Manufacturing Systems Management
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Lecture - 40
FMS Loading and scheduling, Summary of the course contents

In this lecture we will continue the discussion on Sequence in Jobs on Machines. In the previous lecture we looked at machine loading problems.

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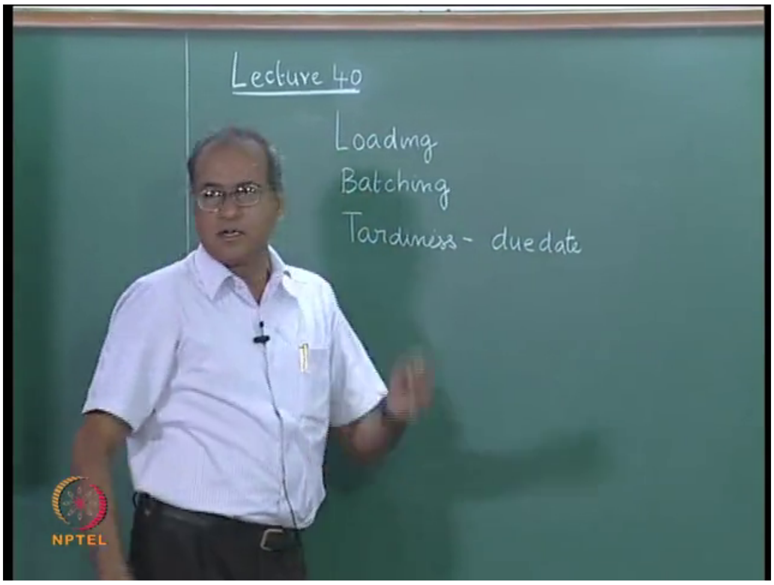

Then we looked at batching problems, in the sense that the jobs that are assigned to a particular machine have to be carried out in batches. And then we also mentioned that we could have objectives that minimize tardiness, which means each job as a due date and we tried to sequence them or schedule them in a manner, such that their completion time is within the due date and in the event of it not being able to be completed within the due date, we minimize the deviation from the due date and that is called tardiness.

So, an integrated problem will be a large optimization problem, fairly complicated optimization problem, which would involve variables like X i J k where job i goes to machine J in the k-th batch.

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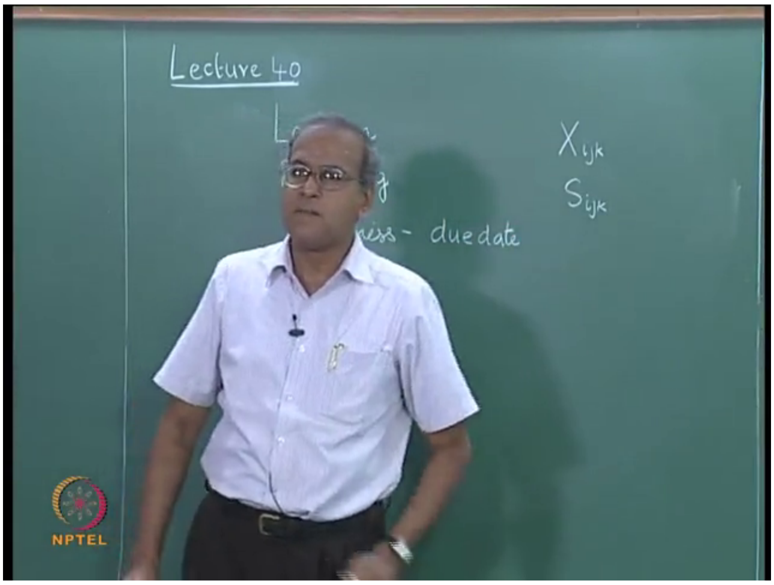

As well as some other S i J k which would represent the start time of job i on machine J in the k-th batch, but there will be another assignment constraint which will say that the job will go to only one machine. Therefore, not all the S i J ks will be active only one of them will be active for one of the batches and for one of the machines for each job it will be at. The formulation will be fairly complicated to do that.

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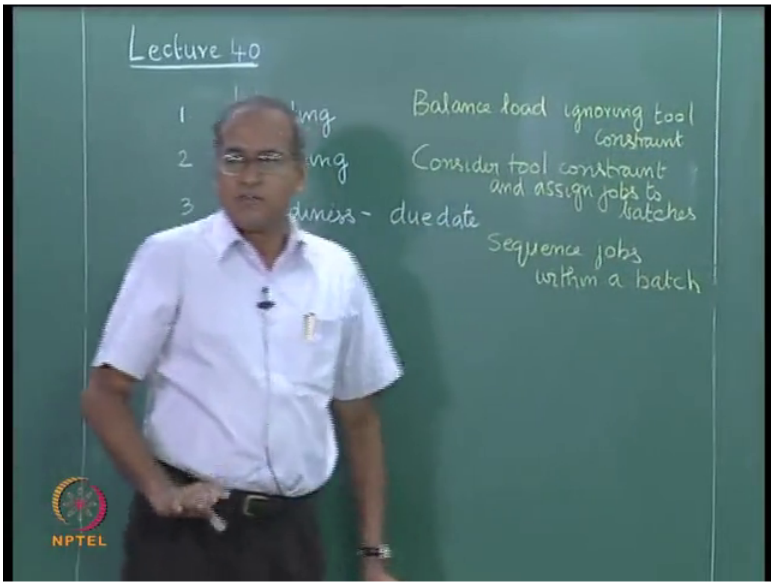

Now as I mentioned a hierarchical way to solve this problem is to first look at the loading problem which will simply balance work load balance load ignoring tool constraint. And as I mentioned this will be equivalent to a non identical parallel processor scheduling on a single machining to minimize make span will balance workload on the machines.

Now, at the end of this we would have said these are the jobs that are going to go M 1 these are the jobs that are going to M 2 and so on. The next one would be a batching problem, now consider the tool constraint and assign jobs to batches such that we maximize the number of jobs that go into each batch on each machine. The constraint is that if a set of jobs go to a particular batch then we should have all the tools required to make this set of jobs on that machine, which means the tool drum capacity of that machine should be capable of having all the tools that are required to process this entire batch.

Now, once the batch is obtained, then we sequence or schedule batches schedule jobs within a batch to optimize a certain performance machine. So, we have a example to look at the last of the hierarchical way of solving it, which is once the batch is made and the jobs are known in that batch how do we sequence them to minimize or to optimize a certain objective.

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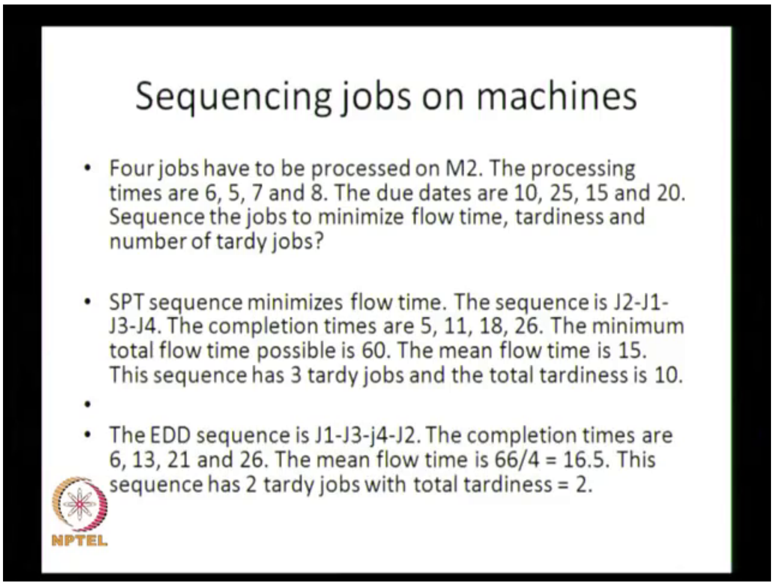

So, we look at this example where 4 jobs have to be processed on M2. So, we call these 4 jobs as J 1 J 2 J 3 and J 4 now 4 jobs with processing times 6 5 6 5.

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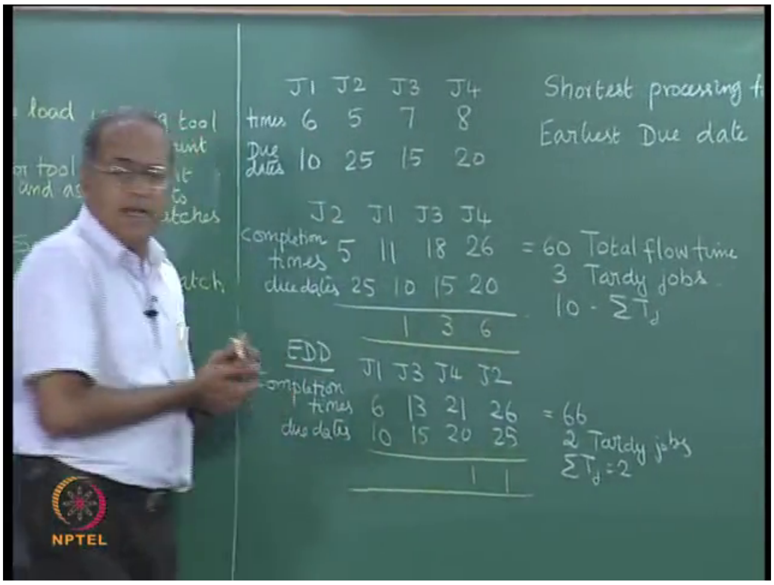

7 and 8 due dates are 10 25 15and 20 sequences jobs to minimize flow time tardiness and number of tardy jobs.

One way of solving it heuristically is by using what are called dispatching rules, to extremely popular dispatching rules are the SPT rule shortest processing time rule and earliest due date rule. Now if we look at s p t rule which means we are sequencing them based on the processing times. So, we will do J 2, J 1, J 3 and J 4 now completion times c t is completion time. So, completion times are 5 here 5 plus 6, 11, 11 plus 7 18, 18 plus 8 26 these are the completion times. Now sum of completion times is 11 plus 5 16, 16 plus 18 34, 34 plus 640 plus 20 60.

So, this is called total flow time assuming that all jobs are available at time equal to 0, job 2 stays for 5 minutes of time job one stays for 11 minutes of time, job 3 stays for 18 minutes of time and job 4 stays for 26 minutes of time. So, total time spent by all the 4 jobs is 60, there is also a theorem which says shortest processing time rule minimizes the sum of completion times, and if all the jobs are available at time equals to 0 the total time at which for which the job stay in the system which is the flow time. Now due dates corresponding to this for J 2 it is 25 for J 1 it is 10, for J 3 it is 15 for J 4 it is 20. So, this is completed before the due date this is completed later. So, the delay is one due date is 15 completion time is 18. So, tardiness is 3 due date is 20 completion time is 26 tardiness is 6. So, 3 tardy jobs and total tardiness is 10 equal to sigma T j total tardiness is 10.

No if we sequence them using earliest due date rule arrange the jobs in the order of due dates. So, we will do J 1 first, we will do J 3 next we will do J 4 and then we will do J 2. Now completion times J 1 is 6 J 3 6 plus 7 13 J 4 13 plus 8 21 and J 2 26. The time at which all the jobs are over is the make span which is 26 irrespective of this sequence that we have; where a single machine make span is always the sum of the processing times. So, total flow time here will be 19, 20, 40 plus 26 66 is the total flow time. So, this sequence is not the SPT sequence therefore, it has a flow time higher than that of the SPT sequence due dates are 10 15 20 and 25. Now we realize that this is before the due date the last 2 jobs J 4 and J 2 are after the due dates with one and one. So, one tardy job 2 tardy jobs, and sigma T j is equal to 2.

So, when we use these dispatching rules, we depending on the objective we could use dispatching rules. So, if we look at total flow time shortest processing time rule will give the optimum solution. When we look at total tardiness the earliest due date rule gives a good solution it does not guarantee the optimal solution all the time, but it gives good solution as you can see here total tardiness is moved from 10 to 2 it certainly does not guarantee optimality all the time. Getting the optimal solution to the tardiness problem is also a complicated formulation, formulation becomes very difficult to solve we will just spend a couple of minutes on understanding it. Now for this if you want to formulate the problem which will minimize the total tardiness alone on this now there are 4 jobs.

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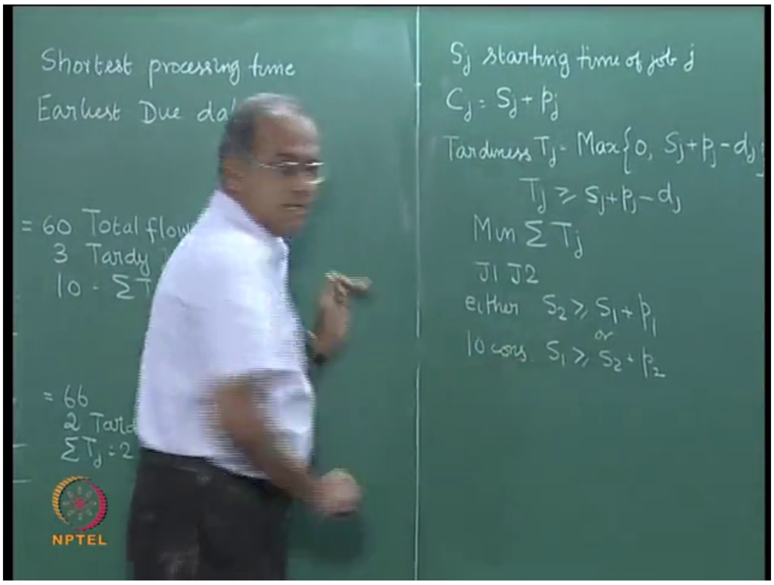

So, you could say that let S j be the starting time of job j. Start now c J completion time of job j is equal to S j plus p j processing time.

Now, tardiness for job j T j is maximum of 0 over S j plus p j minus d j. So, tardiness T j is greater than or equal to S j plus p j minus d j, tardiness is anyway greater or equal to 0. So, it is a maximum of this. So, the objective function will be to minimize sigma T j sum of the tardiness. Now the machine can do only do one job at a time. So, for every pair of jobs, if we take the pair J 1 and J 2 we will have either start time of 2 either S 2 is greater than or equal to S 1 plus p 1 or S 1 is greater than or equal to S 2 plus p 2. Either job 2 starts after job 1 is completed or job 1 starts after job 2 is completed. So, either S 1 is greater than or equal to S 2 plus p 2 or S 2 is greater than or equal to S 1 plus p 1.

Now, there are 4 jobs per each pair we have 10 constraints, 4 c 2 which is 10 constraints now either or cannot go directly as integer programming. So, they have to be modified using M delta and M into 1 minus delta.

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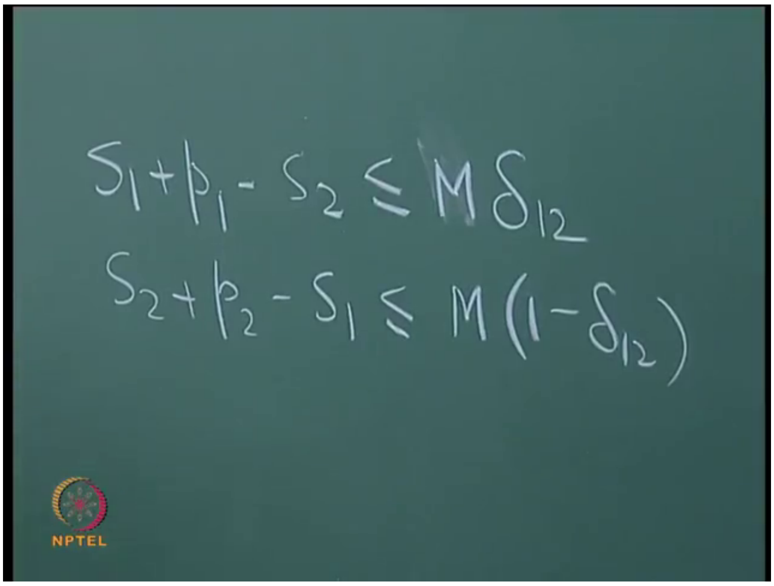

So, this will become S 1, S 1 plus p 1 minus S 1 is less than or equal to 0 or S 2 plus p 2 minus S 1 is less than or equal to 0. So, they will be written as less than or equal to delta M delta M delta 1 2, M into 1 minus delta 1 2 where delta is a binary variable. So, depending on whether delta is 0 or 1 one of the constraints will be active the other constraint will be redundant; so for each pair of jobs. So, there are M jobs we will have n c 2 constraints and n c 2 there are 4 jobs. So, there are 4 c 2 which is 6 pairs and for each pair there will be 2 constraints.

So, for n jobs there will be n c 2 pairs and for each pair there will be 2 constraints, and we will have many or n c 2 binary variables because each pair will now have one binary variable delta ij each pair i j. So, the problem on a single machine with n jobs gives us a fairly complicated integer programming problem. Now if we combine all 3 of them we can now understand how difficult the problem will be. If we also include tardiness to do that, but many times if we separate them if we separate them and when we do the batching without considering due date then we may get into a situation where because we are looking at the tooling constraints jobs which when done together can share tools such jobs will go to one batch.

Now, if it happens that these jobs have different due dates, then that aspect is not taken out and therefore, jobs which have very early due dates may not find themselves in early batches, but will find themselves in later batches and the tardiness will increase. So, it becomes necessary to actually combine these 2 and consider due dates also while doing the batching problem as well as the sequencing problem. In any case we will consider due dates when we do the sequencing problem, but we have to kind of integrate these 2 together to ensure that jobs with very early due dates do not find a place in the later batches and jobs with large due dates do not find a place with earlier batches.

Particularly the first one is harmful the first one can happen if these jobs come and occupy early positions. So, due date has to be considered right at the batching stage. So, this is how the series of loading scheduling problems happen in the context of flexible manufacturing systems. There are many more models and many more problems; there can be formulated and solved depending on the assumptions and depending on the conditions in which the flexible manufacturing system works.

So, we stop our treatment of flexible manufacturing systems, particularly the quantitative models involving loading sequencing path selection etcetera with this, and the models that we discussed where a direct application of the principles of production planning that we actually saw we started with the path selection problem, machine grouping problem and then machine loading problem tool allocation problem and loading and sequencing problems.

So, we have come towards the end of the lecture series, where we have concentrated on several different types of manufacturing systems and methodologies. So, let us have a very quick recap of what we have done over these 40 lectures in this course.

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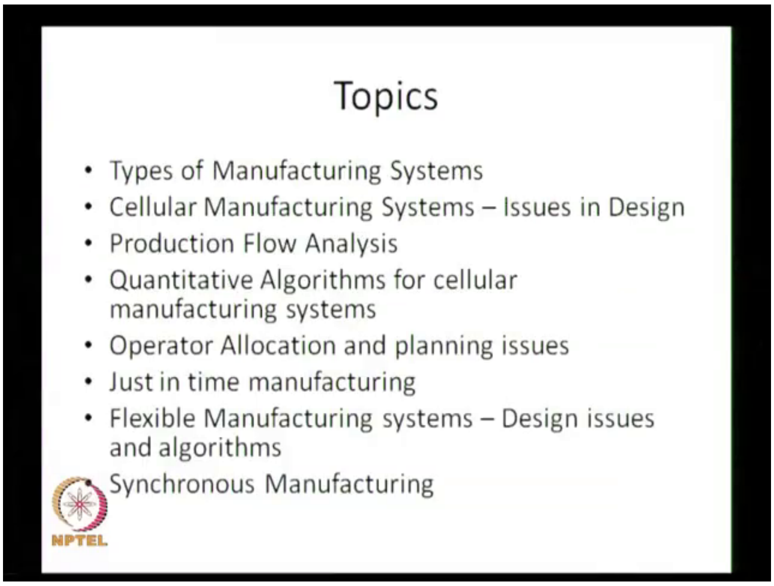

So, these are the broad areas that we have actually covered in this lecture series. So, let us very quickly go back and see what are the various issues and aspects that we have touched upon and what are the various methodologies that we have looked at.

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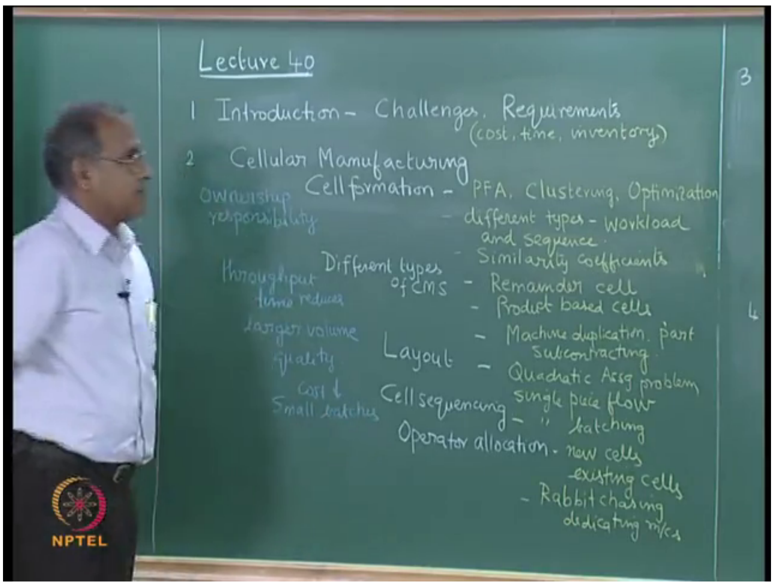

So, we started with some introduction to this course on manufacturing systems management. By talking about the introduction portion essentially covered the challenges, and the requirements of manufacturing. Now particularly in the requirements we started looking at reducing cost, reducing time, reducing inventory even though there are other requirements which is to produce in small runs produce with flawless quality and so on. Primarily it boils down to minimizing cost time and inventory so that products are made with less expense and faster and they are able to meet the customer requirements.

So, we understood the challenges in manufacturing and the requirements and then we looked at cellular manufacturing in detail we looked at cellular manufacturing in detail. We looked at what is cellular manufacturing and what are the various aspects to manufacturing the basic idea that you bring in functionally dissimilar machines together to form a manufacturing cell that can produce a given family of parts with minimal or 0 inter cellular move. So, that we are able to have a factory within a factory concept in cellular manufacturing. Main advantages are ownership and responsibility and to an extent a lot of control. So, within the cellular manufacturing, we looked at cell formation quite extensively. So, we looked at production flow analysis, we looked at clustering methods and we looked at optimization based methods under cell formation.

We also looked at different types of data in terms of work load and sequence. We also looked at different similarity coefficients, considering work load considering sequence of operations and then we solved cell formation problems using these similarity coefficients.

So, again within cell formation we also saw let us classify it further by saying different types of CMS. We looked at reminder cell formation we looked at reminder cell formation we also looked at product based cells, we also looked at product based cells, we also looked at machine duplication and part subcontracting, also looked at some aspects of layout. We looked at changeovers. We looked at some aspects of layout. We looked at the quadratic assignment problem. We also looked at single piece flow, we also looked at cell sequencing and scheduling. Here, also we looked at single piece flow and batching single piece transportation as well as single piece flows we looked at. Then we looked at operator allocation problems, we looked at new cells and existing cells new cells and existing cells we looked at.

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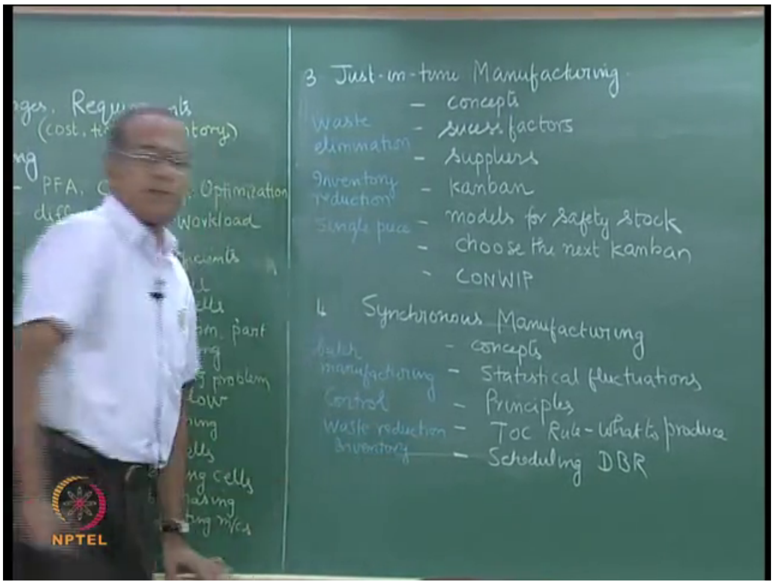

Then we moved to just in time manufacturing. In fact, in some of these we even looked at dedicating manufacturing cells and rabbit chasing and dedicating machines. Now within just in time manufacturing we saw the concepts the success factors, the role of the suppliers and kanban. Then we looked at models for safety stock how to compute the safety stock and what are the linkages with basic inventory problems.

Then we looked at how to choose the next kanban and we also saw conwip as part of the just in time manufacturing concept. Then we moved to synchronous manufacturing and we saw the concepts of synchronous manufacturing, then we saw the role of statistical fluctuations, then we saw the principles of synchronous manufacturing, then we saw the TOC rule and what to produce and we saw scheduling using a drum buffer rope approach in synchronous manufacturing.

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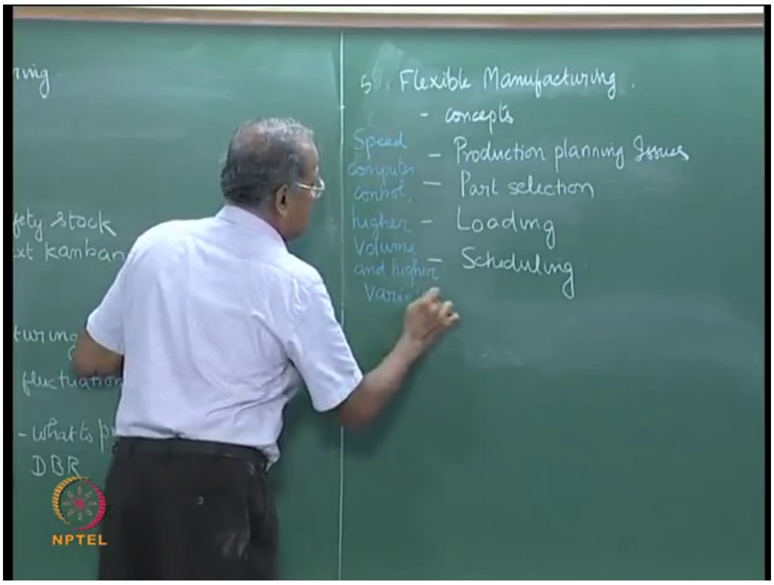

Then we moved to flexible manufacturing, saw the concepts then we looked at production planning issues, then we looked at part selection problem, loading problems and scheduling problems in flexible manufacturing systems.

So, this is roughly what we had covered in about 40 lectures in this course. Now let us go back and try to understand what are the main principles that we have seen in each of these manufacturing methods and where is the relevance of these. So, cellular manufacturing with a very strong emphasis on ownership responsibility brings down throughput time to produce, ability to handle slightly larger volume, better quality lesser cost because all the non value added activities reduce ability to produce in small batches, just in time is about waste elimination, largely about waste elimination inventory introduction through kanban single piece produce variety as much variety as possible.

Synchronous manufacturing applicable in batch manufacturing while these 2 essentially require a manufacturing cell to get all the benefits synchronous manufacturing still talks about a functional kind of a layer slightly larger distances, but focuses extensively on control. DBR is a very significant thing focuses largely on control and it has many things common to just in time it also does waste reduction.

Or one would say inventory reduction by producing only what is needed, and not insisting on economic batch quantities etcetera. Flexible manufacturing is all about speed its all about computer control higher volume and lesser variety and higher variety. What we have concentrated on this 40 hours is a lot of emphasis on quantitative model, almost each one of this topic that i have mentioned here had an associated modelling component which is either solving an Optimization problem or a helustic solution to an optimization problem; such that the objectives are well stated that is all. So, the emphasis is more on quantitative modelling and covering various aspects such as production planning sequencing scheduling, relevant to each of this type of manufacturing system.

Now, one more thing that we will do is to go back to the important slide, where we spoke about requirements of manufacturing very early in this course, and now take a look at how each one of these attempts to meet the requirements of manufacturing and in what way. So, we will do that now.

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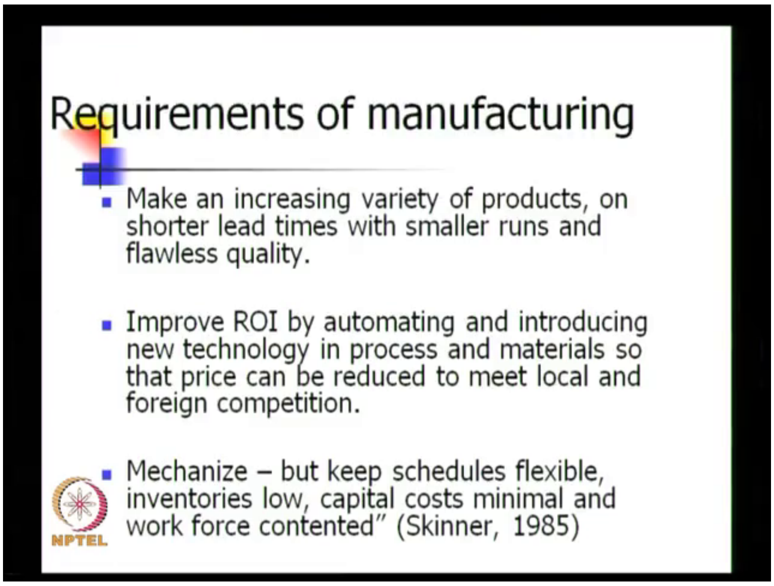

So, this slide tells the requirements of manufacturing, which talks about make an increasing variety of products which is the first requirement of manufacturing. Now cellular manufacturing can handle certain amount of variety, but cannot handle lot of variety amongst these methods that we have seen the same way just in time can handle a certain amount of variety not a large amount of variety. It can handle different variants of the same product as long as these variants do not require too much of new processes.

Flexible manufacturing synchronous manufacturing talk about ability to handle, a large variety whereas, JIT and cellular manufacturing can handle variety, but not to the extent of a meshcam shorter lead times all of them essentially try to give us shorter lead times, particularly the idea of single piece or very small batch production which is common in everything including flexible manufacturing synchronous manufacturing they all try to provide us shorter lead times they all try to talk of smaller runs, which smaller production runs particularly with emphasis on set up time reduction. If we see carefully there is an explicit mention of set up time reduction in cellular manufacturing, JAT systems and flexible manufacturing because set up change over flexibility gives us set of time reduction in flexible manufacturing. Both JAT and cellular manufacturing talk about set up time reductions explicitly.

Therefore smaller runs which come because of less set up time and flawless quality. We have not stressed upon quality in this course, but all of them certainly look for products with flawless quality improve return on investment by automation. If we see all of them certainly talk about automation because when we make manufacturing cells in cellular manufacturing we have to buy new machines and try and automate some part we also spoke about automatic machines where the operator does only loading and unloading while when the actual machining or operation takes place the operator can do some other thing in both CMS as well as in JIT.

JIT has a philosophy does not explicitly talk of automation, but when JIT is put alongside a cellular manufacturing system, there is a lot of automation f M s is centered around automation synchronous manufacturing does not talk so much about automation as the other methods. So, improve ROI by automation and introduce new technology in process and materials. Now this part explicitly none of them address, but all these are addressed by traditional ways of industrial engineering, where there is always an effort to improve process and look at the correct kind of materials price can be reduced. So, all these aim at providing things faster so that price can be reduced to meet competition. Mechanize keep flexible schedules all of them in their own way talk about schedules being flexible.

Just in time gives a certain control also gives a certain flexibility; synchronous manufacturing schedules are also flexible and related to the demand in terms of quantity and in terms of time. So, keep schedules flexible keep inventories low. So, all of them explicitly talk about inventories low, keep capital cost minimum most of them do that except flexible manufacturing is a little and work force contented, all of them are essentially methods which involve a certain change in the culture which involves a lot of cooperation from the workers and the management and when people do new things they are indeed contented.

So, we have now seen how each of these methods try and meet the requirements of manufacturing. Manufacturing systems management is an area with more and more opportunities for newer technologies to come, and it is indeed one area where manufacturing always tries to meet changing customer expectations, which result in changes in the requirements of manufacturing. There will always be more demand for new products, they need to produce more variety and need to produce at shorter lead times. Particularly when manufacturing systems are integrated with information systems which are faster manufacturing is slower compared to information; there will always be pressure on manufacturing to meet the ever changing customer expectations.

So, these tools and techniques that we have seen would effectively help manufacturing systems to meet the requirements of manufacturing as well as changing needs of customer. These tools also will go through different changes and iterations, as newer demands come from the customer, which result in newer requirements for manufacturing.

So, with this we will wind up this lecture series on manufacturing systems management.

Thank you.