hour to do a production batch of 20, but the first transport batch of 10 it takes 30 minutes. So, 105 to 75, second transport batch is 75 to 45. Meanwhile if we release the other part s 90 minutes before, now machine C requires 40 minutes to do a production batch of 20.

So, once again it is split into two slabs of 20 each. So, 90 to 70 will be the first batch and 70 to 50 will be the second batch. So, 90 to 70 again we add an assembly buffer of 10. So, 70 becomes 60 and 50 becomes 40. So, here the first part is available at time equal to 75, but the first part from here is available at time equal to 60. So, assembly will start at 60. As mentioned the assembly time is 35 minutes or time units to do 20 production batch, now for 10 we assume that it is going to be 18 for the ease of computation.

So, from 60 to 42 the first batch of 10 will be assembled. The second batch of 10 is available here at 45, but here at 40 therefore, it can be done only at 40 which means for two time units the assembly will be idle and from 40 to 22 the assembly will be carried out for the second batch of 10 and these two units come out at 22 and 2 respectively here after we subtract the shipping buffer of 20 minutes.

So, what we observe from this is when we started with the 175 and 105 they were available at 47 and 27 respectively. Now when we started at 150 and 90 they are available at 22 and 2 respectively. Now we can still fine tune it a little bit so that we can get a 0 here, but then let us not do that let us assume that two is good enough as long as it does not go beyond 0. So, we can say that this 150 and 90 are meaningful, which also means that the time spent in the system is now 150 from this part of the picture or this path or for this part R and 90 for this part S.

So, 150 plus 90 240 time units is the total time these two parts spend in this system whereas, in the previous one if we had a transportation batch of 170 of transportation batch of. When we had a transportation batch of 20 it was 175 and hun105. So, time spent in the system is higher here. So, when we follow a reduced transfer batch from the product batch, we realize that that there is a saving of about 25 minutes from this side and 15 minutes from this side. So, there is actually a saving of 40 units or 40 minutes and the inventory in the system comes down.

Now we can do 1 more thing here, now even though we said that we release 150 here, we assume that we are releasing 150 we are releasing 20 units of r here and 20 units of s here, but what actually happens when we look at machine A the first 10 is produced between 150 and 1 35 the next 10 is produced between 135 and 120. So, it is not necessary to release all the 20 at time equal to 150, it is enough to release 10 at 1 50 and we can release the next 10 at 135.

Similarly, we can release 10 at 90 and we can release the next 10 at 70. So, to that extent if we multiply the time into the number of units in inventory, we realize that there is a much further gain because there is going to be a 15 minute gain here for the second batch of transportation, and there is going to be a 20 minute gain here for the second batch of transportation.

So, when we reduce the transfer batch and make it different from the process batch and reduce the transfer batch, we realize that we are able to reduce the time spent in the system considerably. The next thing that we have to do is we go back to where we started which is the first picture, we started with product P and batch of 20 production batch is 20 and transportation batch is also 20, and we said that we release at 175 and 105 respectively. Now we have to go back and look at the next product Q and see what happens when we produce this product Q. So, we now superimpose Q on to this picture and we get the next picture which is like this.

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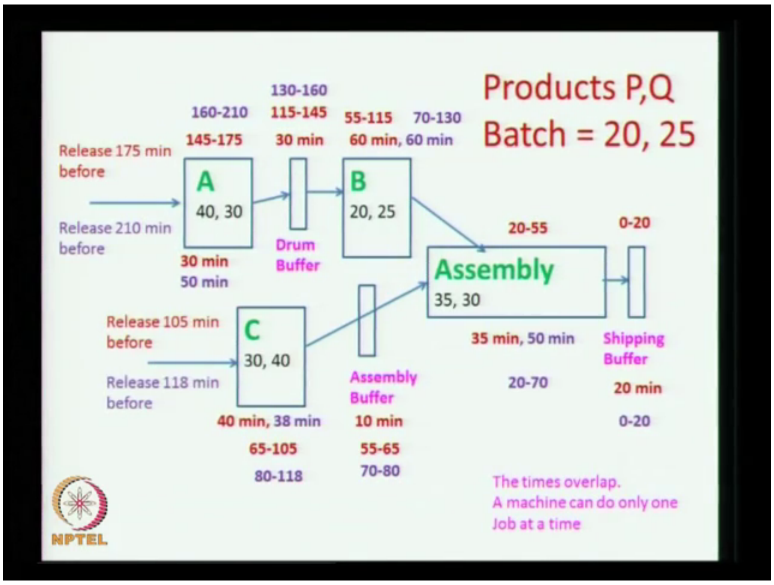

So, this picture superimposes Q.

So, you can see both P and Q that are shown here we produce 20 of P which is shown here and we produce 25 of Q which is shown here. Now we also from the problem or from the problem illustration that we are working machine B is the bottleneck and this can produce 25 units per hour. So, it is going to take another 60 minutes to make this Q. So, we now start doing this computation for Q retaining the computation for P. So, the computations for P are retained the same 175 105 are shown and the computations for P are shown in the maroon colour. Now we are going to show the computation for Q assuming that we are going to start here at 0.

So, the shipping buffer is 0 to 20 here and assembly is going to take 50 minutes. So, assembly is between 20 and 70 for the batch of 25 of Q. So, 20 to 70 is the assembly, then we move backwards machine B is going to take 1 hour or 60 minutes to do Q therefore, time on machine B will be 70 to 130 as shown. Note that the assembly is 20 to 70 therefore, this is 70 to 130 now we add a drum buffer of 30. So, it becomes 130 to 160 now machine a is going to take 50 minutes to make 25 of Q and therefore, 160 to 210.

So, we release 210 minutes before if we want to make 25 of Q, we release the first part to A of 25 quantity released 210 minutes before it is due. Now for P the process batch is 20 the transfer batch is 20 or Q also the process batch and transfer batch are the same, but both are 25. Now from this side we have to look at when the release is for machine C assembly is between 20 and 70 therefore, add an assembly buffer. So, assembly buffer becomes 70 to 80, now machine c is going to take 38 minutes to do a batch of 25 of Q therefore, the time on machine C will be 80 to 118, we added 38 to 80. 80 to 118 therefore, we release 118 minutes before, we release 25 units of raw material S to eventually make a batch of 25 of Q.

So, in this picture what we have done is, we have simply superimposed the schedule for Q over the schedule for P, we made some simple assumptions machine B continues to be the bottleneck machine for both P and Q. And we have completed this picture which says that if it is due at time equal to 0 here then release 175 and hundred and at 175 minutes and 105 minutes, the two parts that are required to make P release 20 of them each and as for as Q is concerned, at least 25 of these at time 210 minutes and 118 minutes. So, this is one way to explain how the computations for P and Q are made, but then when we look at this picture very carefully, we find something which we have shown here the times overlap for example, if I look at machine A, now for P I am doing between 1145 and 175 and Q i am doing between 160 and 210.

So, there is a 15 minute overlap or a gap which is between 160 and 175, as far as this picture is concerned I am doing both P and Q on machine A. Now machine A can do only P or Q at any point in time and cannot do both P and Q at the same time incidentally for the purpose of this computation, I have taken that the changeover times are negligible and therefore, the changeover times are not added here they also have to be added if they are significant.

Now, for the moment let us assume that changeover times are negligible and in spite of that we observe that there is an overlap similarly we can see overlaps on other machines as well between 55 and 115 on one side and 70 on 130 on the other.

So, we need to clear these overlaps and let us see how we do that.

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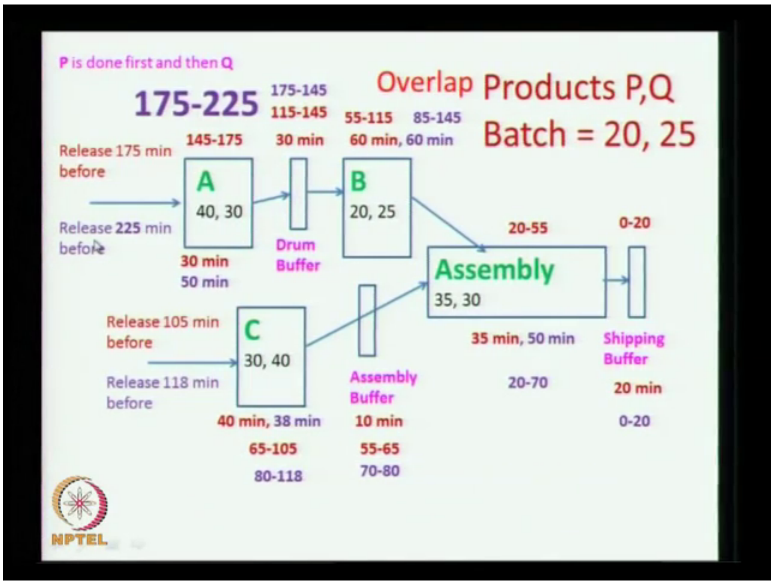

So, we look at the first 1 and now if we want this overlap not to be there, 145 to 175 for P and 160 to 210 for Q, we also have to see which one we do first do we do P first and then Q or do we do Q first and then P. Again for the purpose of illustration we assume that P is done first and then Q is done.

So, in this case what will happen is when P is done first then P is released first. So, P retains its 145 to 175. Now Q has to be retained. In this example I am showing that P is to be done between 145 and 175 and Q is going to be done between 175 and 225, which means in this picture I am showing that Q is done first and then I am doing P.

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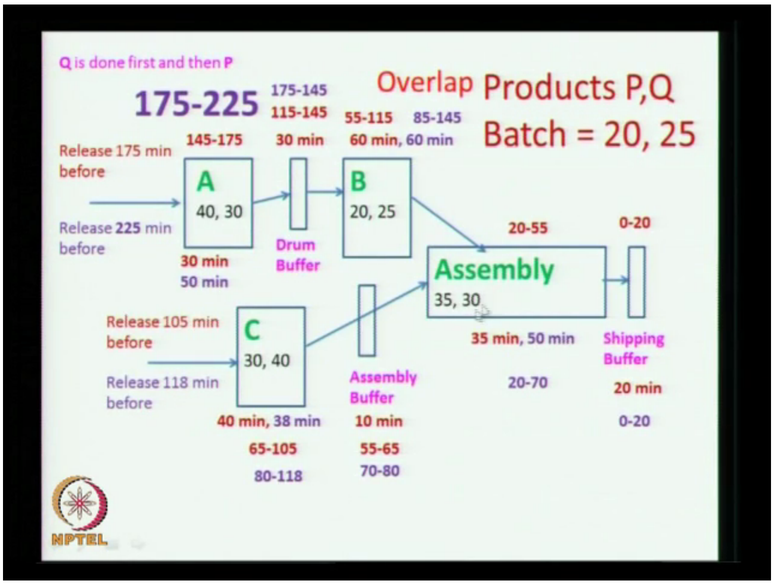

So, Q is done first in this picture, Q is done first and then we do P and then P is done later. So, that Q is released at 225 minutes before. So, that Q takes the 50 minutes 225 175 and then P is released at 175. So, P is between 175 and 145. So, I have assumed now that Q is done first and then P and now I have broken this overlap by adjusting the release of the material for Q sooner, than the release of the material for P such that there is no overlap at this point now when I do this computation. So, 225 to 175 here 175 145 here, 145 to 85 here now P is 145 to 175 here 30 minute buffer.

So, 145 to 115 and then another 60 minutes 55 to 115. Now when I look at this part that is B now again I find an overlap here because this is doing P between 55 and 115 and it is doing Q between 85 and 145. So, between 85 and 115 which is 30 minutes there is an overlap. So, once again I have to break this overlap and I do this overlap this way.

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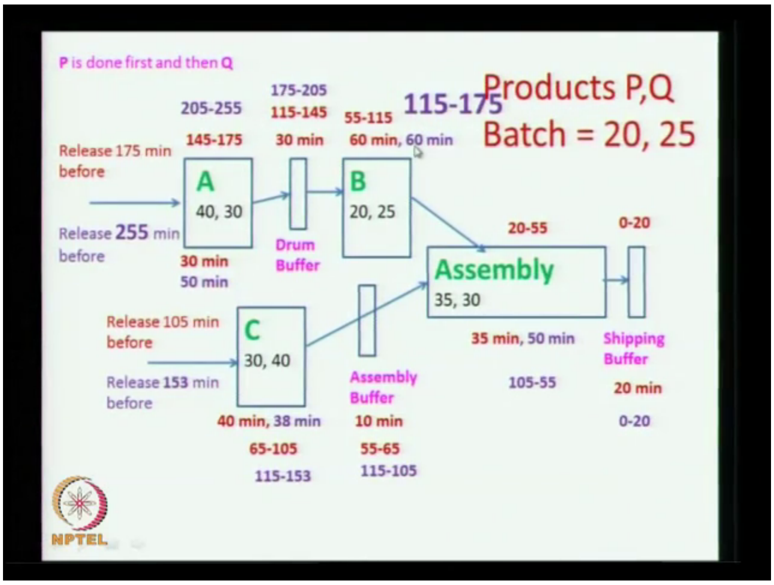

By now again advancing Q. So, Q is done between 115 and 175, P is going to be done later between 55 and 115. Now I move backwards drum buffer is 175 to 205 and A is 205 to 255. So, Q is released 255 minutes before. P retains 55 to 115, 115 to 145 drum buffer and 145 to 175 here.

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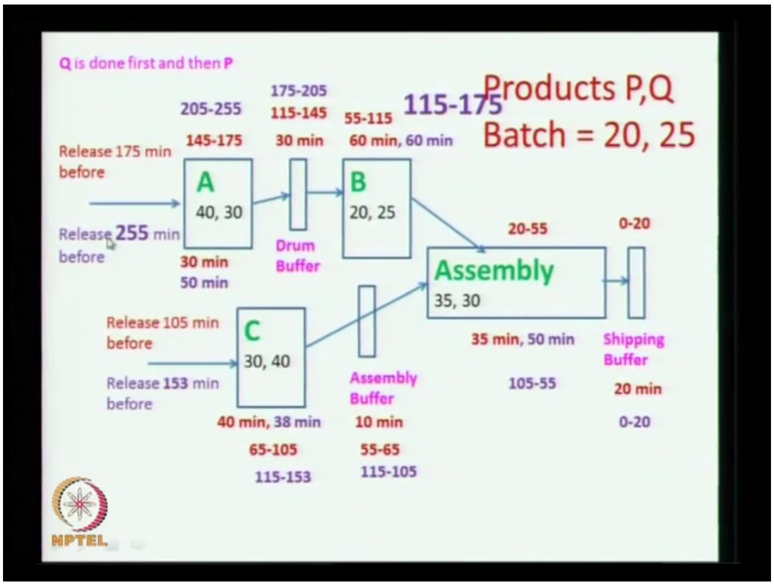

So, Q is done first and then P now Q is released becomes 255. The earlier slide it was 225 we started with 210, but now we realize that if we want to if we do we wish not to have an overlap, then Q should be released 255 minutes before. Now assembly is between 105 to 55 for Q and 55 to 20 for P and then the two things come out. Now if we want to do it for the other leg or the other part of the picture, now for Q the assembly is 105 to 55 assembly buffer is 115 105 to 1 15 and 1 15 to 1 50 three release 153 minutes.

Now, in terms of overlap we do not have a problem, 115 to 153 this is 65 to 105 there is no overlap here it is not an issue and here again 20 to 55, and 55 to 105 there is no overlap. So, finally, if we do not want to have an overlap, then P is released at 175 and 105 we keep P fixed now Q is done before p. So, the release times becomes 255 and 153 as against 210 and 218 with which we started. So, we need to do this. Now if we change this and say that P is done first and then Q is to be done later, then we need to re do this calculation keeping Q fixed and then advancing the release of P, such that there is no overlap. So, the moment we start considering this overlap the computations become a little more complicated not very difficult not very involved, but one has to do this extremely careful.

Now, we have seen two independent things we started with product P alone and then we showed another picture where the transportation batch of P was 10 and then there was a saving. Then we superimpose the product Q on to this and now we realize that there the release times for Q becomes higher or increased, if we Q is done first and then, but then we might wonder that it has increased, but then effectively what we are doing is we are making in this during this period of tw225 to 0 and 153 to 0 and 175 to 0 and 105 to 0 we are making both P and Q together. So, if piece demand is 20 per hour or production is 20 per hour and Q is 25 per hour.

So, in this time frame we are doing both 20 of P and 25 of Q, which we need to schedule accordingly. Now we also have to understand that in all this the bottleneck machine is the 1 that should not be starved and the scheduling goes around the bottleneck machine as it happened in the end. So, the bottleneck machine B schedule finally, dictates how it is being done, some sufficient buffer is given for the rest of the machines which are non bottlenecks.

Now, once again going back we did two things, we did transfer batch less than production batch or process batch and then we gained and then we superimposed another product Q and then we realize that there is an overlap and then some amount of scheduling has to be done some amount of sequencing has to be done whether Q is to be done first and then P or P is to be done first and then Q and the computations will change depending on that.

Now, if we try to have another picture for Q with a different transfer batch from product batch. For example, the product batch is 25 now if we assume two transfer batches of say 10 and 15 or 12 and 13, then you have a different set of computations only for Q for the two transfer batches. And then superimposing the two transfer batches of P along with the two transfer batches of Q and once again sequencing whether P is to be done first or Q is to be done first and then adjusting the schedules keeping in mind the transportation as well as the non-overlap, the computations become complex and cumbersome.

Nevertheless this is a very nice way of understanding how we do sequencing and scheduling in the context of synchronous manufacturing or theory of constraints. And we also try and understand the gain that we can get if the transportation batch is less than the production batch. Of course, as I mentioned multiple products and superimposing the transportation different transportation batches and also sequencing the products, and ensuring that there is no overlap makes this entire thing a little more cumbersome and little more involved.

We can do another thing also we can very go to principle number 7, which we have not shown here we can go to principle number 7, where we can vary the process batch itself. So, we could think in terms of 20 and 25 here, we could possibly think in terms of 10 and 12.5. 12.5 looks unrealistic, but we can approximate it 12.5 and do it as two batches of 12.5 rather than a 10 and a 10 and a 5 which would make the complicate the computations little more complicated. Just for the sake of completion we could think of Q being done as two batches of 12.5 and we can do the calculation. Now when we do that it becomes extremely difficult, because here it should not be start this excess time is fine because this is doing 20 per hour this is doing 40 per hour, then we should look at the changeovers right now we have not modelled the changeovers.

Now, we are assuming that this can start immediately, because 130 130 if there is a changeover of another 30 minutes, then this would mean that this will become 160 and this will become 220, this will become 250 and this will become 290. So, we have to adjust all of that. So, this is how the basic principles of d b r scheduling actually works.

So, in the synchronous manufacturing, we started off by looking at the objectives the measurements the goal of the organization the measurements the role of constraints identification of bottleneck non bottleneck and capacity constraint resource. What to produce and how much to produce the TOC route, the principles the 7 principles the understanding that smaller transportation batch helps, understanding the principles at a macro level using an example and then finally, doing scheduling through the dump buffer rope. By showing a very simple illustration, and by understanding that it can get a little more involved if we start varying the transportation batch size as well as production batch size.

In the next lecture, we will move to another type of manufacturing method called flexible manufacturing systems.