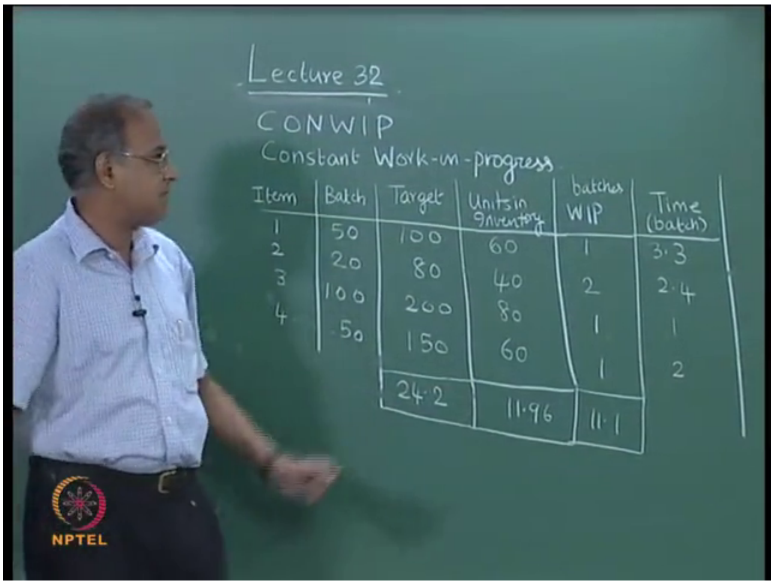
Manufacturing Systems Management
Prof. G. Srinivasan
Department of Management Studies
Indian Institute of Technology, Madras

Lecture – 32
CONWIP, Introduction to synchronous manufacturing

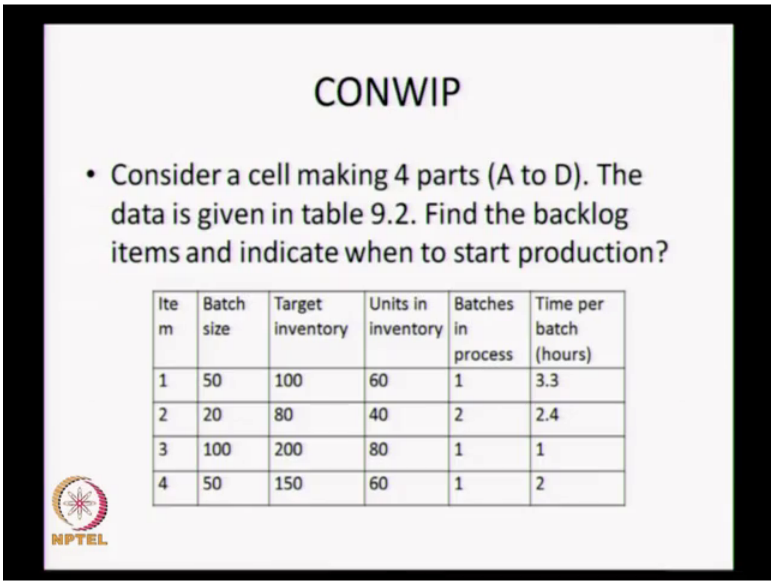
We begin this lecture by studying CONWIP. CONWIP stands for Constant Work In Progress inventory and is another production control mechanism just as kanban is.

(Refer Slide Time: 00:15)



So, we explain CONWIP through a numerical example where we look at 4 items which we call one. So, we have 4 items 1, 2, 3 and 4. We have 4 items; now let us assume that a small factory produces these 4 items. There is a batch size associated with it.

(Refer Slide Time: 01:05)



Item	Batch size	Target inventory	Units in inventory	Batches in process	Time per batch (hours)
1	50	100	60	1	3.3
2	20	80	40	2	2.4
3	100	200	80	1	1
4	50	150	60	1	2

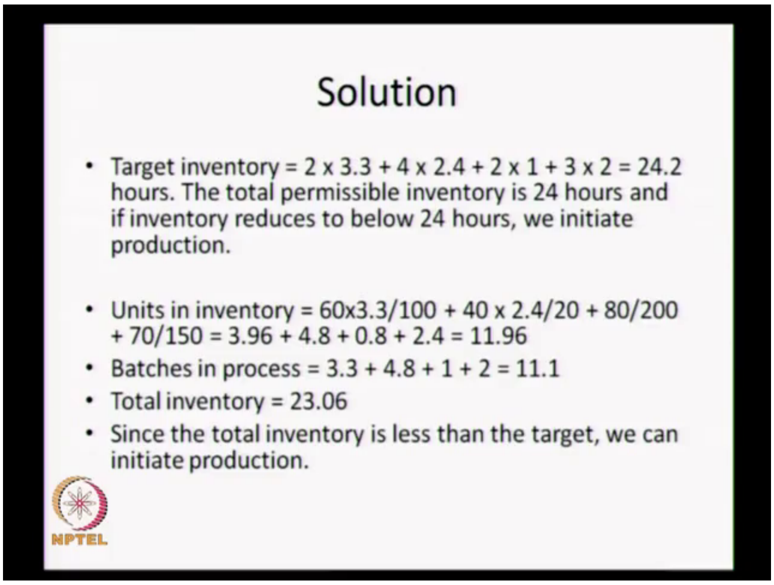
So, batch sizes associated with 4 items are 50, 20, 100 and 50. We also assume that we wish to have a certain target inventory for these items. So, target inventories are 100, 80, 200 and 150. So, from the batch size and from the target inventory values we can understand that this target inventory is equivalent to 2 batches, this is equivalent to 2 batches, this is equivalent to 2 batches and this is equivalent to 3 batches. Now, this target inventory invariably is an indicator of the demand and can change in time.

Now, we look at units in inventory this is the stock available. So, 60, 40, 80 and 60 are the stock that is available. So, this is also will not be in equivalent batches, because while production would be in standard batches the requirement or demand can come in any number. So, when there is a demand that comes now some of this quantity that is there in the inventory will be taken away as items are demanded and consumed.

Now, there is also a Work In Progress that happens, WIP in terms of batches which means batches that are actually under production is 1, 2 and 1. So, right now in the plant one batch of this item, 2 batches of this item are all under production and of course, time taken to process a batch, so time per batch let us say in terms of hours is 3.3, 2.4, 1 and 2 is the time required to produce each batch. So, the system is like this. Now, there are certain amount of finished inventory that we have which are 60, 40, 80 and 60. Now, there is a target inventory for each of these items. Right now all the units in finished inventory are less than the target, but certain batches are currently being produced in the batch sizes.

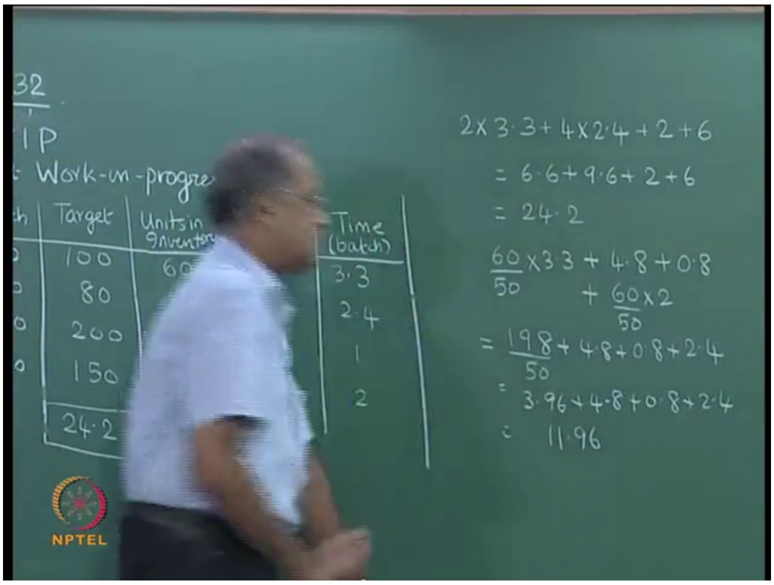
So, if we look at it carefully the target is 100 we have 60 units in inventory, but one batch is going now. So, we actually have 110 in the plant if we include the WIP. Similarly, target is 80, 40 is already in the inventory, 2 into 20, 40 is being produced. So, target is maintained and so on. So, what do we do now? We go back and make some computations.

(Refer Slide Time: 04:30)



Now, what is the actual target inventory in terms of hours? So, total target inventory in terms of hours will be 100 is equivalent of 2 batches. So, one batch is 3.3.

(Refer Slide Time: 04:47)

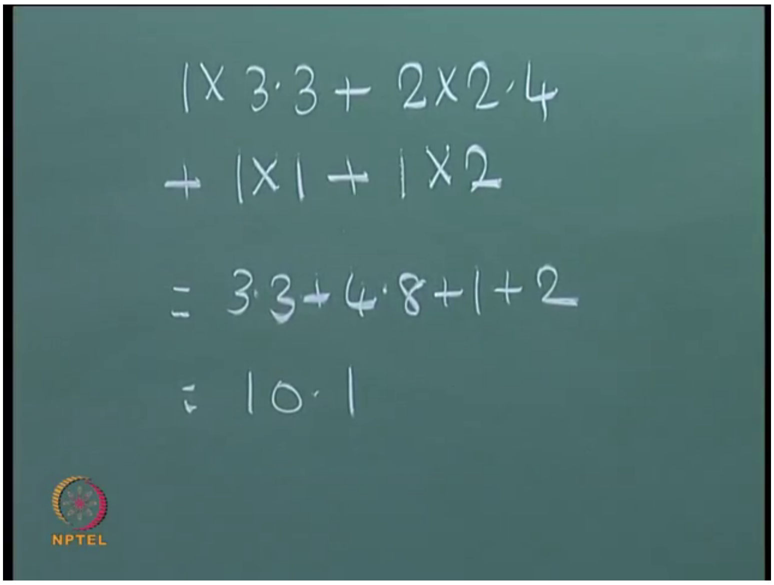


So, 2 into 3.3 is the target. So, 6.6 hours worth of item one is the target for item one. Now, 40 is 2 batches because batch size is 20, 40 target is 80. So, target is equivalent of 4 batches of this item. Each batch takes 2.4 hours, so, 4 into 2.4 hours. Here, target is 200, batch is 100. So, the target is equivalent of 2 batches. So, the production time is 2 units. Here, the target is equivalent of 3 batches 150 divided by 50 is 3, each batch takes 2 units plus six. So, target inventory is 6.6 plus 9.6 plus 2 plus 6. So, this is 16.2, 18.2 plus 6, 24.2 hours is the target.

Now, total permissible inventory is 24 hours and if the inventory reduces to 24 hours we initiate production. So, we now have to see; what is the equivalent in terms of hours of this. So, this is equivalent of in terms of hours, 60 units of one is equal to 1.1, 6 by 5, 60 by 50 batches. Each batch is 3.3. So, 60 by 50 into 3.3; this is units in inventory is 40, which is 2 batches, each batch is worth 2.4 hours. So, this is 4.8 hours.

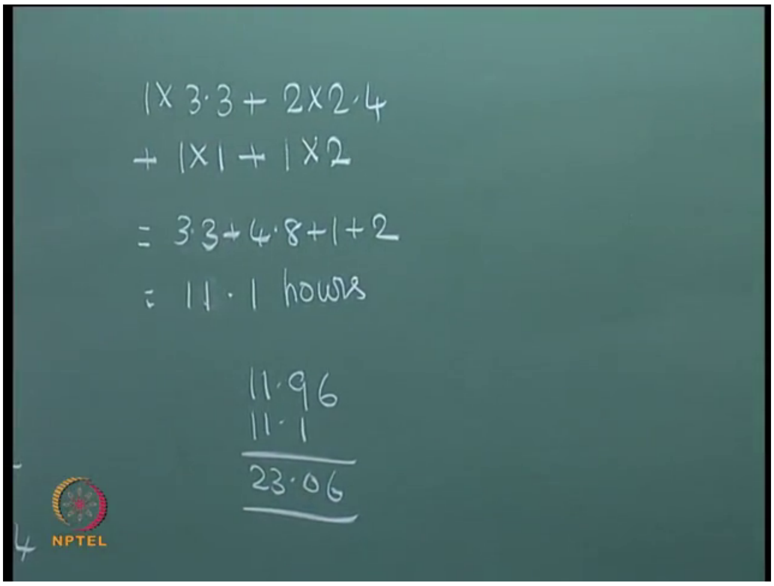
Units in inventory is 80, batch size is 100. So, this is 0.8 batches. So, 0.8 into 1 is plus 0.8. Units in inventory is 60 batch size is 50, so, 60 by 50 into 2 plus 60 by 50 into 2. This is 198 by 50 plus 4.8 plus 0.8 plus 120 by 50 which is 2.4. So, this is 3.96 plus 4.8 plus 0.8 plus 2.4. So, 3.96, 4.76, 5.56, 5.96 plus 2 will give us 11.96 is the hours of inventory that we actually have. Now this is the finished inventory that we have as equivalent of 11.96 hours of material. The target is to have 24.2 hours worth of A, B, C and D. Now batches are in progress, so, this is worth 3.3.

(Refer Slide Time: 08:52)



1 into 3.3 plus 2 into 2.4 plus 1 into 1, plus 1 into 2; so, this is 3.3 plus 4.8 plus 1 plus 2, so, 7.1 plus 3, 10.1.

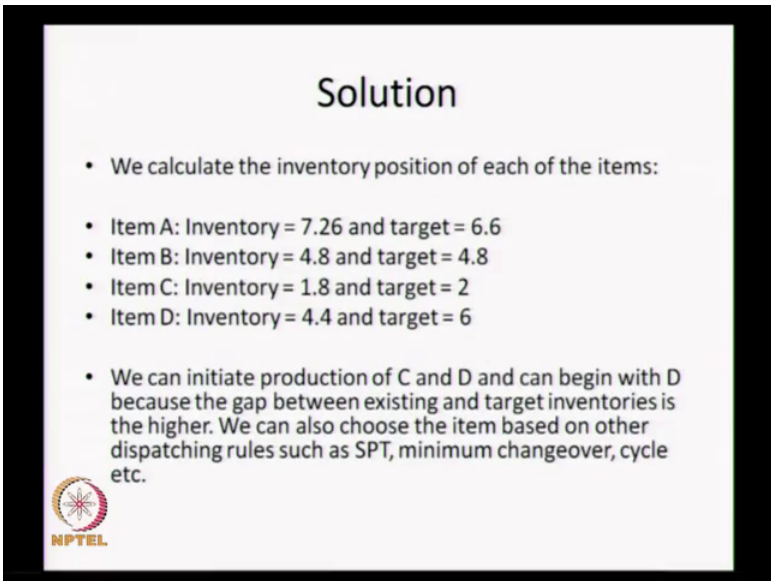
(Refer Slide Time: 09:23)



11.1. 3.3, 4.1, 8.1, 11.1 hours. So, this is equivalent to 11.1 hours. So, we wish to have a target inventory of 24.2 hours worth of items. The inventory finished goods we have is 11.96 hours worth of items. The Work In Progress is equivalent to 11.1. So, what we have is 11.96 plus 11.1, which is 6 0 3, 23.06 is what we have. So, what the target is 24.2 hours worth of inventory, what we have right now is 23.06 hours worth of inventory.

Since we have less than target we can produce now. So, we can produce now. So, we could produce either 1 or 2 or 3 or 4. So, we will trigger a production or we would initiate a production right now.

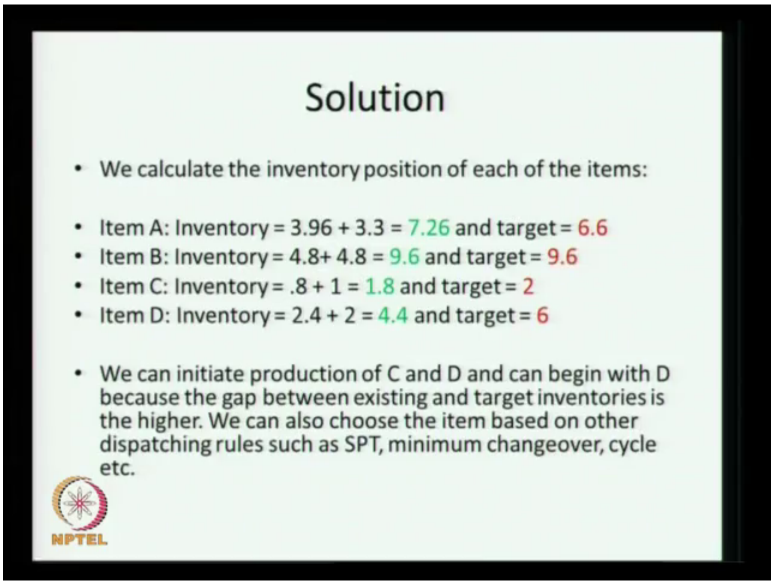
(Refer Slide Time: 10:41)



So, we could produce item 1 or item 2 or item 3 or item 4. If for example, instead of having if we had one more batch of this running under WIP then this quantity would become plus another 2. So, this would have become 13.1 and this would exceed 24. So, right now we will not look at that case. We will look at that case a little later.

So, right now, we can initiate production of all of these. So, we will now look at what happens to item A. Item A is target is 6.6, target is 2 batches; 2 batches into 3.3, target is 6.6 and availability is units in inventory is 60. So, 60 by 50 into 3.3 plus one batch WIP plus another 3.3 would give us 7.26.

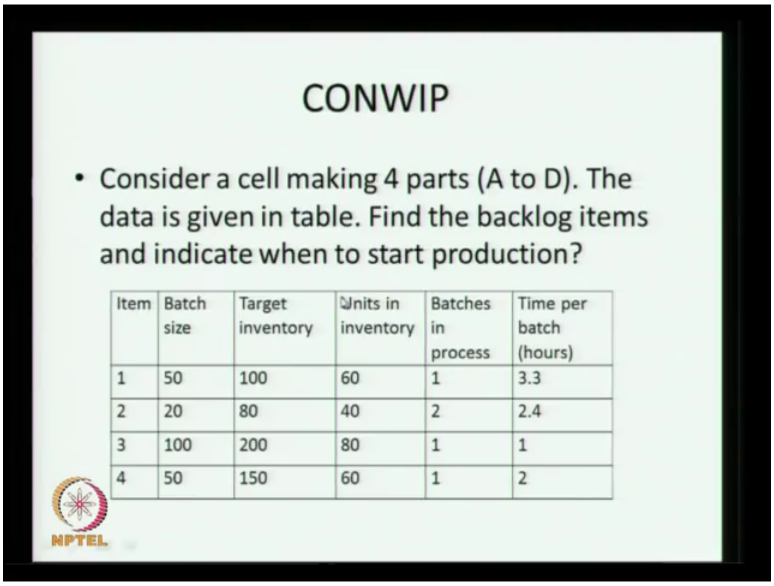
(Refer Slide Time: 11:53)



We are now looking at the inventory position of each of these items. The items are shown as A, B, C and D here.

Now, we have already seen for item A, that the target is 6.6 hours; while the inventory on hand including the Work In Progress and finished items is 7.26 hours.

(Refer Slide Time: 12:21)



For item B or the second item, the target inventory is 80 units, the batch size is 20, so, 4 batches, time per batch is 2.4 hours. So, the target is 9.6 hours which is shown here. Now, the items in inventory are units in inventory is 40 which means 2 batches, which also means 4.8 hours and batches in progress are 2 batches, which is another 4.8 hours. So, the inventory that is on hand including the finished and Work In Progress is 9.6 and target is also equal to 9.6 hours.

For item C or the third item the target is 200 units, batch size is 100. So, target is 2 batches and the target time is 2 batches of 1 hour each, so, 2 hours is the target which is shown here. The units in inventory for this are 80. So, 0.8 batches into 1 hour is 0.8 hours and batches in progress is 1 batch for 1 hour. So, total units in inventory are 0.8 plus 1 which is 1.8 against a target of 2.

Now for item D or the fourth item, the target inventory is 150 which is equivalent of 3 batches, time per batch is 2 hours; therefore, target inventory is 6 hours and 6 hours is shown here. Now, units in inventory is 60. 60 is equivalent of 1.2 batches, time per batch is 2. So, units in inventory is equivalent of 2.4 hours, batch in progress is one batch which is another 2 units of time. So, 4.4 hours is the units in inventory available with target equal to 6 hours. For a quick calculation we know that the sum of these 4 targets 6.6 plus 9.6 plus 2 plus 6 is 24.2 hours, while the total of the inventory is 7.26 plus 9.6 plus 1.8 plus 4.4 which would give us 23.04 hours. So, total available inventory is less than the target and we know that we have to produce one of these items.

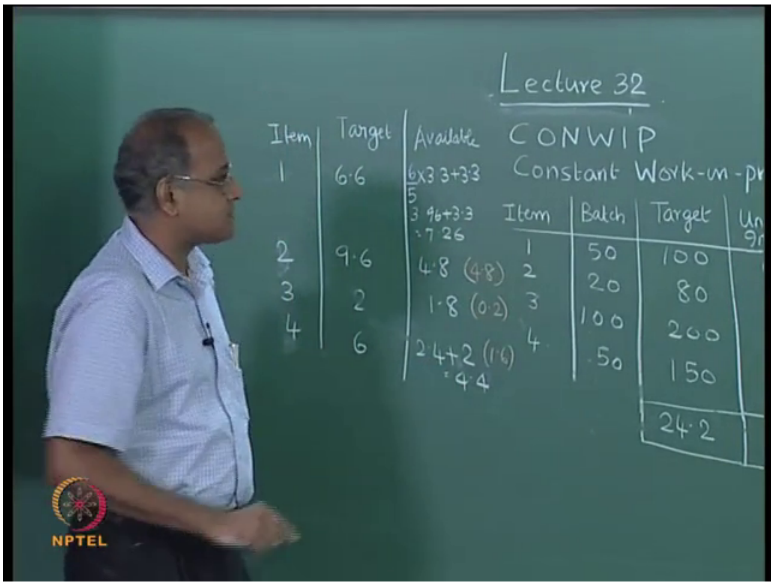
Now out of these 4 items we observed that item A or the first item has more inventory 7.26 than the target 6.6. Item B has equal amount of inventory compared to the target, item C has fewer inventory 1.8 hours of inventory against a target of 2 hours, while item D has 4.4 hours of inventory against a target of 6 hours. So, we can start production of items that have less inventory than the target. So, we can either start item C which has inventory of 1.8 against a target of 2 or item D or item 4 which has 4.4 against a target of 6. Therefore, we can initiate production of C and D and perhaps begin with D because the gap between the existing inventory of 4.4 and the target inventory of 6 is higher than that of C.

We can also choose the items based on other considerations or other dispatching rules such as shortest processing time; for example, we might like to among the eligible items we may choose the one that has the smallest processing time per batch or we may choose the item that has the smallest changeover or we may go or use a particular cycle like A, B, C, D and then if the previous one had been B then we might do C and so on.

It is also important to note that when we look at this table as we produce the batches in process will now increase and as the batches in process increases the inventory will also the inventory on hand will also increase. Now at some point as the batch ends the inventory on hand moves from a batch in process inventory to finish goods inventory or moves to units per inventory, but then we are looking at the sum of these 2 terms. But, then once there is demand then finished goods inventory is going to reduce and therefore, the total inventory in the system will reduce.

So, as and when there is a demand we know that the inventory in the system is going to reduce, so we could check whether the inventory at that point is total inventory at that point is less than the total target inventory and if it is less we initiate production of one more item. It is also important to understand that the target inventory can also change with time depending on the demand positions and depending on the inventory positions and therefore, the whole system will also be a little more dynamic and will change with time. So, essentially CONWIP talks about at the aggregate level trying to balance the overall inventory and then move to the individual level where we try to make a decision on which one to produce.

(Refer Slide Time: 18:40)

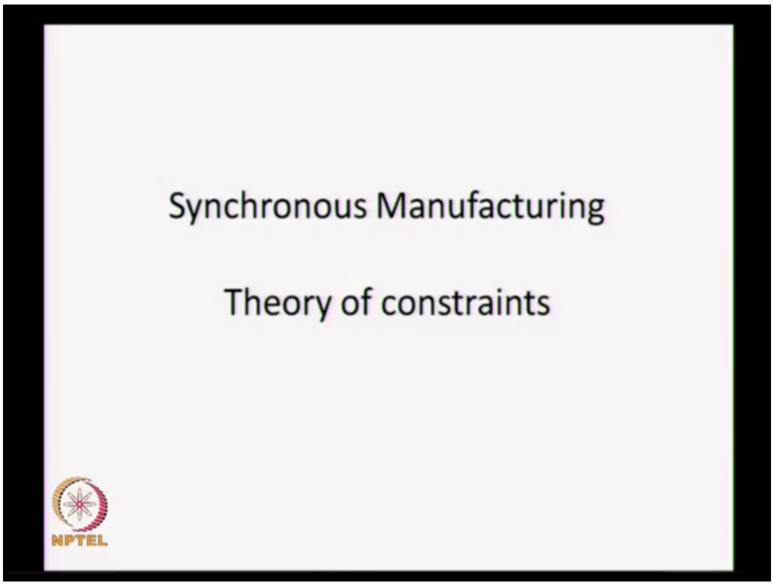


Now, one of the requirements in CONWIP is when we have a large number of items we actually have to keep stock of what kind of batches or when the batches are completed and then we need to update the completion into units in inventory and when items are withdrawn from inventory we need to update them and then we need to trigger production. So, CONWIP in principle would involve some kind of a computerized control, where these things are done as and when batches are completed as and when units in inventory are taken away and new production batches will have to be created to meet this kind of a demand which is presently there.

So, CONWIP does not explicitly have things like containers and cards as kanban has, but CONWIP in it is own way through a certain computerized control mechanism is able to keep the Work In Progress inventory and total inventory in the system as constant and then trigger release of items depending on the inventory positions. So, this is how the CONWIP system works.

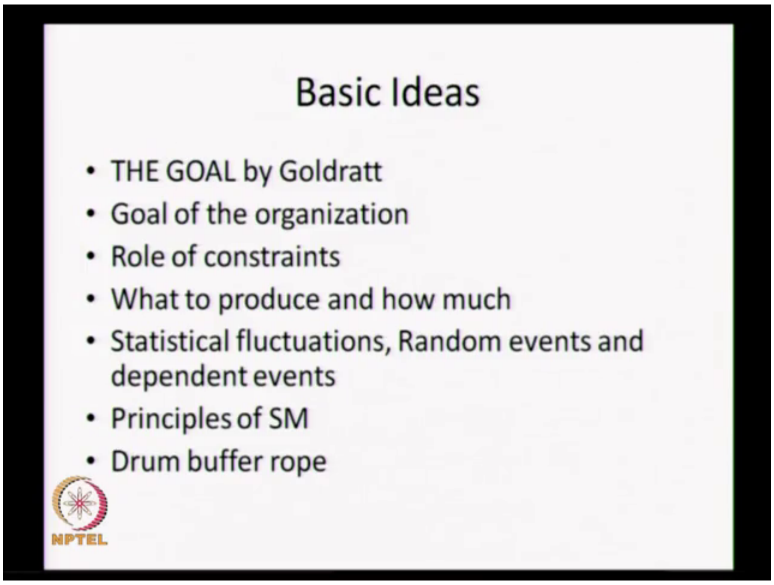
And now we move to another topic which is called synchronous manufacturing or theory of constraints.

(Refer Slide Time: 20:08)



We now look at synchronous manufacturing or theory of constraints. We use these terms interchangeably. Synchronous manufacturing is a manufacturing philosophy which came in the early eighties and is being practiced by several manufacturing companies. It is also called theory of constraints because it primarily addresses or attacks constraints that prevent manufacturing systems from attaining their goals.

(Refer Slide Time: 21:10)



The first effort on this concept or philosophy called synchronous manufacturing started by Professor Eliyahu Goldratt who wrote this book called The Goal. The Goal was first published in 1983 and The Goal was in the form of a novel which captured the essence of manufacturing and the principles of what was later going to be called as synchronous manufacturing or theory of constraints. So, it is about 30 years since The Goal was first published in 1983, say 28 years ago and several manufacturing organizations have used these principles.

We will see some basic ideas in synchronous manufacturing or TOC or theory of constraints as it is called, but before we do that we also spend a little bit of time about this book called The Goal which has almost become a textbook in several universities in courses related to manufacturing, manufacturing systems management and synchronous manufacturing and so on.

So, as I mentioned this book is written in the form of a novel and essentially captures the fundamental principles in manufacture. The main character in the book is a plant manager, who faces difficulties in his manufacturing plant. The book begins with the plant manager coming to office on a Monday morning and it captures almost all the issues that the plant manager faces; for example, late deliveries, need to complete things in time and start the delivery, the issue over changeover times, issues of tool breaking down and alternate tools not being available, having to go elsewhere and borrow it and all the firefighting that happens in a manufacturing plant and finally, at the end of the day they complete what is to be completed for the day. Now, the plant manager starts thinking that almost every day of mine at work goes like this and is there a solution. The plant manager also goes to attend a review meeting in a different city and is told by the corporate that unless he turns the factory over and makes improvements within a certain period of time there is a risk of the factory being closed.

So, the plant manager faces 2 dilemmas. The manager cannot go and tell his people that the factory could be closed. At the same time, the manager has to get things done and show improvement so that, the factory remains and everyone retain their job and work. So, he sets up a small task force and slowly understands the principles of manufacturing and particularly the role of the constraint. He also in between meets an old professor of his who also asks him some specific questions related to manufacturing. In fact, this professor is not a professor of engineering or manufacturing, but is a professor of science and some of those questions were very probing which makes the factory manager understand the strong relationship between science and manufacturing.

The rest of the book follows as some kind of conversation. Occasionally, the plant manager meets the professor and invariably the professor does not solve his problems, but through a conversation makes a plant manager understand some important aspects and basic aspects of manufacturing. Now, the story goes on that the plant manager learns almost all aspects of manufacturing, the role of constraints, the goal of the organization, how much to produce and what to produce, the effect of statistical fluctuations, random events and dependent events.

Now, these points I have listed here under the basic ideas though all of these are mentioned indirectly in the book, sometimes directly, sometimes indirectly in the book, they are not mentioned as specific chapters or specific lessons per say, but they are part of a novel that is the main theme of the book and how the main character of the book understands all these aspects. Eventually, we lead to the principles of synchronous manufacturing and how we do drum buffer rope scheduling.

So, coming back to the book the plant manager understands all the aspects as we move along in the book and slowly brings in the changes that are required and shows improvement in manufacturing. This improvement leads to meeting the requirements of the corporate and the plant is not closed at the end of the day and the plant manager actually earns a promotion and becomes a general manager at the end of the book.

The book also talks about some simple happenings that happen in the family of every person, every professional and it also explains how these principles that one uses at work can be suitably used to meet these challenges and the factory manager applies some of these principles to his life and makes his life little more rewarding than what it was before.

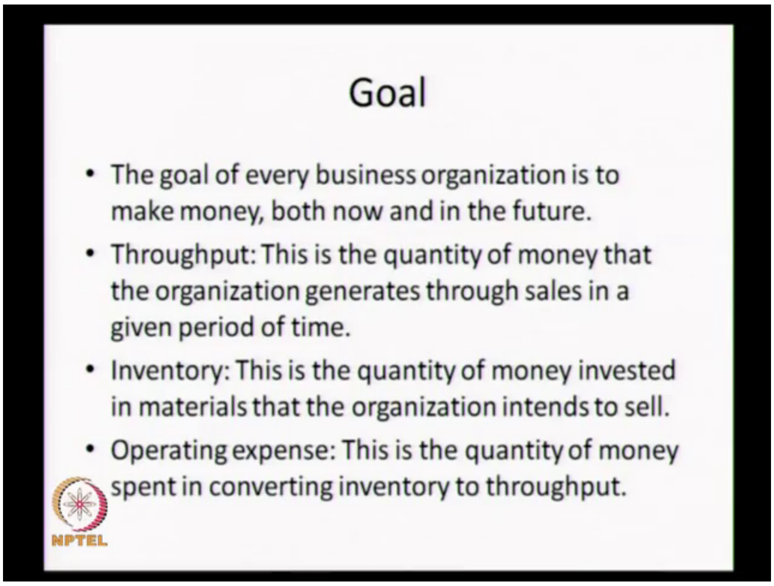
So, this particular book called The Goal by Eliyahu Goldratt made a huge impact on the manufacturing industry and several people have read and implemented the principles that he talks about in that book. In fact, the main character of the book, the plant manager, can be equated to the reader who is expected to be a professional network and the professor could be equated to the author who tells the person what the principles are.

The book is not restricted only to manufacturing even though it started in the context of a manufacturing organization, but the principles can be extended to overall business also. The author had has also written several other books which also highlight the role of these principles in several areas such as supply chain, such as project management and so on. So, today, almost every practicing manager and every student of manufacturing systems management reads one or more of these books and particularly the book titled The Goal by Goldratt.

Much later, several books and several research articles on the synchronous manufacturing or theory of constraints appeared and particularly the book by Umble and Sreekanth formalized these ideas into specific chapters and topics. So, we will be seeing some of these specific chapters and topics as well as some of these basic aspects of synchronous manufacturing in this lecture series.

The things to understand as a follow up of the book called The Goal are to understand the goal of the organization, what is a constraint and what is the role of a constraint and what are different types of constraints. Then we address production decisions as to how much to produce and which products to produce; then we understand constraints that could come in the form of statistical fluctuations, random events and dependent events and the relationship among these 3 things. Then, we study the principles of synchronous manufacturing and we also study scheduling in the context of synchronous manufacturing which is called the drum buffer rope system. Throughout this discussion wherever necessary we will go back and revisit the book and some ideas represented in the book and explain how the author had indicated some of these in the book.

(Refer Slide Time: 30:55)



So, let us look at the goal of the organization. So, Goldratt defines, the goal of every business organization is to make money, both now and in the future. So, it ties up with what is usually taught on the first day of a finance course or in a business school that the goal of every organization is to make money and when we talk about organizations here we are not talking specifically about nonprofit or social service organizations, we are looking at organizations that manufacture a product and sell or provide a service and sell and the objective or the goal is to make money, both now and in the future, so that, they can sustain and continue to grow. The importance of defining this as to make money comes in the way the other 3 parameters are defined.

So, 3 other important parameters are defined by Goldratt and these 3 are throughput, inventory and operating expense. Now, throughput is defined as, the quantity of money that the organization generates through sales in a given period of time. This is not the first time that throughput is defined, throughput is defined in many other ways by many other authors, but this specific definition of throughput relates throughput to money.

Throughput can also be defined in terms of number of units produced or the time worth or money worth of items that are produced that are to be sold. The only difference between a traditional definition where throughput is defined as number of units or time value of the units or money value of the units that are produced and this definition of throughput is that in this definition throughput is the quantity of money generated through sale and not through production. So, this difference in the definition is to be understood that throughput relates to sale and throughput does not relate to production. So, the definition given in synchronous manufacturing is that throughput is the quantity of money generated through sale.

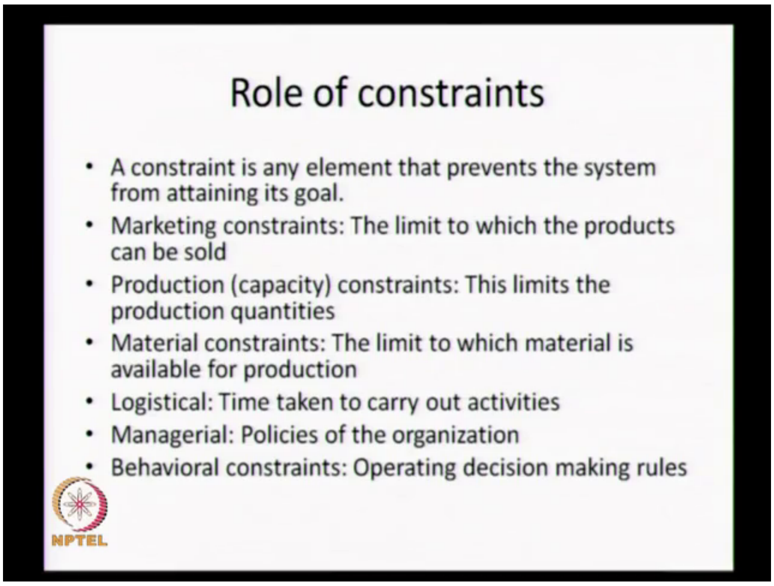
The second parameter that is defined is inventory. Now, the definition here is inventory is the quantity of money invested in materials that the organization intends to sell. The important phrases intend to sell. Traditional definition of inventory is the number of units that are available in inventory or the number of the units in terms of money value that are available or units in terms of time value that are available. For example, a term called days of supply is a way to define inventory in time value.

An inventory can be represented in money value or units. Many times it is represented in money value or time value because the number of units of a particular item and number of units of another item may represent different quantities of money. So, inventory is defined in money value, but in this definition the important phrase is the quantity of money invested in materials that the organization intends to sell. So, the money is invested in materials and it is still in the form of raw materials or Work In Progress or finished goods that are not yet sold, but there is an intention to sell them. So, in a way the definition of inventory is similar, except that very explicitly the term intends to sell is added in the definition.

The third parameter is called operating expense, which is defined as the quantity of money spent in converting inventory into throughput. Now, operating expenses also traditionally defined as the quantity of money that is spent in transforming raw materials to finished products. Here, the differences to convert inventory into throughput and both inventory and throughput are defined in terms of money value.

So, all the 3 parameters throughput, inventory and operating expense are now represented in terms of money. They are defined in terms of money and they are measured in terms of money. Since all the 3 are measured in terms of money, every activity will now be measured in terms of money. There is a normal saying that each person will behave according to the way he or she is measured and now since the measurement is based on money we would expect every activity of the organization to be in tune with or to synchronize with the measurement which is money.

(Refer Slide Time: 36:42)



Another aspect of synchronous manufacturing is to understand what is called the role of a constraint. Now, a lot of emphasis is given on the role of constraints in synchronous manufacturing and theory of constraints. In fact, the very term theory of constraints which is an equivalent term for synchronous manufacturing would tell us the importance given to constraints. When these principles are applied to manufacturing they are called synchronous manufacturing and when they are applied to other areas other than manufacturing, be it business, be it administration, be it personal lives, it is called theory of constraint. So, constraint is the most important thing in this aspect.

So, definition of a constraint is, constraint is any element that prevents the system from attaining its goal. So, here we have defined the goal as to make money and anything that prevents the system from attaining its goal or making money is a constraint. Constraint definition is well known fact very field of operational research or operations research talks about constraints and this definition is also consistent with a definition that we have in the field of operations research.

If we take a simple operations research problem, say linear programming, if we have a maximization problem if we do not have a constraint we could have a very high value of the objective function. So, we add a constraint the objective function value comes down. Then if we solve a linear programming problem and add another constraint now, the new constraint can only worsen the performance and cannot make it better. So, the new constraint would now prevent the system from attaining its goal. The same thing is true of a minimization problem in linear programming as well. So, constraint definition is the same here as well as in the field of operations research.

There are slight differences here the categories of constraints are also given. So, constraints could be of any of the following type. The constraint could be on marketing, constraint could be on production, constraint could be on material, constraint could be on logistics and logistical activities, constraints could be on managerial activities and constraints could be on behavioral activities and behavioral constraints.

Now, let us look at some examples from each one of them. A typical marketing constraint is the limit to which products can be sold. Now an example is that we could have a manufacturing facility which could make 100 units a day and if we assume that we work 5 days a week then we could make 500 units, but if the marketing department can fetch orders only for 400 units then we can produce 400 and sell 400. Producing 500 in this context is not going to be useful at all, because we cannot sell the remaining 100.

So, the constraint comes in the form of marketing even though we could produce 500 we can sell only 400, so, marketing is a constraint which determines the production quantity. Now, the goal ideally would be to make the 500 and sell the 500, but this constraint that we can sell only 400 is preventing the system from attaining its goal of making 500 and selling 500.

Second type of constraint could be from production constraint or capacity constraint and this limits the production quantities. Now, if we have a system where the marketing can have got orders for 400 and now we need to make try and make these 400 and sell, but now if the manufacturing process requires a particular machine and that machine can make only 60 per day then the production can do only 60 per day or 300 in a week or in a 5 day week. Now, marketing may be able to sell 400 if given, but production now becomes a constraint with 300.

Now, this particular resource which can produce only 60 is called a bottleneck resource and we will see the definition of bottleneck in due course. So, this machine which can make only 60 becomes the bottleneck because the capacity available is less than the demand. So, here when production becomes a capacity restriction, production becomes a constraint then the capacity available with production is less than the demand of the item. Sometimes we could get material constraints also.

So, we can have a situation where the marketing have got orders for 400 per week, let us assume that production can make 500 per week. Let us assume they have an extra machine of that type and can make 500 per week now, but then we need materials to make. So, materials have to be bought and then they have to be transformed to a manufactured product. Now, if we do not have suppliers who can give us 400 per week then we will not be able to make this 400 per week even though production is capable of making more than that 400. So, in such situations material becomes a constraint. So, the limit to which material is available for production now makes material a constraint.

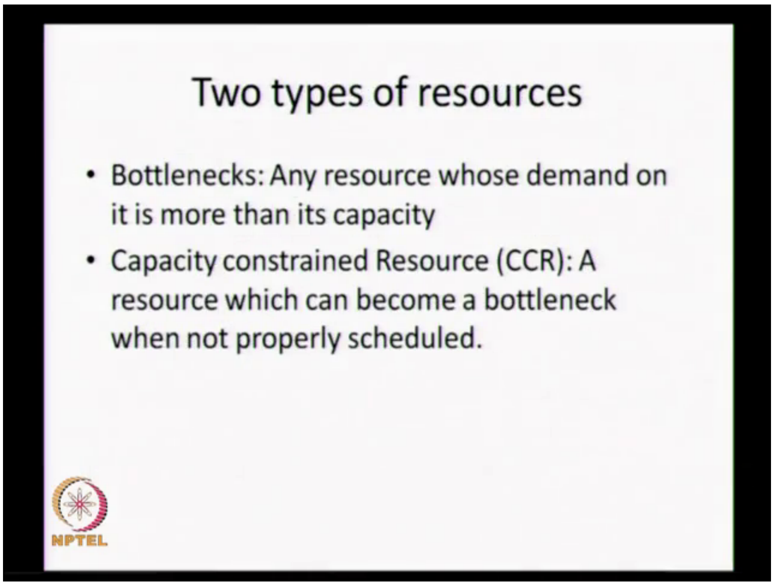
So, we have seen that constraints could be on marketing, constraints could be on production and constraints could be on materials. Now sometimes constraints could be logistical. Now, when we say logistical we say, for example, that if we have to make the product say we make 400 in a week which means let us say we make 80 per day, but for some reason the production schedules are drawn late, because of logistical issues. Material is available with the supplier, but the material does not reach here because of logistical issues then production we are unable to start say on a Monday morning. Production starts later and in such cases the logistical systems become a constraint.

There are times we could have managerial constraints also. Managerial constraints could be on policies such as first in first out. There are policies such as shortest processing time rule that is chosen to pick and because of these policies we may end up with not the best schedule. So, schedules will vary depending on policies that the organization uses. So, different policies can give different schedules and because of different schedules the scheduling could become a constraint and we will be able to produce less than 400 when the market can actually take 400. So, we could have managerial constraints which are there which reflect or which depend on certain policies that the organization takes.

Now, there could be behavioral constraints, where we could have certain decision making rules which reflect certain behavior and culture of the people. Examples could be using a last in first out to pick material or to use economic order quantities and if for some reason the supplier does not have the amount equal to the economic order quantity then the supplier delays sending the items in time. So, it could become a material constraint. Sometimes insistence on a last in first out policy would make sure that that the material that came first is not consumed at all and becomes a waste whereas, the accounting system could show that there is enough inventory of that material. So, the books would show that there is enough inventory, but then that inventory could not be used.

Therefore, behavioral constraints result in other constraints such as marketing constraints or production constraints or material constraints. So, we could have several types of constraints which actually prevent the system from attaining its goal.

(Refer Slide Time: 46:22)



We also now talk about 2 types of resources which are called bottlenecks and capacity constrained resource. So, if we define a bottleneck then we could also define a non bottleneck. So, we have to define 3 things now. A bottleneck, a non bottleneck and a capacity constrained resource.

Now, if we have a demand of 400 and if we have a machine which can produce only 60 units a day of that particular item then this machine can produce only 300 in a 5 day week. Now, this machine the demand on the machine is 400 per week the capacity of the machine is 300 per week. So, it is a bottleneck. So, any resource or any machine, bottleneck need not be only a machine, it could be a different kind of a constraint. For example; the market demand could be 400, but all the suppliers put together can give us raw material of only 300 in a week then the supplier becomes a bottleneck. Normally, we use the bottleneck to identify or denote a machine in manufacturing, but bottlenecks can also be other constraints and resources.

So, a general definition would say that bottleneck is any resource whose demand is more or demand on it is more than the capacity. Those resources whose capacity is more than the demand become non bottlenecks. For example, if the demand is 400 per week and we have another machine which is carrying out one of the processes now that machine can handle hundred per day and can do 500 in a 5 day week. So, that machine is not a bottleneck machine with respect to this product whereas, a machine that can do 60 per day and 300 in a 5 day week is a bottleneck machine.

Now, what is the capacity constrained resource? A resource which can become a bottleneck when not properly scheduled becomes a capacity constrained resource. So, the machine that can do 100 per day and 500 in a 5 day week is not a bottleneck, but if for some reason material arrives on the middle of the second day due to poor scheduling then this machine can do less than 400 in all the 5 days put together or in the remaining time. In such a case, it will become a bottleneck even though it was not a bottleneck. It will become a bottleneck because of poor scheduling and because of poor planning on that resource.

So, when the resource is not planned and scheduled correctly and even though it is a non bottleneck it can become a bottleneck because of this, then that resource becomes a capacity constrained resource called CCR. Other aspects of synchronous manufacturing we will continue to see in the next lecture.