Manufacturing Systems Management
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Lecture - 01
Introduction to Manufacturing Systems Management

This course is titled as Manufacturing Systems Management. This course is essentially an elective course and advanced course either in a management curriculum or in a master's program in industrial engineering or manufacturing systems engineering. Now this course can be learnt after one complete course in operations or production management. This course also assumes that the student is familiar with basic concepts in operations management.

The topics that we would be covering in this course are shown here.

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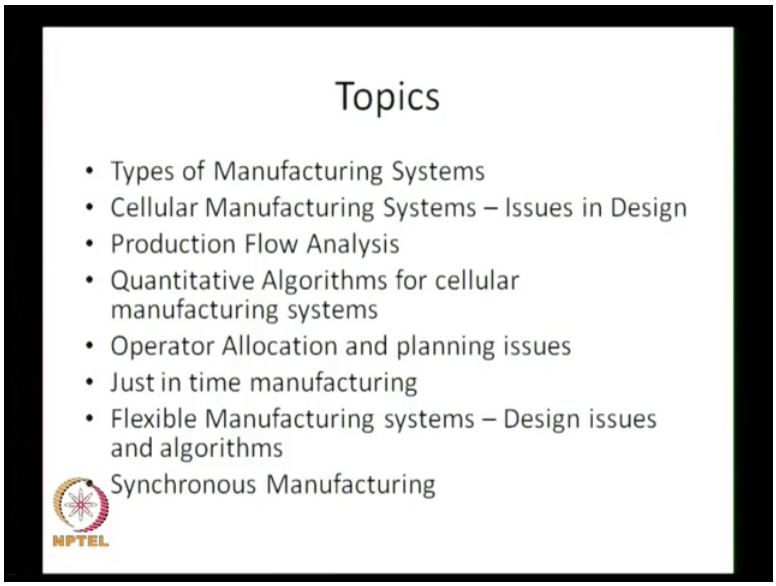

We would introduce manufacturing systems management and also talk about various types of manufacturing systems. And then the course will have a strong emphasis on 4 aspects, which are cellular manufacturing, just in time manufacturing, flexible manufacturing systems, and synchronous manufacturing. Synchronous manufacturing is also called theory of constraints. We will spend a fair amount of time trying to understand cellular manufacturing systems. And within the topic of cellular manufacturing systems we would concentrate on design as well as some aspects of cell

scheduling and sequencing. Cellular manufacturing is also called group technology. We will see it in detail as we move along. So, we will be using the term cellular manufacturing and group technology alternately in this course to mean the same concept.

We will study production flow analysis which is one of the ways of creating cells. The main issue in cellular manufacturing systems is to create the manufacturing sense and among the many methods available production flow analysis is a very popular one and is used extensively in practice. So, we would learn the production flow analysis method in this lecture series.

We would also be looking at other quantitative models and algorithms for cell formation or design of cellular manufacturing systems. We would also be looking at operator allocation problems and planning issues in cellular manufacturing. Then we would move to just in time manufacturing, we would see the basic ideas of just in time manufacturing, some aspects of Kanban controlled manufacturing and some quantitative models which also help us understand and model sequencing issues in just in time manufacturing.

We would also spend a little bit of time understanding con web which stands for constant WIP or constant work in process inventory and try and understand and study the difference between con web and con bar. We would then move to synchronous manufacturing or theory of constraints, which is a very popular manufacturing methodology, which is about 25 years old it is also called theory of constraints. So, we will see the basic principles in synchronous manufacturing, we will see what synchronous manufacturing is and we would also look at some aspects of scheduling in the context of synchronous manufacturing.

We would then move to flexible manufacturing systems which are again very popular and well known flexible manufacturing systems have also been in place for over 25 years and we would see some quantitative models in flexible manufacturing system design as well as in scheduling of flexible manufacturing systems. So, this is the broad overview of the topics that we are going to see in this course. In this first lecture of this manufacturing systems management course, we would introduce the idea of manufacturing systems management and very briefly lead to what are the requirements of manufacturing and how over a period of time manufacturing methods and methodologies have come into place.

So, we begin the first lecture of this course formally with an introduction to manufacturing systems and some of the issues in manufacturing.

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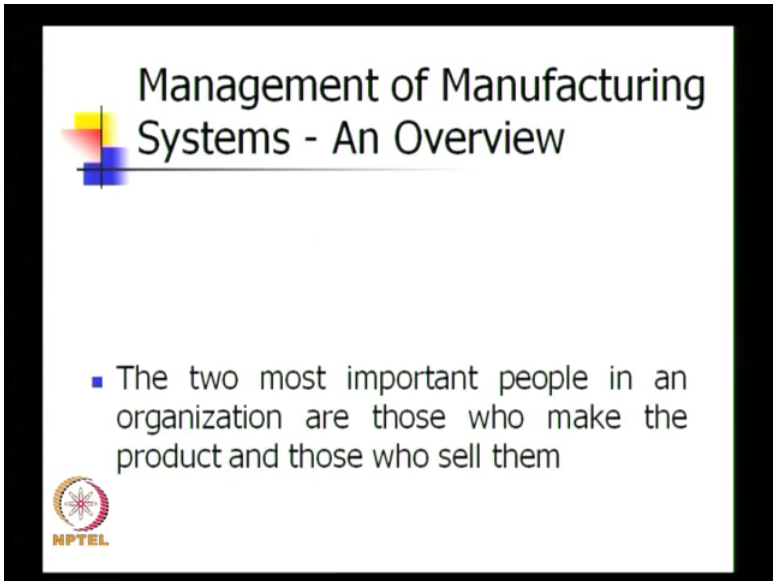

So, we begin with an important observation that 2 most important people in an organization are those who make the product and those who sell them. So, whenever we talk of manufacturing we are talking of an organization which is making a single product or a set of products or a variety of products or several variants in within a certain variety of a product now these products are manufactured and sold.

So, we are talking about the importance of manufacturing and the need to perform the manufacturing in a least cost and in a very effective manner. So, in this context the quotation that you see here which says that the most important people in an organization are those who make the product and those who sell them stresses the importance on manufacturing and the people who are involved in the activity of manufacturing.

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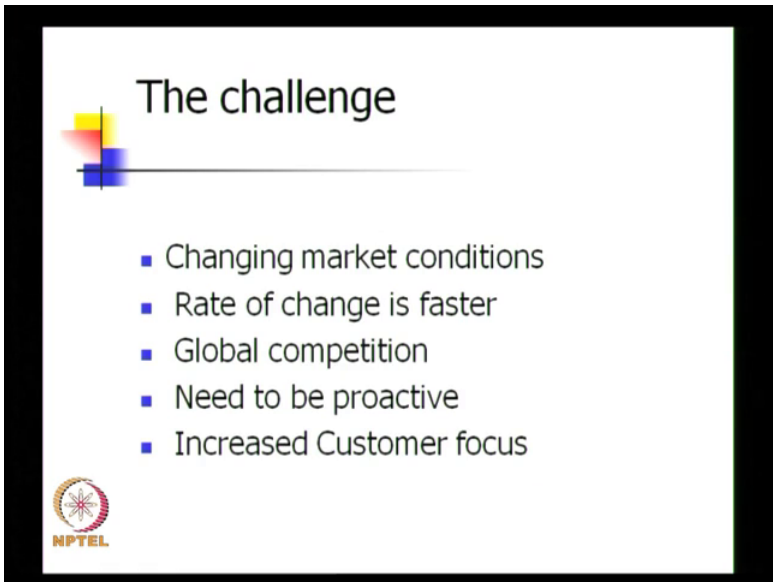

Now, what are the challenges that manufacturing faces or has been facing over so many years. There are several challenges it has never been an easy task to make the products in time and sell them in time, these challenges have also changed over a period of time, some of these challenges are listed here first and foremost is changing market conditions, which talks about the customer requirement changing over a period of time. Now several years ago we did not have as many varieties of the products as we have today, if we look at India 30 years ago or 40 years ago we did not have as many automobiles plying on the roads as we have today.

Our production of automobiles has also increased considerably and significantly over the last years along with the variety of products that have come into the market. There are several ways by which the market conditions have changed there was a time people would buy new products only when the old products were not usable or could not be repaired for further use. Today every one of us wants to buy new products because the products are available and affordable and offer newer specifications which we can use.

The rate of change is also much faster change happens and change is continuous and change happens always at a much faster rate than it was before. So, manufacturing has to adapt to the requirement that rate of change is faster I mean addition we have global competition 20 years ago or 25 years ago in India we did not have so much of global

competition, but the changes in governance policies in the nineties brought a lot of foreign players and competition from abroad.

So, today every organization be it a company that is completely owned in India or a company that that exists in India will have to look at global competition for almost every one of these products. Even whatever product we name we can easily find a company that is making it and it is not an Indian company and it is competing with Indian companies. So, global companies bring in different ways of manufacturing they bring in different aspects of managing their manufacturing systems which is able to give them the ability to make products faster to make products at less cost and to make products with high quality.

So, every manufacturing organization will have to meet this challenge of global competition, many times global competition in terms of scale as well because several of these companies are very large companies. So, global competition is always a challenge which manufacturing has to meet. Importantly manufacturing organizations have to be proactive and cannot be reactive many times best practices come and best practices are followed.

Best practices are followed for multiple reasons someone is able to find the best practice in a different industry and brings it to the industry, under consideration. Sometimes competition drives us to borrow best practices, but when we borrow best practices and when we change the manufacturing the ways of manufacturing, we need to be a lot more proactive than reactive many times we end up being reactive, but the need is to be proactive. So, let me explain the relationship between being proactive and reactive using a graph.

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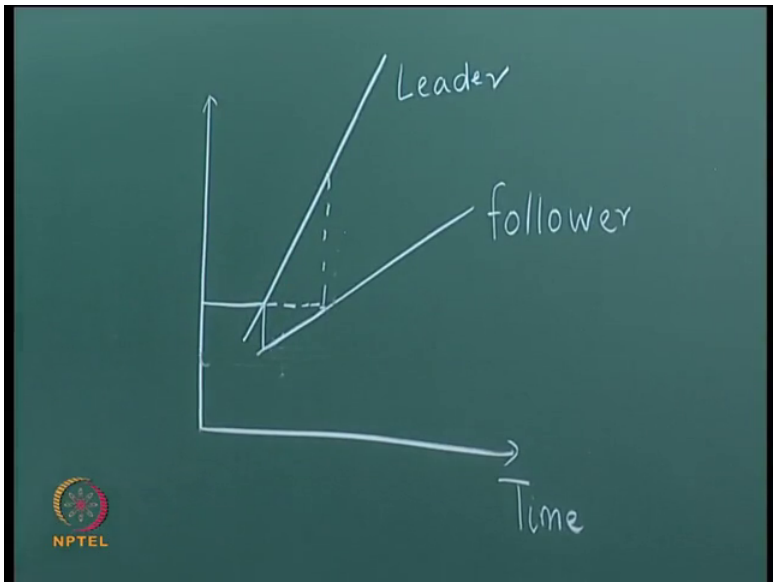

Now, this is called a leader follower graph now this is the way the leader is moving with respect to time and this is the way the follower is moving with respect to time. So, when the follower is in a reactive mode which means the follower looks at the leader takes best practices and implement. Now what happens is at this point in time the leader is here and let us say the follower is actually behind. Now the follower borrows the best practices from the leader and moves like this, but as the follower moves and reaches the same position that the leader is after a certain while one can see that the leader has actually moved further upwards.

So, the follower would always be behind the leader unless the follower does certain things productive, one of the reason is this gap increases is the difference in the slope between this leader line and the follower line, but it is also true that the leader moves faster and moves at a higher slope compared to the follower. So, this simple graph explains to us the need to be proactive and not reactive and to try and do new things rather than to follow also in addition to following best practices from leaders.

Over a period of time manufacturing also has moved towards increasing their customer focus, the reason is the product is sold to the customer and the organization makes it is money by selling the product to the customer. So, over a period of time with more emphasis on aspects such as quality the customer focus has increased and manufacturing organizations, now have to adapt themselves to meet the demands of the customer and to

make the customer happy and to meet the expectations of the customer. Now increasing customer focus invariably increases the variety of production, makes new products come into the market quickly and moves manufacturing from what is called mass production to mass customization. So, whatever the customer requires manufacturing should be able to provide. So, that they maximize their profits.

Now, let us understand how the customers' requirements have changed over a period of time.

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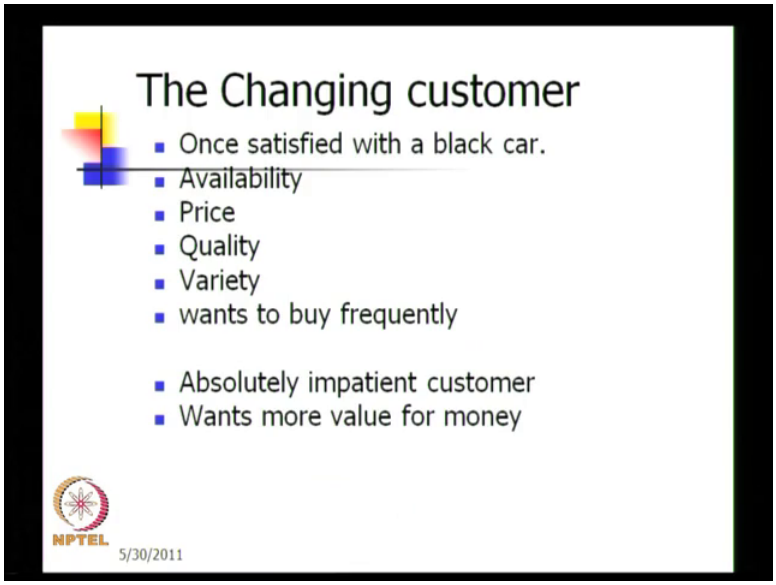

Now, the first bullet which talks about the customer once satisfied with the black car explains the origin of manufacturing and indicates that the customer was able to take what was given to them which talks about the black car that came in the early twenties. Now the customer started looking at availability of the product. So, the customer asks questions like is the product available if I want to buy.

So, this customer requirement change the focus of manufacturing to making the products available, which meant that production was largely based on high volume as much volume as possible was made by the manufacturing companies. Then the customer started looking at the price now the customer started looking at the affordability of the product, which meant that manufacturing had to cut down or bring down the cost of production. So, that the customer pays less and buys the product then the focus shifted on to quality and the customer started demanding quality.

Now, this meant that manufacturing had to spend lot more emphasis or lot more time and effort on quality; quality is a separate topic by itself quality is a separate area by itself, but then since we are looking at quality let us also start defining quality here. Quality has several definitions the standard definitions are fitness for use and conformance to specifications. Fitness for use or fitness for a purpose is quality defined in the context of service and conformance to specification is a traditional definition of quality, which is for a manufactured product. Now over a period of time quality has also moved towards customer focus and one of the important definitions of quality as given in the ISO is the ability to meet the stated and implied needs of a customer.

So, the word quality now is associated with the customer, the customer has certain needs sometimes these needs are stated, sometimes these needs are implied. In the context of manufacturing most of the times the needs are stated as specifications and quality takes it is traditional definition of conformance to specification. Now in service the customer needs are implied.

And therefore, quality takes a definition of fitness for purpose, when the customer feels that the service is good enough to be utilized, but quality over a period of time has moved from the service provider or the manufacturer perspective to the customer perspective. Quality definitions have also changed over a period of time from the definition of ability to meet stated and implied needs of a customer 2 a definition which says ability to meet the needs and requirements of the customer and other interested parties.

Now, quality the other interested parties are the legal statutory and regulatory bodies. So, quality is the ability of an organization to meet the stated and implied needs of the customer, at the same time meeting all the legal statutory regulatory requirements including ethical requirements and so on. So, quality over a period of time has changed considerably, but in the context of what we are talking about we are talking more about the customer expectation of very good quality. So, very good quality in terms of availability of spares, in terms of after sales service, in terms of overall quality of the product, including it is appearance and so on.

Then customers started looking at variety, now within the same product we now have so much of variety in the market, several years ago we did not have that kind of variety and

today even products which are for example, food products for example, rice and salt and even products of that type or commodities that are used there is so much of variety to buy and choose; obviously, for other consumer goods like a variety of goods which would include automobiles, which would include things like cell phones, pen drives, audio systems, we find enormous amount of variety and the customer has a lot to choose from. It is also important to note that the customer wants variety because of which manufacturing has to adapt itself to provide a variety of products last, but not the least the customer also wants to buy frequent and already mentioned earlier that in the past the customer would change the product only when the product was not usable or when the product could not be repaired.

Now, today the concept of repairing an existing product has almost become obsolete now products are such that they are either taken back or they are simply disposed of the concept of repairing something that does not exist so much today. Also means today that the customer wants to buy frequently simply, because new products with similar and better features are now available. Now, one could see examples of that in automobile in phones, in computers, in television, and other products. Now there is a need to buy something frequently simply because new products are available and the customers' ability or buying power has increased.

So, when the customer wants to buy frequently now it brings into manufacturing the need to create new products and these new products have to be designed and conceived before the existing products become obsolete and when the customer wants to buy new products. In addition to these we have 2 more points that I have written down here one is the customer is also impatient. Today the customer does not pay or is not required to pay for the transportation between for transporting the product between the shop and the house earlier we used to do that.

Earlier the customer was patient and was even willing to wait for a day or 2 for the product to be delivered, but today we do not have that. Now these have implications on distribution and logistics, earlier the customer did not have the choice most of the times as to when the particular product could be delivered at home, today the customer has a choice to tell the shop owner as to when the customer wants the products to come.

So, that creates a whole lot of time window related distribution problems which also increases the cost of distribution and transportation this does not impact manufacturing directly, but certainly it does impact some aspects of distribution. The point that I wish to make here is that the amount of time that the customer is willing to get the product between paying and getting the product is far less and that also has some implications on wanting to buy frequently and so on.

Now, similarly the customer also wants more value for money today, the package would include for example, certain warranties or it could include certain other sales after sales services and so on, along with the price of the product. So these 2 are also additions with respect to the changing requirements of the customer. Now each of these changing requirements of the customer also puts a certain requirement on manufacturing and which we will see after we look at some other couple of slides which are which talk about changing events in history, but each of these changing requirements of the customer also creates what is called a requirement of manufacturing which we will see as we move along.

Now, there are a couple of other slides which I have included here which talk about some events in history.

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Which essentially talk about how computers and other quantitative modeling has come to stay in manufacturing and business and how speed also plays a role with respect to the

way by which manufacturing and manufacturing support systems work. So, the purpose of this slide is to talk about that. So, the first bullet talks about the second world war when manufacturing or as well as the world started understanding the requirement of resource availability and the need to work with constrained resources. So, that was felt during that period and afterwards up for well over fifty years we have started looking at managing things when resources are scarce.

Now, after that came computers which were essentially used for cost and information control to begin with because the early applications were in payroll after that applications came in purchasing and in information control as well as cost control. So, the computer has provided a way by which certain things can be done error free and it could be done at higher speed. Then came advances in quantitative methods field of operations research which spoke about doing things better how to optimize and how to achieve the objectives in the context of resource constraints.

After that came advances in communication systems where the gap between the manufacturer or the service provider and the customer came down, then moved areas of electronic commerce and home offices, but the essential purpose of this slide is to say is to explain how speed has come in to stay and from being slow processes or time consuming processes several of the support functions today have become much faster. They have become much faster largely because of computers largely because of internet and connectivity and largely because of communication systems.

All these have actually helped manufacturing in carrying out the activities of manufacturing faster and better, but the bottom line is still manufacturing is slightly slower compared to some of these and that is yet another challenge that manufacturing has to cope up because most of the manufacturing support systems are computer based and have become much faster. Now we also trace a little bit of how manufacturing evolved over a period of time.

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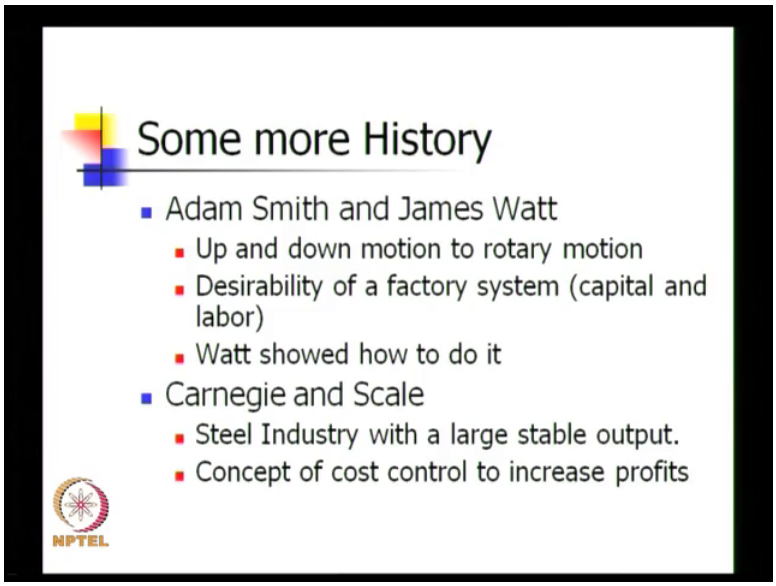

And what are the implications of that in today's context of manufacturing and how people understood various aspects such as volume, such as scale, which is volume variety and so on. We would also look at the contributors in this field. So, a lot of history of manufacturing evolves around a lot of people that we are going to talk about. So, the first one is to talk about James Watt and Adam Smith. So, the early part of evolution of manufacturing was the time when then man learnt to convert a reciprocating motion to a rotary motion and around the same time with the pioneering work of Adam Smith people understood that there is a need to have a factory type of system, and how to kind of bring capital and labor together and make products which can be sold to people.

The next advancement came in scale which is the advancement in the steel industry in the US where the Emphasis was on a large stable output which meant volume production and concept of cost control to increase profits. If we go back to the previous slide where we spoke about changing customer we did speak about the requirement of high volume as well as less cost.

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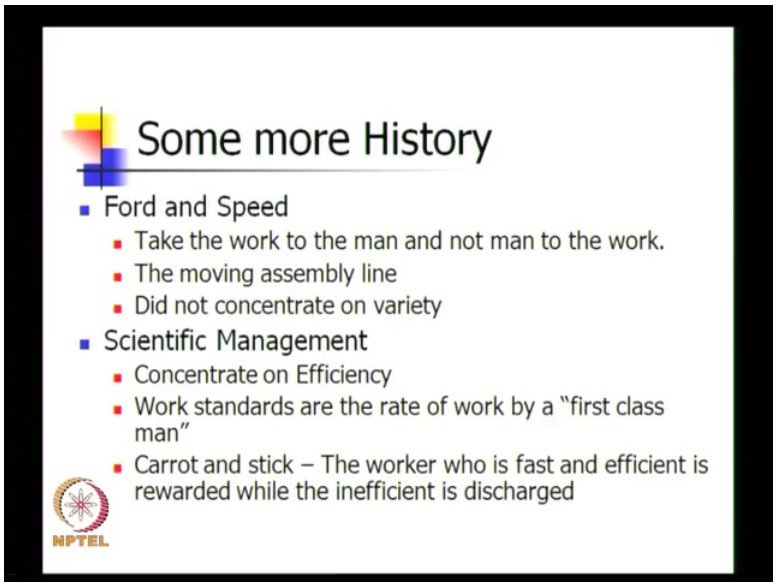

The next aspect that came into manufacturing was understanding speed now speed the emphasis of speed came from ford and the basic idea was to take the work to the man and not man to the work which resulted in the moving assembly line and there was not so much concentration on variety, but there was concentration on volume and speed of production.

The next effort came in the idea of scientific management where the emphasis shifted to efficiency then people started measuring how well an operator is able to do or carry out an activity. So, they also followed what is called work standards where the speed of the best person was taken as a benchmark and then they followed what is called a carrot and stick approach where a worker who is fast and efficient is rewarded while the inefficient was discharged.

Now, this was changed after some time and then the standard was that of the work done by the average person and not by the best person. Now then the people who are who have the ability to perform slightly poorer or slightly less efficient than the average person, were given extra time to carry out the activity.

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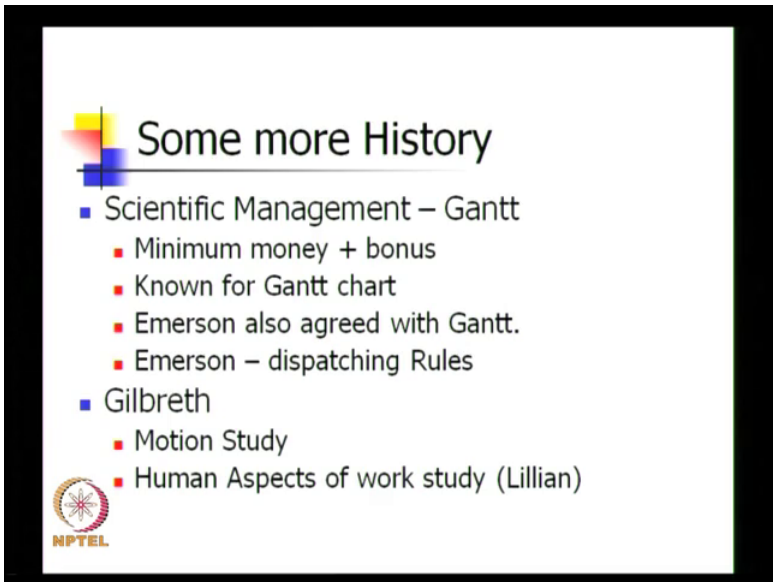

Then the principles of scientific manner and also developed with some other ideas about giving guaranteeing a minimum amount of money to the person and then providing a bonus if the person is more efficient, we have also written down the name of some eminent people who are involved in this thinking Gantt who is otherwise famous for the Gantt chart in scheduling as well as Emerson who is famous for the dispatching rules, they believed that a certain minimum money should be given to the worker and the better performing ones should get a bonus.

Then it moved to time and motion study to try and understand how the people do the various jobs as well as some human aspects of work study which the current which are the contribution of Franklin and Lillian Gilbreth to industrial engineering.

So, these 3 slides have essentially told us how over a period of time aspects such as a factory, system scale and volume, speed efficiency and understanding the way processes happen have all come or evolved into manufacturing through this field of industrial engineering.

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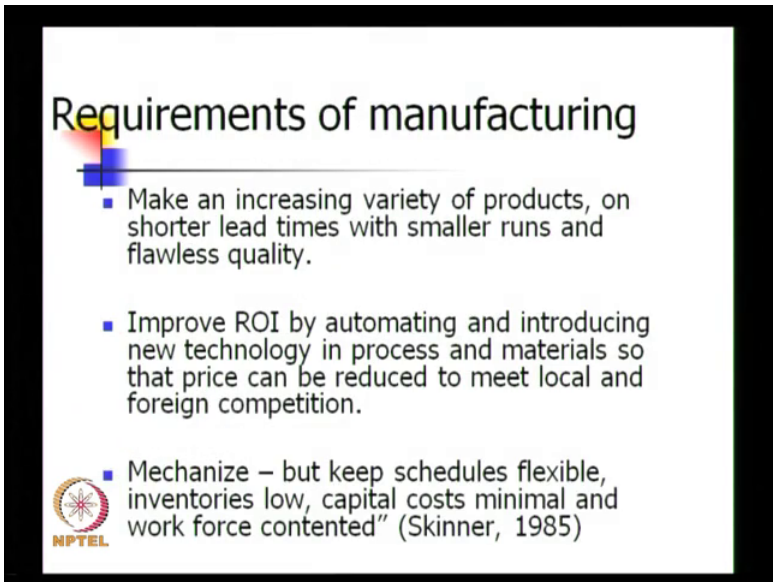

Now, the next slide talks about what is called requirements of manufacturing, but before we go to this slide let us quickly go back to this slide which talks about the changing customer expectation. Now the change in customer expectation is about availability which is volume, cost, quality, variety, and new product development.

So, these are 5 important aspects that we have seen in this slide and let us understand this right which is requirements of manufacturing. Now make an increasing variety of products on shorter lead times with smaller runs and flawless quality improve return on investment by automating and introducing new technology in process and materials. So, that price can be reduced to meet local and foreign competition, mechanize keep schedules flexible, keep inventories low, keep capital costs minimum and keep the workforce contended.

So, this slide is called requirements of manufacturing and these requirements of manufacturing are as given by skinner in his book in 1985. Now this definition is about 25 years old or more than 25 years old, but this definition is extremely relevant in the context of manufacturing for well over 15 20 years and different organizations are trying to meet this requirement of manufacturing.

Now, let us go through this requirements sentence by sentence to try and understand the context as well as the how this relates to what we have been seeing in this lecture. So, first is to make an increasing variety of products because the customer wants variety

todays customer is interested in variety before a customer buys a product the customer wants to see the alternatives and choose the best alternative for him or her. So, make these products on short lead times because the customer wants to buy frequently. So, that is another aspect that we saw in an earlier slide. So, the production lead times have to be shorter the mark the products have to come to the market quickly because the customer wants new products and customer wants to buy them more frequently.

Make products with smaller runs smaller ones would mean a slightly large variety production and a smaller run or batch size with respect to this variety. So, as product variety increases the best quantities come down. So, that a variety of products can be made in a given time period, a variety of products have to be made with smaller runs and make them with flawless quality a very important objective here is the word flawless which means that almost 100 percent quality which also leads us to something called 0 defects.

Today if you work into a factory you would find in many places boards like 0 defect 0 inventories etcetera we all know that it is extremely difficult to have 100 percent on anything, but 0 defect is an ideal state to which manufacturing moves, right now there could be at 99 percent quality or 99 and a half percent quality which means they could be at one percent reject or half a percent reject and so on.

We also know today that rejects are not measured in percentages, but are measured in parts per million. So, there could be about 3000 ppm 5000 ppm and so on. Which are much smaller than 1 percent? So, on what is important is that we have to move towards a situation where there are lesser and fewer rejects. So, the quality has to be flawless the word flawless is a very interesting objective because it not only talks about a quantitative measure of a reject less than a certain pre specified percentage it also talks about a very very qualitative way of looking at quality we say a perfect and flawless only when something is as close to 100 percent.

So, quality has to be extremely high on the agenda and manufacturing has to make products with absolutely flawless their products have to be flawless in nature and with flawless quality; this also shows that the customer expects products with flawless quality. In fact, many times the example that is given for flawless quality is from the pharmaceutical industry when we go to a shop to buy a medicine we do not question the

person who is selling the medicine to us whether this medicine will work or does it have all the ingredients which it should have every small tablet that we buy performs the same way or is expected to perform the same way.

So, that is the example of flawless with respect to specification, with respect to meeting the requirement. Further the requirements of manufacturing move to improve return on investment by automation and introducing new technology in process and materials. So, automation today is an essential component of manufacture we need to have automatic machines. So, that the speed of manufacturing is increased with manual machines the speed was less and the quality was also not so good. So, automation helps us in increasing the speed as well as in making the quality much better.

So, improve return on investment by automation. So, invest in automation and if manufacturing has to improve the ROI through automation exploit the aspects such as speed and quality and ability to produce variety and aggregate volume produce more sell more and improve the return on investment. Introduce new technology in process and materials.

Now this definition is extremely exhaustive it does not talk only about the machining aspect of manufacturing, it talks about 2 other aspects of manufacturing which are process and materials; materials is a separate aspect of manufacturing. So, it talks about manufacturing systems to introduce new technology in materials, be constantly in the lookout for new materials which can bring down the cost because it is well known that the material cost alone takes nearly 60 to 70 percent of the cost of the product.

So, by introducing new technologies in materials it may be possible to bring down the price. So, this definition talks about that introducing new technology in processes which is essentially the focus of this course on manufacturing systems management. So, this will talk about different manufacturing management processes, but the word process also includes the manufacturing process itself.

So, there is a need for manufacturing systems to try and change the manufacturing processes themselves. So, that once again speed, quality, and specifications can be met, because of which price can be reduced and price can be reduced so that the manufacturing company can meet both local as well as foreign competition.

Now, we have to go back to our earlier slide where we had spoken explicitly about foreign competition. So, the word foreign competition explicitly comes in skinners definition of the requirements of manufacturing. Now mechanize bring a lot of automation into the system, but keep schedules flexible do not keep schedules rigid give some space for uncertainty keep schedules flexible bring in a certain flexibility which can be brought in through autumn automation and by mechanizing the manufacturing system.

Keep inventories low right through this course we are going to talk about how inventories have to be kept low and what is the role of inventories and how high inventory is detrimental and not required and is not very effective for functioning of a manufacturing system. So, keep inventories low concentrate on inventory control keep capital costs minimum and keep the workforce content. Now the workforce contended talks about TQM and talks largely about total quality management which is TQM which essentially talks about employee empowerment and giving lot more opportunity for the employees to contribute in the manufacturing.

So, this is a very exhaustive definition of manufacturing which essentially is the need of the hour today, even though this definition was given nearly about 25 years ago. One should also look at how various newer methods and methodologies relate to this requirement of manufacturing. For example, the emphasis on quality is stressed in 2 places one is the flawless quality which talks about quality in the manufacturing process and service and also talks about TQM in the place where this definition looks at workforce being contended.

Now if we look at flexible manufacturing systems the place where FMS comes here is improved by automation, keep schedules flexible, produce a larger volume which is not explicit, but implied is the place where you find the role for flexible manufacturing. If you look at cellular manufacturing you look at places where inventories are low and introduce new technologies in processes.

Now, there are some areas where you find supply chain management contributing where it talks about lower inventories. So, if we look at this definition and if we look at how various manufacturing methods had evolved over a period of time we would see that all these manufacturing methods and advances are trying to address a good number of the

requirements as large the requirements as possible. And there is a strong relationship between how these manufacturing methods try and address these requirements of manufacturing as given. We still look at a few things in this lecture even before we get into detail about different methods of manufacturing management and relate them to the 4 topics that we spoke about cellular manufacturing just in time flexible manufacturing and synchronous manufacturing.

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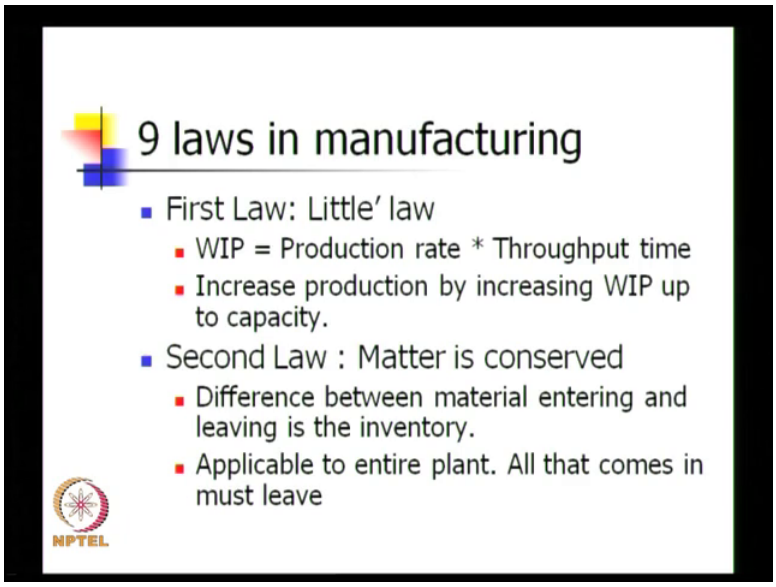

Before we do that we also look at some aspects of this now I am going to talk about these 9 laws in manufacture there are many laws in manufacturing I have just picked up 9 of them from the literature.

Some of these are extremely relevant and important and help us understand manufacturing as we move along in this course therefore; I have picked up these from the literature in manufacturing. The first law is called Little's law which is well known this law is well known in Queueing theory the famous Queueing equation is L is equal to lambda into W, where L is the length of the system lambda is the arrival rate and W is a waiting time in the system. So, the Little's law when written in the context of manufacturing is written as work WIP is equal to production rate into throughput time LS equal to lambda into WS, LS is the length of the system in queueing theory, here it is the number of items that are there as work in progress. So, L relates to WIP lambda is the

arrival rate which is the production rate here and W is the waiting time in the system which is the time taken to produce something or throughput time in this system.

Now, this equation has several implications and can be interpreted in many ways in many ways the idea is to increase the production which is the basic thing by increasing VIP WIP and keep it up to capacity. Second law is called matter is conserved it is an understanding that whatever enters has to leave, but when the things that enter the plant is more than what leaves the plant the excess stays as inventory in the plant. So, difference between material entering and material leaving is the inventory which we need to understand and eventually everything that enters the plant should also leave.

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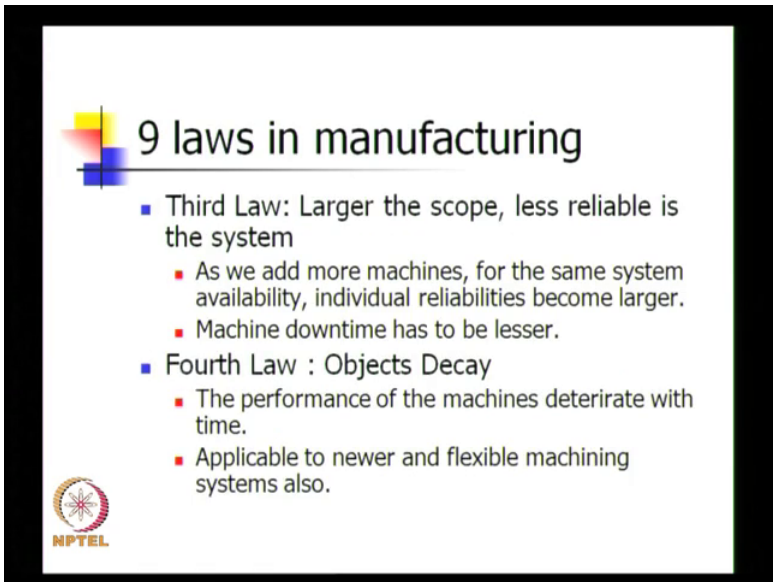

Third law is larger the scope and less reliable is the system. So, as we add more machines for the same system availability individual reliabilities become larger and downtime has to be less, but the understanding is larger the scope less reliable the system. The fourth law talks about performance of machines deteriorate with time and this is applicable to newer and flexible machines also.

Many times when we do our calculation we keep a certain efficiency of the machine and use that consistently in our calculations one has to understand the machine efficiencies come down with respect to time.

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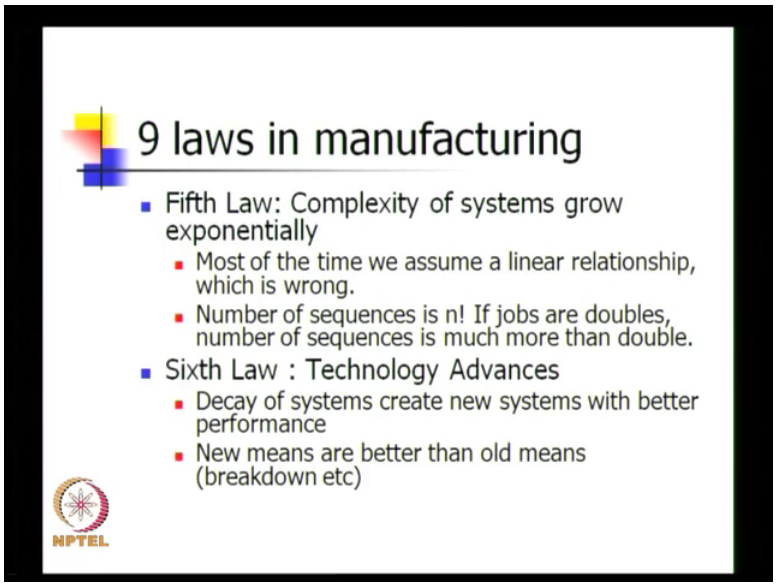

Complexity of systems grow exponentially this is also important many times we assume a linear relationship amongst parameters, but then we have to understand that complexity of systems grow exponentially, a simple example is for n items if there are n factorial sequences for 2 n items we will have 2 n factorial which is not 2 times n factorial. So, the moment systems exhibit non-linearity it becomes difficult to model them the sixth law talks about technology advances the decay of systems create new systems with better performance.

Now, this is something that we see now we observe that new products are better than the old products simply because newer production systems are better than older production systems. So, as different technologies die or if they are they are not used they are replaced though the replaced ones are newer technologies are able to show better performance.

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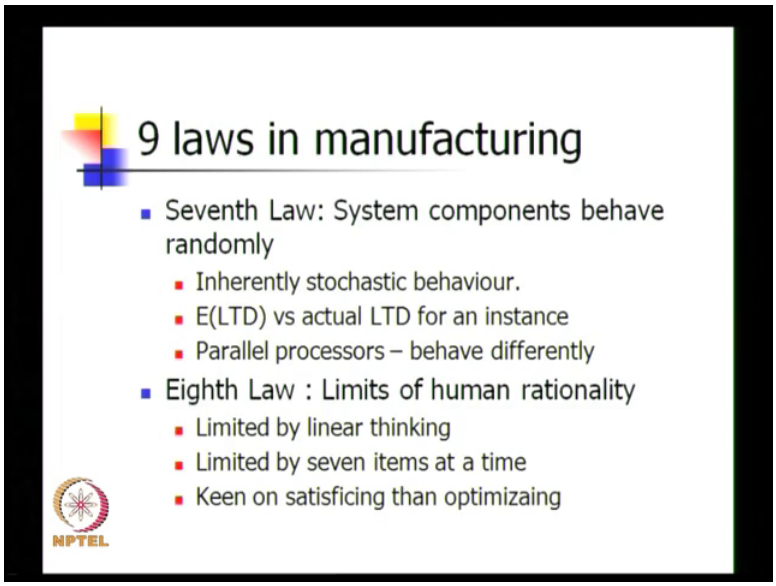

System components behave randomly and they show inherent stochastic behavior, we need to take this also into account. For example, if we look at lead time demand the actual lead time demands are different from the expected value of the lead time demand. And there is a stochastic relationship behavior with respect to these parameters the eighth law talks about limits of human rationality many times we are keen on satisficing rather than optimizing something.

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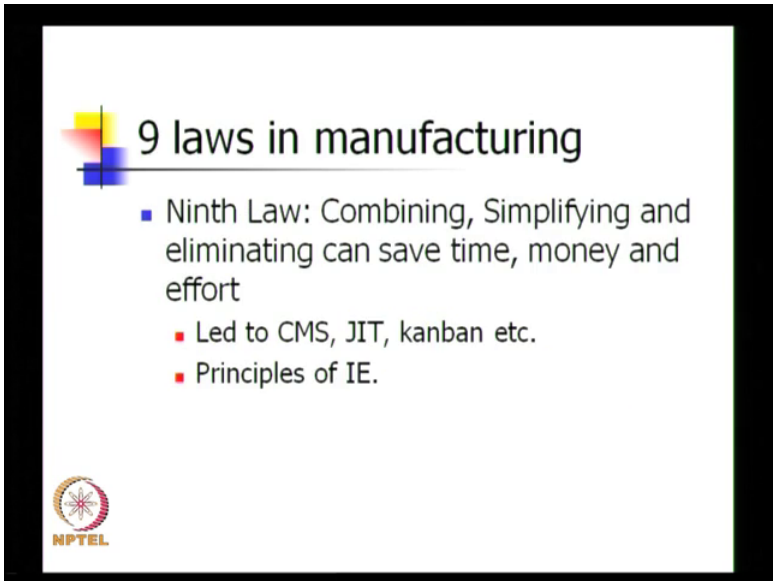

The Ninth and important law which will be the backbone of most of the things that we will see in this course is combining simplifying and eliminating can save time money and effort. Now this leads to things like cellular manufacturing just in time manufacturing systems Kanban systems etcetera and also leads us to several principles of industrial engineering.

Now, one of the reasons for seeing these 9 laws is because these laws provide us with a certain framework to understand and analyze manufacturing systems. So, in that context I had introduced the these 9 laws, even though these 9 laws are not going to in a very strong way influence what we are going to do in this course. Now these 9 laws are slightly away from what we are going to see, but these 9 laws provide us with a general understanding of what are the things we need to look at when we try to model and analyze manufacturing systems.

Now so far what we have seen are; what we have seen are basically the requirements of manufacturing from a customer perspective the implications of that towards what is called requirements of manufacturing and how manufacturing systems have to adapt themselves to meet the customer requirements and then we also saw these 9 laws of manufacturing which provide us with a framework to study.

We also spend a little bit of time to position the various methodologies that have come like cellular manufacturing, flexible manufacturing, just in time and synchronous manufacturing. In the context of the definition of the requirements now what we will actually do is to trace and understand how manufacturing systems evolved to meet these requirements.

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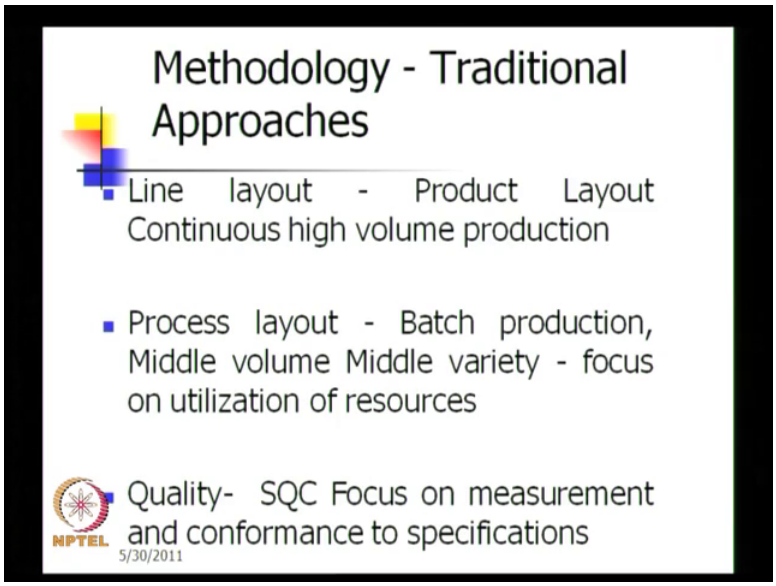

And these are given under 4 heads which are methodologies of traditional approaches.

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Methodology is based on process improvement.

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Methodology is based on human resources and processes.

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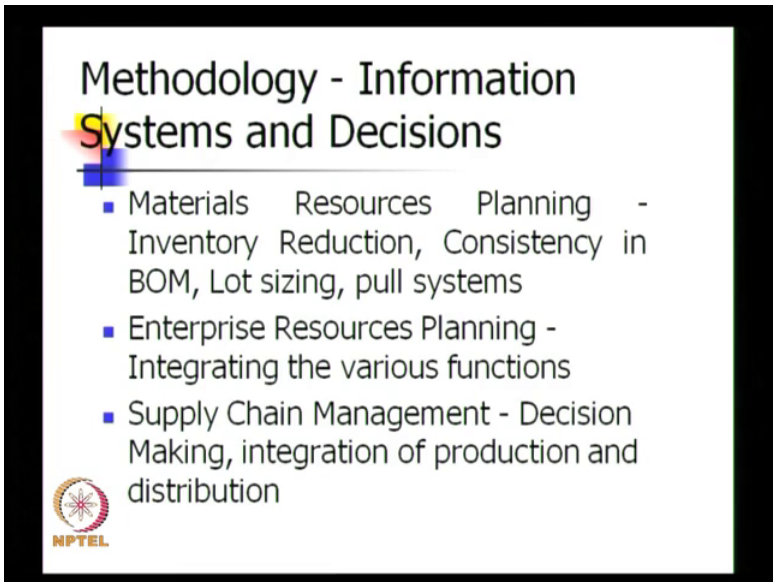

Methodology is based on information systems and decisions.

Now, we will look at each one of these in much more detail in the next lecture and then start with our discussions on some of these in the process improvement, which are essentially group technology cellular manufacturing JIT systems flexible manufacturing systems as you see here. And we would look at a little bit of constraint management or synchronous manufacturing as part of this course.

So in the next lecture, we will start studying how manufacturing evolved over a period of time through these areas of process improvement and so on.