Six Sigma
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Lecture No. # 32
Six Sigma in Supply Chains

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Good afternoon it is Tapan Bagchi again, and we will resume the series of lectures here on Six Sigma, the special topic that we have for this session for you is the use of Six Sigma concepts in improving the performance of supply chains. As I get into this topic I will be discussing things that have more to do perhaps logistics and some with quality, and you will see how we take an example, take a real problem and we define it then we measure the performance as it is, then we try to analyze it, then we look for improvement objectives, improvement possibilities, and then of course we try to control the optimum settings of the various parameters of the system.

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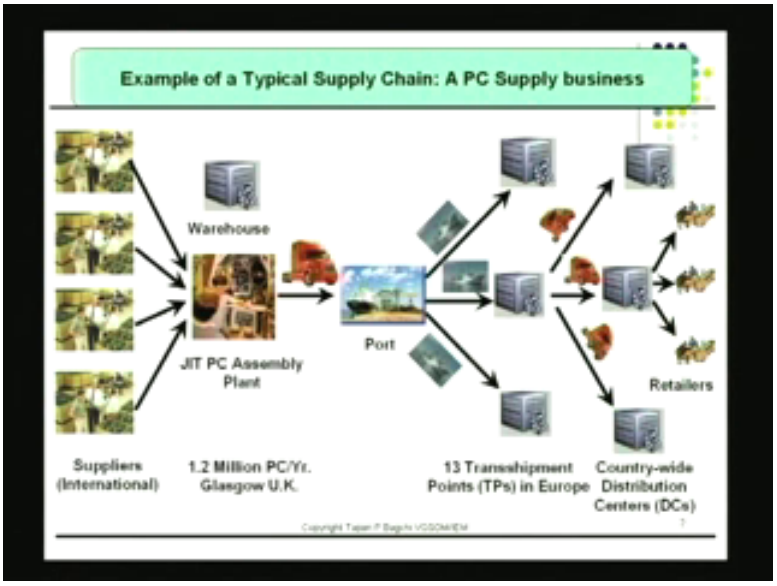

So, to begin with let me give you an idea of what is supply chain really is, a supply chain basically starts with raw materials in many cases, it starts with some very basic input material and the objective primarily is to deliver products which are directly usable by consumers, that is what the goal is. A supply chain comprises many steps, many stages, whereby we transform the input into intermediate products, then tranparts, then perhaps transport them to a process to a stage where it is processed.

Parts are assembled into a product, then finishing touches are produced and then of course, we ship it out towards the customer actually is. So, this supply chain consists of acquiring materials all the way to the final delivery of the product and installation of it in the consumers location, that is what a supply chain is. Now in doing this of course, you got to worry about logistic, that is one thing, you also have to worry about the processing speeds, you have to worry about transportation speeds, that are something you got to worry about. We also have to worry about moving various parts to an assembly place and this could involve for example, going through assembly plants.

Then going through a port which does the transit, then doing the assembly, then of course, moving out the assemblies to a place where retail parts shop is and from there customers are served. In fact, the diagrams that I show here is the supply chain for A PC the personal computers assembly business, it comprises suppliers who are international and they may be spread around the globe. Then of course, we have got assembly plants

which are also located at various different places and these places may not coincide with the place where the parts are made. Then of course, the assembled parts they are moved by shipping or by truck or by some other means, to places where we have got transhipment points. Here we probably sort out the orders and we try to make sure that the final destination they receive, whatever they have ordered they would be receiving those things. And then of course, we move them out to retail shops and that is a country wide distribution network. And from there retailers pick up their material and they supply to the final consumer, this is a full supply chain for A PC supply business.

There are issues; obviously, of transportation times, processing times and quality checks and so on and. So, forth and try to make sure what does the customer wants, when he wants in the right quantity and so on. That is like the overall objective of a supply chain, this is a much more complex process than just trying to operate your single unit, your processing plant or your assembly plant or just your transportation system, this is an integrated system and all parts of it must function properly and in a synchronous manner.

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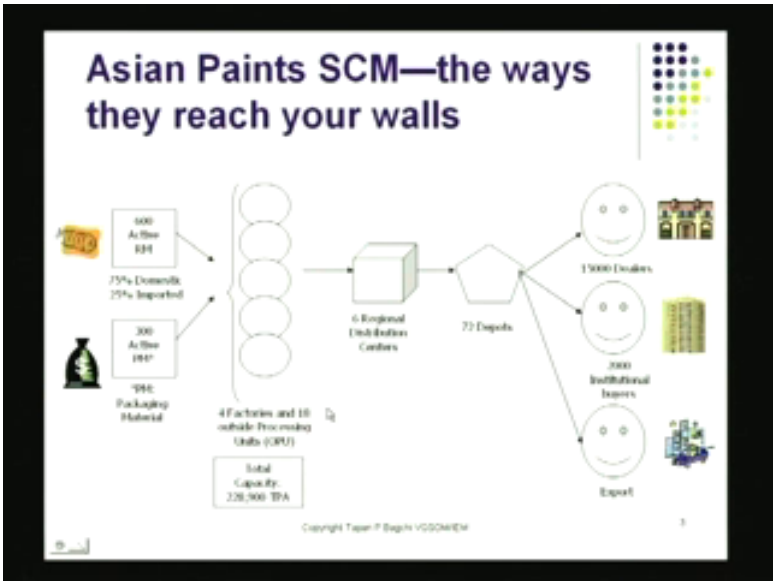

Here is a supply chain schematic for the Asian paints company in India and it shows the various steps they go through to try to reach your walls, walls in your homes or apartments. They begin of course, with ingredients which are like active materials these go into making the paint, then they have got certain components that must be brought together, then they have got packaging material These are all brought together into what

we call factories, these factories are places where the paint is made and the basic packaging is done, after the packaging has been done which could be in tin containers put in cardboard boxes then palletized and so on and so forth, those are moved to regional distribution centres. And Asian paints has six of those country wide within the country and within the subcontinent of India.

Then of course, there are these regional distribution centres they feed in turn 72 depose, these are simpler smaller ware houses from there 15000 dealers are served, 2000 institutional buyers are served and exports are made, and then you can see the final product.

The final product is put on your walls or these are supplied by the dealers and then institutional buyers they would be probably acquiring large quantities of paints. To paint up an apartment complex for example, then of course, you have got exports which could be going for outside coating of automotive vehicle or they could be also going into the domestic market and appliances and so on.

So, put the export market to which the same paint features, you can actually see it goes through several stages and many of these stages, basically are processing steps. Then of course, there are some stores, depos and warehouses, then of course, you have got transportation systems involved and then you have got dealers and so on.

I should tell you one thing that the final product gets customized right at the dealers shop, there what they do is they take the base paint, that is made by the factory in large quantities and those are put in containers which are fairly large containers. Then those are put into a measured container and there the right kind of tint is added to that base paint to match for example, your curtain or your furniture or your flooring or your roofing or whatever it is, whatever you want to achieve a colour match for the best colour.

That is done right at the dealers shop by using a special machine which does this tinting of the base material, then of course you can take the product, and you can put it on your walls, same thing applies all the way when you reach the final customer.

So, this is like a big supply chain which has got many stages, many transportation units that is utilized by Asian paints. They use a fair amount of technology here they make

sure that they have the stock control, they have sequencing done, they have scheduling done, they load and unload these different equipment, which are mixers, they are tanks, they are pumps and so on and so forth, there are pipelines they are required to make sure that the raw material and the various process which you have to move to the next stage in a planned manner.

Then of course, when the final packaging is done its packaged right, it is stacked up correctly and it is palletized and so on, then trucks pick them up from these distribution centres, they take them to depot. From the depos based on the orders placed by different dealers, items would be shift either to dealers or to institutional buyers directly or to the export area that is probably near shipping dock some place.

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What exactly is then supply chain management? It is the management of this total supply chain, that starts with the raw material and that ends up with the final use of that final product in the hands of the final user, this total thing is called the supply chain. Like I said it is got many stages and there may be storage involved, there may be processing involved, there may be transfers involved, there may be quality checks involved and so on, and every time you are making sure that the following stage gets the right feed from the preceding stage and this continues all the way till the product reaches the final destination which is the hands of the user that is really what a supply chain really is. It is a network of organizations, not a single organization probably will be vertically

integrated in that it will probably not make all the raw materials, it will probably not make all the base oil; for example in the case of oil paint. The goal really is to make sure that each stage produces value for the ultimate customer, there is the least amount of waste and there is a least amount of delay caused in doing the total process.

We want to definitely supply customer needs that is something that we would like to be able to do with a supply chain. We should be able to manage the flow of goods one way that is going to the customer and customer demand is fed back planners. First to the shipping areas which could be like a dealers shop for example, or a depot then of course, it will go back to the factory and the factory has to do the right amount of planning, the right quantities brought at the right time and produced appropriately. So, that there is the least amount of stock that is carried from period to period, because this is how you reduce your stocking cost and you try to reduce the overall price that the customer has to pay.

Then of course, there is the raw material that is brought into the factory. So, that the actual processing can take place and the raw material is probably acquired somewhere and again it might move through some storage and then into the factory where the processing would be done.

This is the flow of goods one way, there is a backward flow of demand, demand information that goes this way, that starts from the customer and it slowly trickles down all the way to your raw material supplier. Money also goes like wise from the customer to the dealer, to the person who is handling distribution and back to the manufacturing shop and then eventually the hands of the material supplier that is how money flows.

So, you got goods flowing one way and you got information flowing in the reverse direction also money flows in the reverse direction, that is the total operation of the supply chain. You got to make sure you manage the flow of goods and information in the best manner possible, you also have to make sure that in the process you generate some profit for yourself this is very y important unless a business or an enterprise or a processing step or an activity step is profit making nobody would be involved in it and therefore, the supply chain would collapse. So, you got to make sure that whoever is involved in this supply chain business, he makes some profit. You got to make some very critical decisions when you are operating a supply chain for example, deciding a

location, where should you locate your plant for example, where should you locate your factory, should it be close to the raw material supply or should be close enough to the final user, where should it be?

Where should the depot be located? Perhaps there is there are one or two big factories that produce all the goods, but what about the distribution depot, what about the dealers, where should they be located? This is a very important decision in which what you really try to reside, which products to produce at what stage, how to produce, how much to produce and how to do the distribution? Unless these things are done optimally in an overall manner, the supply chain would not be profitable. And then of course, the whole business may collapse, because if people lose money in providing these products, and the service and the associated services to the final customer, he is probably not going to be ready to pay for it and the business would collapse.

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So, supply chains have become a pretty large undertaking, something you got to remember now is because of globalization we are doing a lot of integration, we are doing a lot of coordination. And now goods and information they are moving through a coordinated network and this network adds value at each step. What we are really doing is we are adding value to each step of the business process, whether we are acquiring raw materials, we are transforming them into the final product, whether we are providing services or we are delivering the product in the hands of the customer, which involves

the following activities procurement of the raw material and the packaging material; for example, and perhaps the technology. We are doing the manufacturing and assembly operations and these are again places where we are spending money. We have got some inbound logistics to bring in the raw materials and the parts and the components. We are doing some warehousing which could be done for example, at the raw material stage, it could at the intermediate stage or the finished product stage we would be doing some warehousing.

Then of course, we have got distribution, which is we have got the products now in our hand. How they would be distributed? First to the depots, then to the dealers and then to the final customer, this distribution also has to be planned in an optimal manner.

Then of course, you have got outgoing logistics which is like shipping everything out the finished product to the customer to the ultimate user, these steps procurement, manufacturing assembly, inbound logistics, warehousing, distribution and outbound logistics. I should caution you these are no more made in a silo manner, we do not try to optimize procurement by itself, we worry about the full supply chain when you make some procurement decision, same thing we do for manufacturing also. When you decide batch sizes for example, we try to make sure that the overall system is profitable, not just that the manufacturing system works very well, but we end up with large inventories that stay for a long time sitting in the warehouse.

And also we worry about supply quantities there also we got to do some optimization, that worries about the inbound logistics, should we move in parts one at a time or should we move them in batches, should we move them in large lots, should they move within, should we be moving them in trucks or should we courier them or; however, we are going to be doing it this inbound logistics also has to be optimally fitted into the total supply chain.

Then of course, we have got warehousing, warehousing by itself does not really add value to anything. Yes it does keep a few people employed and perhaps, it consumes utilities of the companies they stay in business for example, but warehousing itself, if I take some goods and I just put them in storage somewhere, I just leave them there, they are not producing money, they are not producing any income from anyone. In fact, the time they produce money is when the product is given to the customer and he pays some

money for it. That is when he is really making money, the company is making money, the company is not making money if this just lays in the warehouse in one storage, then it is not making money the same thing applies to a supply chain also.

Whenever you have got stagnation; that means, the goods are sitting waiting to be picked up by the next stage this is no good for anyone. So, what we got to make sure is again warehousing, which really involves many times very large quantities of the inventories, they must turn over fast, unless they turn over fast, the working capital is going to tied down. And that is going to raise the cost of production and eventually, the price at which I can offer those products to the final user and the business is going to have a tough time competing with other people. Who are more efficient, who has got more efficient in supply chains for example, operating for them and they plan them right and they schedule them right, they operate in and correctly they are going to be out competing us and it is not going to be easy for us to do this.

Then of course, we have got distribution now mind you all of this must happen with perfect quality, if you do not have quality if you are doing all these things it is all useless. So, many times what you have to do is you have got to take a step back you got to make sure you are also doing your quality inspection you could do your quality checks all the way. And ultimately the goal of six sigma is to try to make sure number one you reduce losses, number two you reduce defects, both of these have to be done. Reduce losses, losses could be in the form of any of these resources, time, money, material resources any of these actually cost you money man hours, labour hours, machine hours, if there is wastage anywhere this is not a six sigma operation. So, Six Sigma does try to cut down losses by applying various methods, by applying actually the DMAIC framework this is the one approach we can utilize six sigma the philosophy of six sigma.

The other of course, is quality assurance or quality control or minimizing defects and they of course, today we are using fancy methods such as design of experiments that is what we are trying to do.

I will show you an example in this lecture here today and you have seen this example before, but I am going to be explaining this a little bit more with clarity that one is about using design of experiments to try to improve the performance of the supply chain,

which happen to be a real situation, which is in the auto sector and I am going to be doing that a little later in this.

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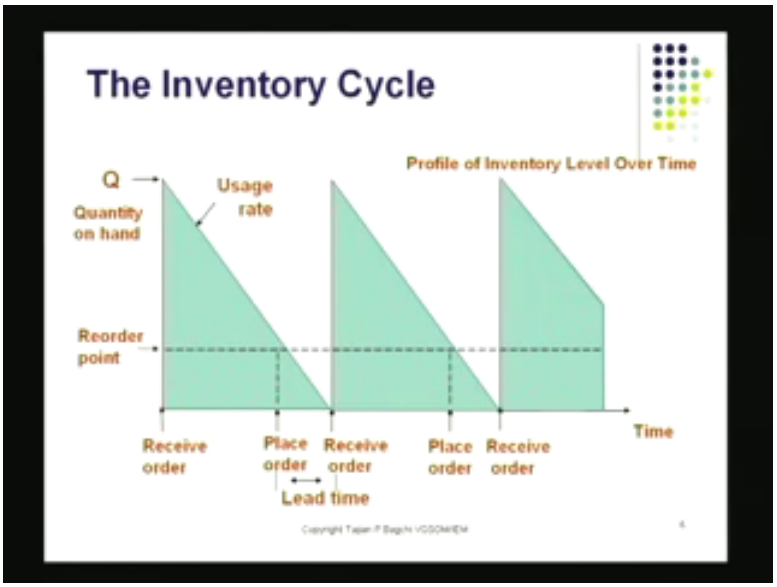

Let us worry a little bit about inventories, because inventories as you as I just mentioned they form part and parcel of the supply chain. Let us see how an inventory typically operates, there are couple of things to consider when you considering inventories, first of all if your factory could produce one pen at a time, if you could economically transport one pen at a time from the factory to the ultimate user of the pen, which could be a student somewhere in some college. If you could just produce one, transport it singly economically and then give it to him you are taking care of his needs, that is not much of a problem, but generally what happens whenever you get engaged in this sort of activity, it always pains to form a lot and to do what we call batch processing see you would like to take similar objects.

You would like to acquire the plastics for all of them together in a large order; you would like to produce them all together with some customizing done, so you get different shades and colours and so on. But you would like to produce these things because they are all very similar in a batch, you would like to make sure these things move in a batch and they also get transported in a batch, then the per unit cost of transport also is going to be less. Then of course, you take it to a depot where it is stored temporarily, then you move it out to a dealer who displays it and then of course, the customer buys whatever he

wants. So, in effect what I have introduced inventories along the way. I have introduced for example, initially I would have some plastic inventories, and I have probably some ink inventory and so on, then from there I will move into partially finished goods which could be perhaps only caps, caps produced, many different caps I will have all the different caps produced all at once and I will be storing them.

Then I would produce these bodies and I would be storing them again, then I come to the assembly place where I will be putting them together and that is also being done in a batch mode. So, that I utilize the scale effect and I am going to be utilizing my full capacity to make sure I produce a full batch, instead of just producing one item at a time.

If I do that again I am talking about inventories, I am not talking about a single pen, but I am talking about many pens being handled together and these of course, depending on the order system they may be sold one at a time. So, my inventory is going to gradually come down, but they are made in a batch, so when the batch arrives, inventory jumps up all in one shot. So, my inventory was here somewhere with almost no pens with me, then suddenly I have got the inventory I have got all these inventories. So, this is the distance this is the height of my inventory stock that is what I am showing here in the picture.

I receive the order and immediately my inventory goes up and then of course, as I sell the items or if I use the items inventories starts coming down. Now there is a policy there is a certain inventory operating policy that is put in effect. What we do is generally speaking most good take some to produce, if I place an order today it will take some time for the supplier to make sure he is done the production and he is supplying the stuff to you, it takes some time this is called the Lead time. In fact, it is very important for us to realize that there is always nothing that has got instantaneous supply, there is always some Lead time involved.

If that is, so then I should not probably wait when my inventory runs down to the 0 level and then place an order, because where is the lead time I may have not given the supplier any kind of lead time. How is he going to be instantaneously supply the goods to me? This happens even in the case of pens for example, which are kept in an office. The office clerk, she is got a drawer there and in that drawer she keeps all the spare pens which are to be issued to different people and what she does is she keeps an eye on that inventory.

The moment it gets down to probably perhaps, 2 black pens perhaps, 2 blue pens perhaps, 2 red pens perhaps, 1 green pen she places an order and the quantity of the orders of course, has to be optimal. And how would she place the order? That depends again on the stock level and the Lead time. let us take a look at that in this picture, here is the reorder point which basically says whenever inventory gets down to this reorder point I must place the order on the supplier. So, he takes the order and he takes this Lead time to really make sure goods arrive at my door and of course, my inventory then jumps up to this level, this quantity is the ordered quantity, this is the ordered quantity and this is how much I ordered.

So, my inventory when it was planned in such a way that the moment my inventory would get down to almost 0, I will receive a lot and the lot would raise my inventory to quantity Q which is the ordered quantity size.

Then of course, again the cycle will start, and I will start consuming the product, it will get down to the reorder point. This is when I will place the order and the Lead time will lapse and at that point the order will arrive and my inventory will go up. And these cycle they repeat, they are like a saw tooth, like the saw with which you cut wood, they just inverted so it is got that saw tooth. So, this is the saw tooth model this is quiet common and this you can observe. If you go to a real warehouse you will see the variation of the warehouse inventory in a saw tooth manner.

The important points here are couple of things, one the reorder point then of course, the lead time and then the order quantity. When your ordering it is a very important decision, your ordering in this case, if this is the policy that you are using the one that is shown in this diagram, you are ordering as soon as your stock level in the warehouse gets down to the level of the reorder point as soon you are placing the order. How much you are ordering? It is actually the quantity that is called the Economic order quantity. I am going to be talking about that in just one minute when I get to the next slide.

So, when you order depends on the reorder point and your rate of consumption, how much you order depends on the economic order quantity that is; how much you order and if you repeat the cycles you ordered. Whenever your stock levels get down to the level of the reorder point, you place your order, then the supply gets in action and by the time that full lot arrives, it is time for inventory to rise and inventory rises to the top level, this

quantity being the order quantity and then of course, it again starts to come down in the saw tooth manner that is what it happened there.

So, this is what I am showing here as the profile of inventory level over time, time is this way and inventory level is this way that is what we have done there. At any point in time if you want to know what your quantity on hand is, just draw a horizontal line you take the time and you from there you draw a horizontal line, you will end up with a reading on the quantity axis, that is how much inventory that you have at this point in time. So, I can do that for any point in time if this pattern persists of course, I have got a pretty neat arrangement there by which I can read of the inventory.

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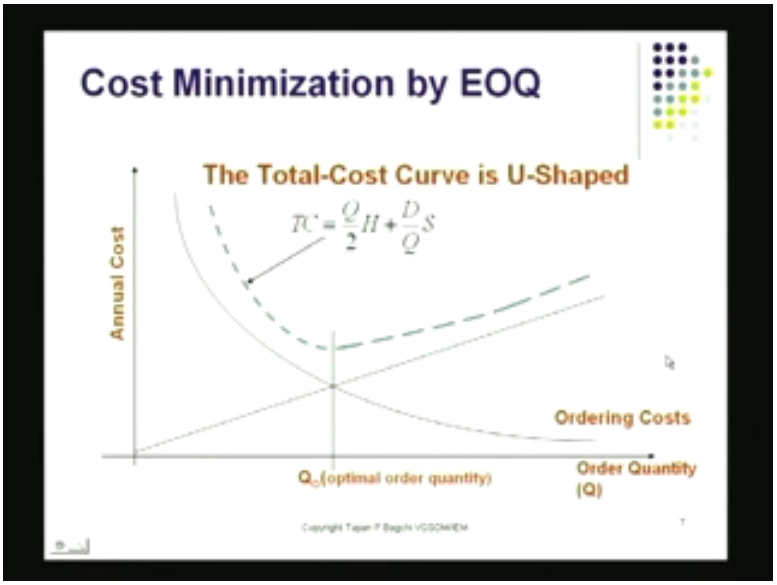

Now, let us try to find out how do I figure out how much to order? That is done by this little formula here and this formula actually does a little optimization. There are two parts of it one part is called the Ordering cost, this is how much it costs you to place a single order regardless of quantity, this is like checking inventory, making sure you know go to the formula you figure out your optimum quantity and so on. And then you place the order that will involve some paper work, then you transmit the order to the supplier this total activity costs sometime, this is not of course something that is 0 cost.

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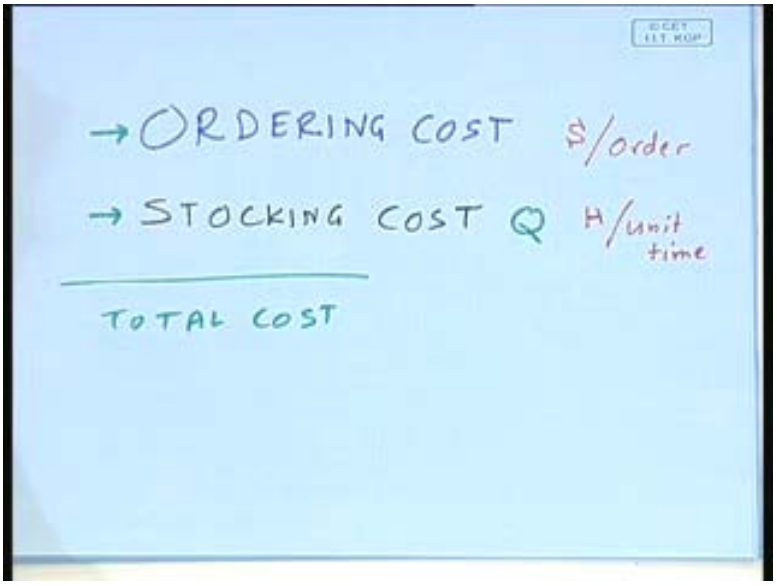

It is an operation that is if I write it here is the operating costs, but it is actually the Ordering cost. Ordering cost is independent of the quantity ordered.

Now, this is one kind of cost and other cost that I have got involved in inventory management is called Inventory cost or Stocking cost. So, ordering cost would involve the paperwork that is involved in placing a single order, regardless of the quantity stocking cost. Of course, is the cost of holding the material in storage at your side, at your location, what kind of cost these could be? It could be for example, material handling moving the inventory, it could be the floor area that it occupies the inventory occupies, it could be the air conditioning that is going on, it could be the insurance that you have got for the quantity or that you got on the floor and generally speaking this stocking cost depends on quantity. So, there is something that depends on quantity and this depends on quantity Q, Q is the amount of inventory that you are holding at any point in time.

Generally speaking, ordering cost is ordering cost per order, which in our case we are going to be ordering a certain quantity and there is going to be an ordering cost and I am going to be denoting this guy by S. So, S is going to be my ordering cost, S is my ordering cost per order and Q is the quantity that I have in inventory and with this I have a cost involved that is called the Holding cost it will be H and this is generally translate

into per unit time. Now if you look at the total cost of operating my inventory, it will comprise some ordering cost and some storage cost.

So, what I have to do is I have to look at the total cost and this total cost as the equation is shown on the slide here, this depends on H is the holding cost multiplied by Q, Q is your order quantity divided by 2, because of the saw tooth pattern at any point in time if you have ordered quantity Q at the beginning of the order cycle, at the end of the order cycle you have got Q by Q has got reduced to 0, which is the average inventory that is during the inventory cycle it is going to be Q divided by 2. Whereas, Q here and 0 there, so Q plus 0 divided by 2, that is Q by 2 all the way, that is your average inventory throughout. So, you should be paying your holding cost is then is going to be Q divided by 2 multiplied by H that is going to be your holding cost component.

Now, let us say your demand per unit time is D and your order quantity is Q then how many times will you be ordering per unit time is D divided by Q? That many times you would be ordering and each time you order it costs you S units of money. So, therefore, S times D by Q this is the quantity that is the ordering cost component of total cost. So, I have got two components here I have got the Ordering cost component and I have got the Stocking component or the Holding cost component.

This total cost is now a function of the unknown decision variable which is Q quantity to be ordered, it is not very difficult to show that the total cost reaches a minimum and that is this dotted line here, this is the total cost time, notice here it is got a minima and if your order size is this, the total cost of operating the inventory again and again over a number of different cycles is going to be minimum. So, this quantity Q is then called the Optimum order quantity or the Economic order quantity this is called EOQ, EOQ is the economic order quantity.

Now, what are the big challenges in supply chain management is that in each stage of production or transformation it ends up finding its own EOQ, because it is subjected to know one kind of demand, it is subjected to its own holding cost, it is subjected to its own ordering cost and so on. So, they each end up with determining different EOQ and there is a way to show this kind of fluctuation gets more and more amplified. In fact, this effect is called the Bullwhip effect within a supply chain, so that dealer or the final user may have small fluctuations in demand, by the time it reaches the factory demands, it

would have gotten somewhat blown up and when it reaches the supplier, there the variations in ordering cost in the supply quantities those have wide variations this is called the Bullwhip effect. It is like that bullwhip with which we whip a bull, and you notice there can be a small shaking at one end of the whip there, but the far end kind goes with a big variation there.

So, small fluctuation at one end causes a very large fluctuation at the other end, this is not something that is desirable for inventory. This can be reduced this can be almost minimized if you have got information sharing, that is if your supplier finds out what your customer requires, because then your supplier is not going to panic based on the order faced just by his immediate customer. His customer is going to be the first stage of your processing and that guy again, if he is aware of what the final customer is using his inventory level fluctuations are also going to be smaller and so on. . So, this way I can reduce this huge fluctuation that is there, this is a big challenge this actually requires couple of things, one of which is do not break down the total decision into silos and do not let these guys sub optimize their different stages, do not let them do that.

Try to work out the overall cost model and then try to work out how these different stages must be operated in an integrated manner. So, that you have got total overall reduction in the overall cost of delivery, starting from the raw material, all do it till the finished good, this is something we got to be able to do.

Unless we do that, the supply chain is going to have a lot of irreflections throughout and someone is going to pay for it, eventually it is going to be the customer. If the customer has to pay a high price he probably is going to go somewhere else. So, it is in your interest to make sure your supply chain cost stay at the very minimum level possible to sustain your business.

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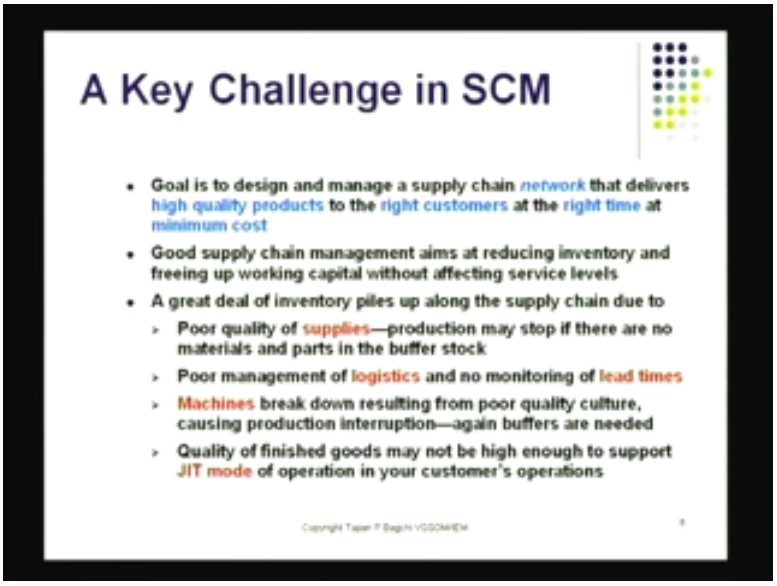

One key challenge in supply chain management is going to be of course, to make sure this full network operates optimally. Couple of problems are there, poor quality of supplies are there sometimes, sometimes logistics is not quiet in your control, sometimes lead times fluctuate, sometimes machines break down, sometimes of course, we are not really able to manage everything right and the reason is we then in end up putting buffers in between and we try to decouple the different stages of supply chain. We try to decouple them by putting inventories in between these become buffers they try to absorb some of the fluctuations and they do not let the fluctuations downstream, you know get transmitted upstream they try to avoid that, but you then require these buffers, you require these buffers and of course, nothing is free like we just saw no matter what kind of you know supply chain.

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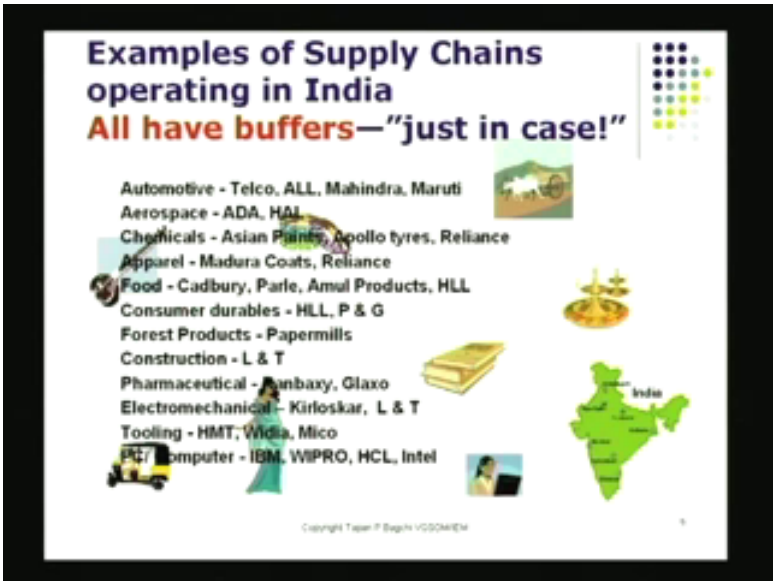

You looking at these are some typical businesses in the country for automotive youhave got the Telco, Telco company we have got Mahindras, Marutis, General motors and so on. They are engaged in automotive sector they get lot of their parts made by different people some made even overseas and they assemble them together aerospace industries ADA HAL and so on. Chemicals we got lot of finance suppliers for clothing, apparels we have got various suppliers you know people in business food we have got Cadbury, Parle, Amul products and. so on.

Consumer products we have got many of them forest products construction activities those are managed by the likes of L and T for example, pharmaceutical we have got Ranbaxy, we have got Glaxo and so on .Electromechanical parts we have got Kirloskar, L and T and these different people produce these final parts which are either sent to industrial customers or they are sent to consumers tooling, there are companies that are engaged in that kind of business and of course, PC and Computers they are large number of companies involved there.

We are talking about finished products at one end and each of these products at some point start with raw materials. So, around the country there are many different locations where raw materials are available, there are many places where partial processing is done and of course, markets are spread around most of the metros and now of course, the rural market is also growing. So, supply chains have become more and more complex and

they are spanning particularly coast to coast the full country all the way from Kashmir to Kanyakumari and from the east in Gujarat Rajasthan all the way to Assam and so on. So we have got the full subcontinent covered by our supply chains.

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Many of these have buffers, they are buffers in the form of local inventory, there are buffers in the form of stock at the retailer, there are buffers in the form of for example, where the depot are, there are buffers in the form of warehouses, they also have buffers inside factories and many times part suppliers they maintain buffers and any of these buffers they cost you money. And in fact, what we are looking at now is we have got to make sure that the supplies take place smoothly. What are the hindrances to these supplies? Is going to be breakdown of machinery or a failure in logistics or some quality problem and these may interrupt processing at a particular stage; that means, that the downstream process steps, they have to stop, they have to become inactive and to try to avoid that what we do is, we create these buffers and we start drawing from these buffers, but anytime you are adding a buffer you are adding cost.

The cure to this is going to have perfect quality which is like there should be no breakdown, there should be perfect quality, should be supplied to each feeding stage and so on. This is really going to be the way you will be able to remove the buffers all together. Let us take a look at some of these things in the supply chain of course, we have got both the suppliers and a customer that is what we have, and it is very important

for us to be customer focussed. We got to make sure the corporate vision is that way and one of those things really requires you to have the TQM orientation like I had said to you earlier in one of the earlier lectures TQM requires top management to be involved directly in the delivery of customer satisfaction.

There should be strong customer orientation that is also part and parcel of TQM and everyone should be involved that is like companywide participation for TQM to succeed, then you got systematic problem solving method that is also there and the things should be continuous improvement. If you are doing these things with your 7 tools and so on you are approaching perfect quality, you are approaching that of course, you need some fancy methods also for example, you need design of experiments. So, a will set up your mindset will TQM is going to get top management involved TQM is going to give you strong customer orientation and so on.

And good problem solving methods at hand to be used not only upstairs, but also right at the shop level, this is going to give you ultimately competitive advantage with the help of which you can raise productivity, reduce inventory, this is what we are after this is what a supply chain manager is after, reduce cycle times, boosting customer satisfaction, market share and profits of course, these will be the advantages.

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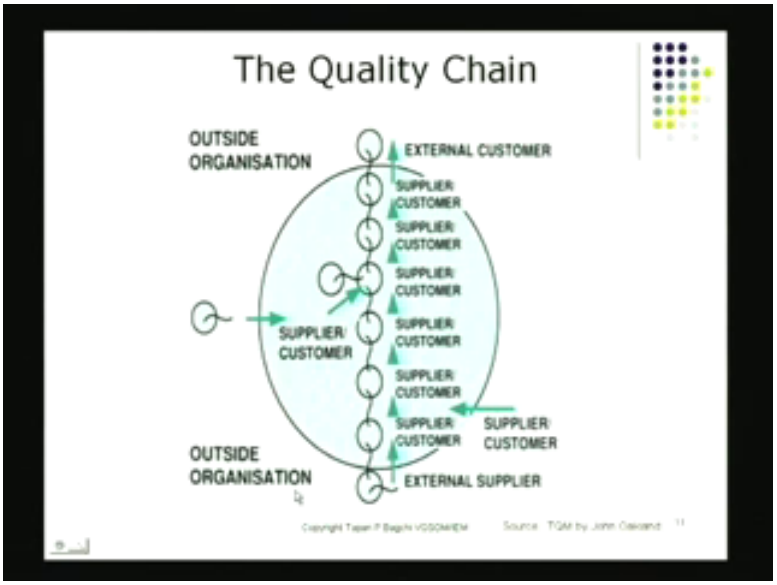

If you look at the full chain, the supply chain can also be looked at as a quality chain, we have got a number of suppliers and customers, suppliers and customers yes the external

customer is out there right at the end and you got the external supplier here. So, if the external customer is there, the external supplier is there in between are all the intermediating processing steps; if these processing steps work perfectly you got no problem at all, but suppose they have break downs in there quality problems and so on. Then each stage is going to build a bit of buffer before it and perhaps there may be some buffer after it also and you will end up with a lot of unwanted extra inventory in the full system, that is going to cost you money in terms of working capital that is going to cost you business also perhaps.

So, this is something we would like to minimize, what are some of the steps, what are some of the tools to try to keep a process in control; that means, a process at high process capability level you should use process control charts.

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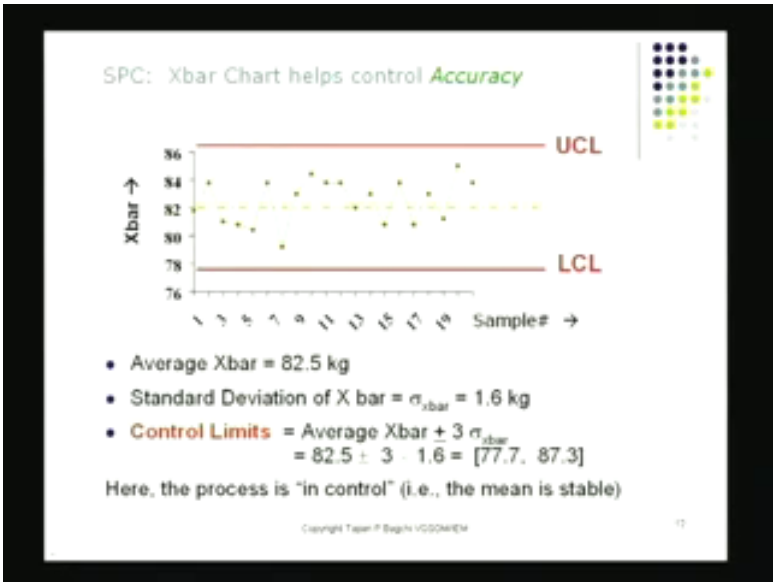

So, that is like one big use of SPC and you see a control chart here, this is the X bar control chart which is used to make sure the process stays on target as close to the target as possible.

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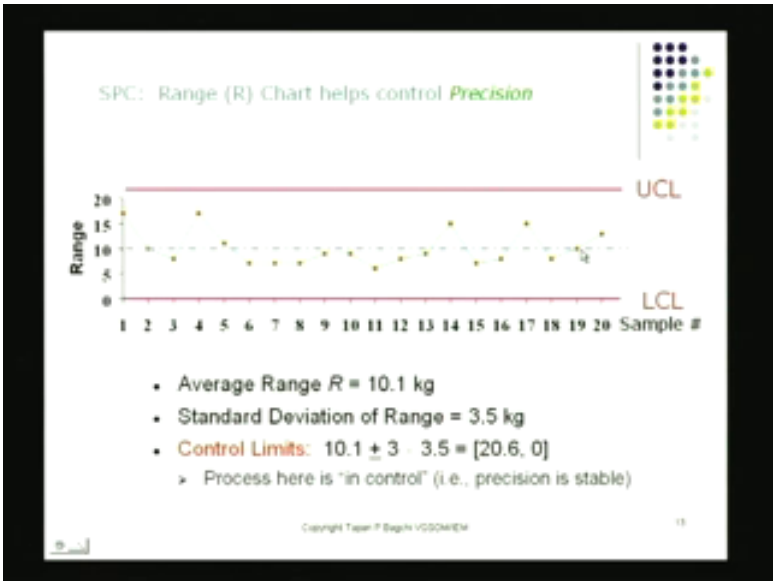

Then of course, you also want to make sure that precision is there in the process and therefore, you would like to use the range chart and that is also parts and parcel of how to operate a properly functioning supply chain, make sure you got control charts operating at your plants.

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Then of course, let us take a look at again the role of TQM in supply chain, wherever you got a quality problem, costs are going to add on costs are going to rise and customer satisfaction going to go down

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And this would also be true for a supply chain it is very important first to realize that it is going to be important for you to keep your supply chain in order and for that your quality has to be in order. Let me give you an example; here in 1995 the Chrysler company it looked at the quality of its supplies and what it found was that the defect levels of these suppliers many of them ranged between 300 to 400 parts per million, that is a very high level of defectives coming into the plant and; that means, this company Chrysler could not go into JIT directly.

They just could not because if they would pick some parts and they would like to have a place for this part to go in and get fitted the part that would not fit because of quality variation and these variations were to the extent for this, you know in this stage of business whenever they were doing 300 to 400 defective parts per million parts purchase by Chrysler, how would they improve it? They went after their first year supplier, remember the supply chain, then remember has many of suppliers you got your factory then you got tier 1 supplier, then you got tier 2 supplier, then you got tier 3 supplier and so on. Ultimately of course, you got the raw material supplier.

Chrysler made sure that the factory whatever it got fed by tier 1 supplier they used the same high level of quality control and then anyone that followed that were like feeders tier, 2 supplier tier, 3 supplier tier, 4 supplier and they all set to come up to the level of this tier 1 supplier. So, the strategy that they used was they forced all the downstream

suppliers, this were a hard tier numbers tier 21, tier 3, tier 4 those guys they had to be at the same level as the tier 1 supplier. That the tier 1 supplier quality level was most visible to Chrysler, but the other guys they were kind of hidden, but Chrysler made sure that the other guys also improved, they got to the level of this tier one supplier, so that the pains of the of the tier one supplier minimized the result as they were able to get down to the level of getting supplies from tier 1 supplier, that was at 100 parts per million pushed all the way back.

So, every supplier regardless of what tier he belongs to he came up to the level of 100 parts per million that of course, is not very high, but starting from where they started it is like 400 parts per million stating from there to hundred that was like a full improvement in quality. And that of course, this march was on as you know six sigma never really stops, because even if you reach 4 sigma 5 sigma, there is always that six sigma to shoot for and even beyond it, because even at the six sigma level you have got a few parts 3 or 4 parts per million that are defective. So, you could even shoot for better quality of level.

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If you do not do these things there is going to be huge buffers all the way in the system and there will be inventories and the result is going to be raw material inventory, working process inventory, finished goods inventory, these are all going to be large. You may also require capacity buffers, because your rate of production must once in a while get bumped up. So, you must have some capacity buffers as well and also perhaps you

would like to get more lead time, because you get that time to fix your problems. So, lead times can also get expanded all of these things would add to inventory and it would add to non productive use of money that is something you would be able to like to avoid.

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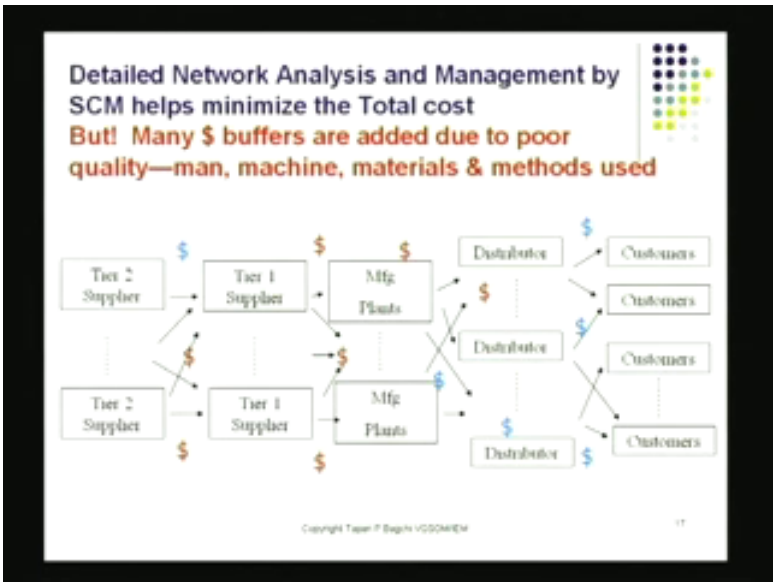

In fact, if you look at a supply chain here I have got a supply chain and there are some inventories which are required by the nature of the process to achieve some sort of a synchronization and I put them in blue dollars, these blue dollars are kind of required, but look at all the red dollars, these are unwanted buffers these really should not be there in the system, but they are because of quality problems.

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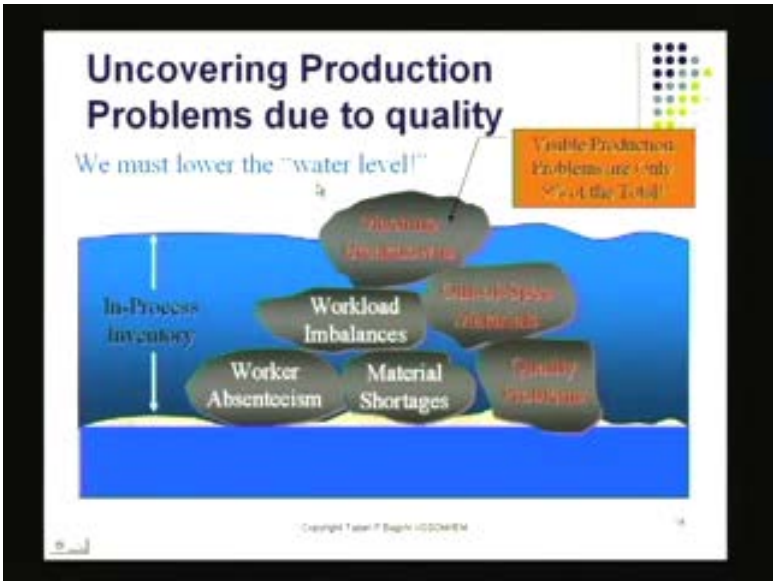

In fact, it turns out that whenever you got inventory, lot of problems hide behind these inventories for example, if your inventory is just about you know where normally it is the problems that are visible to you are machine breakdowns. So, if your machine breaks down in a shop you can spot it, because there is pile up of inventory there and that is because there is a lot of inventory on the floor. Any how a machine break down becomes quite easily visible, but what about if there are work load imbalances that is not quite visible when you have got large inventories, because the inventories they end up absorbing a lot of these problems, what about out of spec material again. If you got large inventories of products which have been screened and so on, again products being out of spec either at the finish stage, intermediate stage or the raw material stage, those also stay hidden quality problems they are also stay hidden.

If we have got large inventories material shortages, notoriously they stay hidden and I have personal experienced this things, when I was operating plant I had the same issue there I had large inventories. So, many times material supply problems they were not visible to me and if one or two workers are absent again and if that is a problem that is a recurring problem that also gets hidden. If you have got large inventories you can leave off the inventory and that problem will not be there. So In fact, it turns out when you have got large amount of inventories only 5 percent of the total problems are visible to you.

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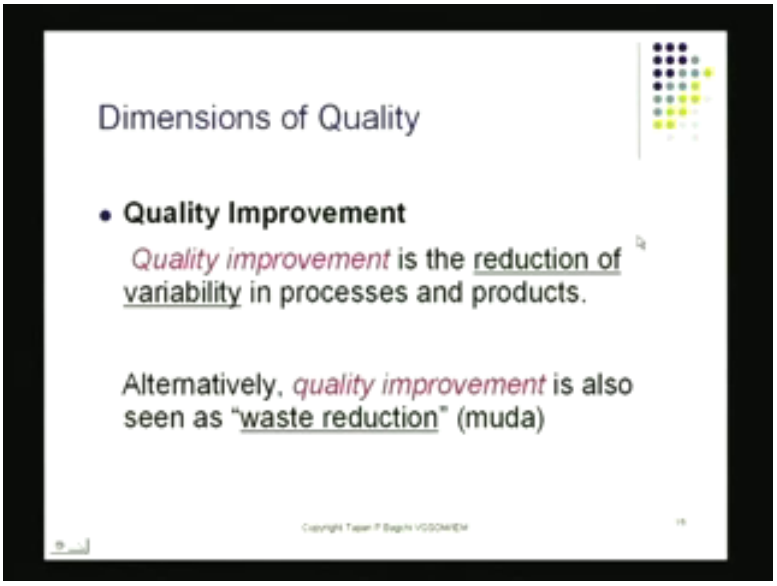

Couple of ways we can improve quality which is the first is of course, reduction of variability that is like one way, the other is go after waste reduction, these two also are the targets of six sigma projects. And you try to reduce variability that is like first you would like to reduce the fluctuation in quality for example, you would like to make sure your production is perfect and it is consistent and its all tight within a narrow band, that is what you would like to be able to do like we do in six sigma production, the other thing is also waste reduction if you do not have waste again you are improving the system.

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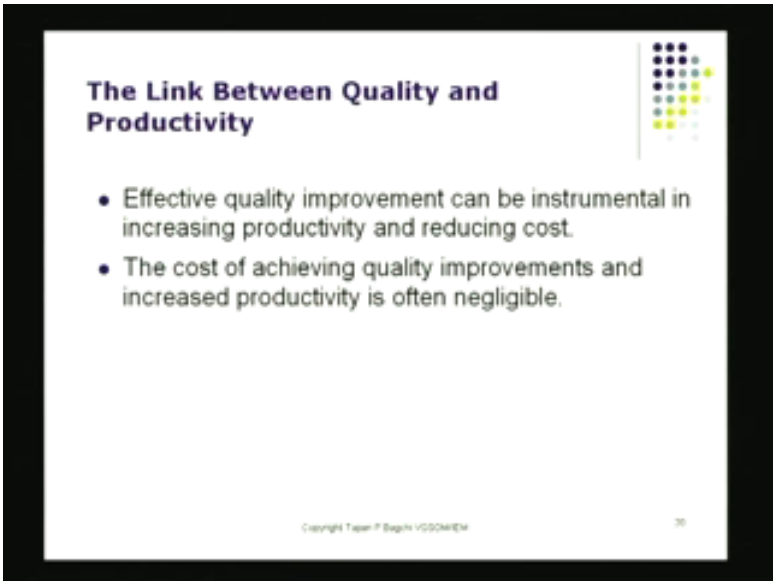

There is clearly a link between quality and productivity, because if you are lacking quality then you are producing lot of stuff, which you cannot sell in the market place. So, that link is also pretty clear.

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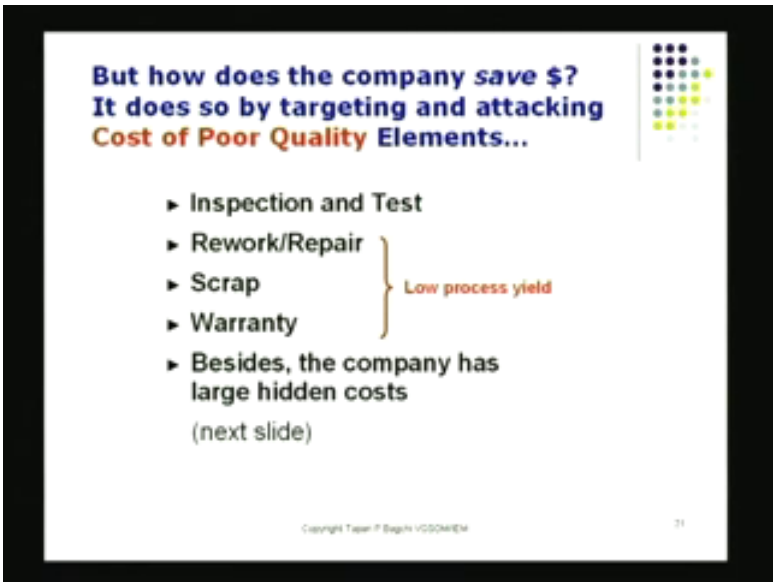

In fact, it turns out that if you get poor quality and that can be quantified in the form of cost of poor quality, you will have high inspection and testing costs, you will have lot of you will have a lot of repair and rework you will have lot of scrap you will have a lot of warranty service. And these probably are going to reduce your process yield for sure and of course, then you have got a lot of hidden cost also, these are costs of these are preventable costs, but unfortunately if I do not take the preventive steps and these can get quantified in the form of cost of poor quality.

I should caution you that the traditional accounting systems except for perhaps reporting scraps and perhaps warranty through these C R M systems, they do not really report a lot of these things and they stay hidden from management.

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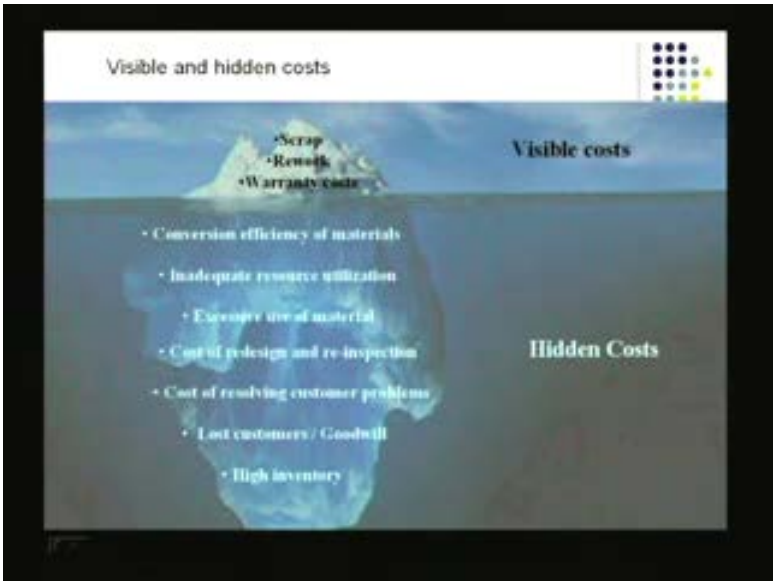

Then of course, we have got what we call hidden costs and look at them appearing one after the other in the slide, there I have got certain cost that are visible, which are like scrap rework and warranty cost, those are visible, those are the tip of the ice berg literally, then there are these other costs which are highly cost intensive, but they are there conversion and inefficiency inadequate use of raw materials and resources. Excessive use of materials for example, cost of redesign reinsertion and so on, that is also an additional cost of resolving customer problems, because if there is a problem with the product that I sold him, I will lose customers goodwill these are also corporate cost and of course, high inventory, these stay hidden when you got high inventory.

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That is just the tip of the ice berg here is an example of a company how they avoided quality failure, they implemented with their supply, they implemented what we call real time SPC. They did not have real time SPC before SPC is statistical process control, which is your control chart use of the control charts, this was one company quick tools, they went after their suppliers and they forced them to use SPC and the result was just amazing; yes it was painful, but what he did was it reduced the risk of receiving bad products and that would lead to higher level of customer satisfaction. Both business could actually share some of that extra profit, some of the extra money that they made with their suppliers and this is how they ended up incentivizing. In fact, they provided incentives for their suppliers to produce superior quality product and parts.

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And there are of course, quality tools, various quality tools you could use TQM is one that you have already mentioned 7 tools. We also discussed them in one of the earlier lectures statistical process control that is also a ways to try to improve quality and this can also help in a supply chain management and of course, the DMAIC procedure

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Let me give you an illustration, you might actually think that getting to the Six Sigma level is really for the best. Most of us do not really need Six Sigma, but if you really look at the best in class people, they really have Six Sigma type of performance.

So, if you are stuck down here somewhere with 2 or 3 Six Sigma level that is for your percent products are not going to be a very good situation. What you really should be able to do is move to the upper end, when you are really got very few defects on the level of parts per million.

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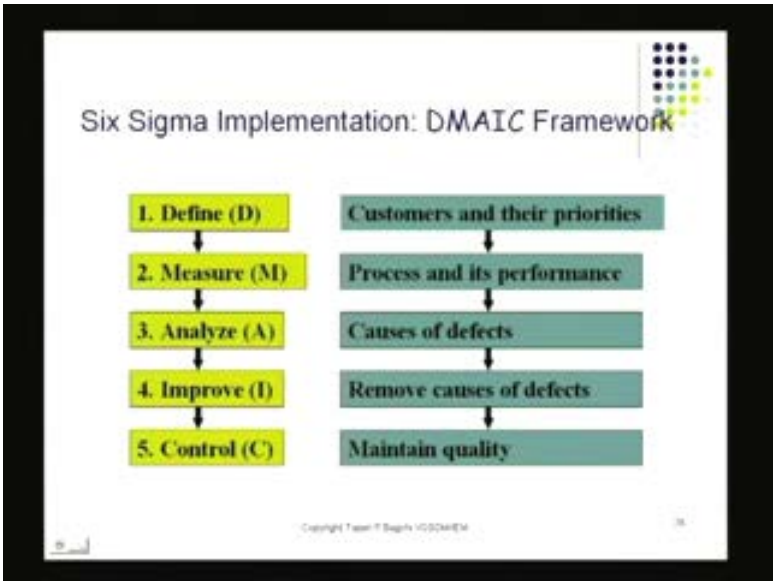

Let me move to an example where I use these DMAIC framework, I define customers and their priorities, I measure the problems and I do that by looking at the process and I measure its performance, I analyze the data and I try to look at the cause of the defects and then I try to improve using various causes that might be causing those problems and then of course, I try to control try to maintain quality

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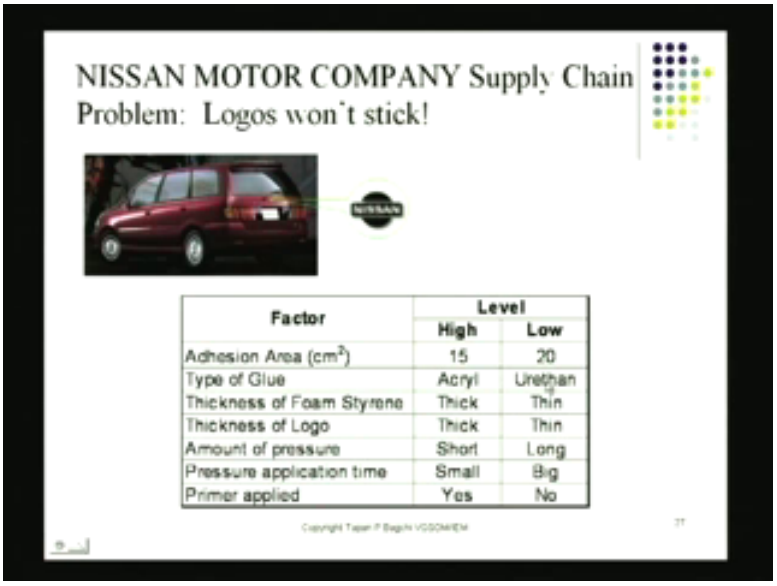

And here is an example of a supply chain situation, the Nissan motor company found in their full supply chain, which is like producing the car and giving to a customer and then waiting for his experience for example, they found that the logos in the back of the car were kept falling off and this is a big problem, they did some brainstorming about it, this was a supply chain issue, because it really hurt the ultimate customer and they would not having a good experience with this.

So, what they said was let us try to approach this using a powerful method, which is of course, design of experiment and what they did was first identified through a process of brainstorming, they identified the various factors that could have caused this and they set them up at two levels.

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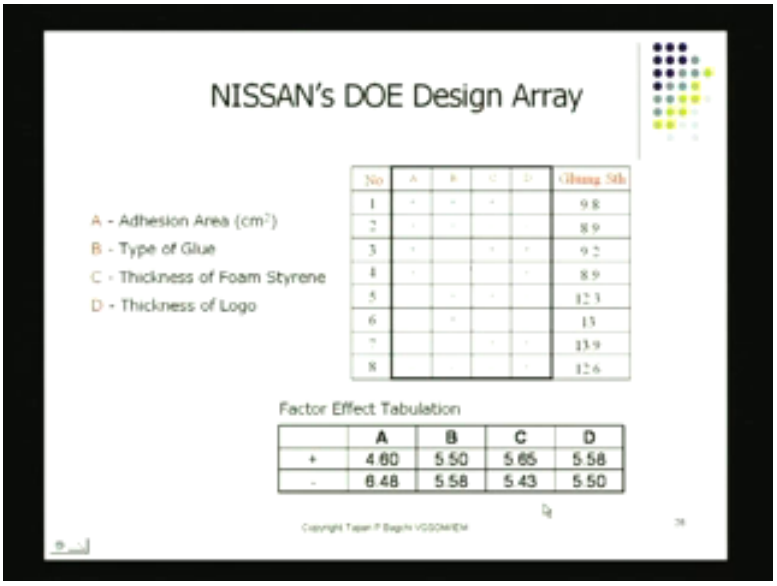

Then of course, they used this design matrix, this is the DOE design matrix in this particular matrix have those job eight different trials and the process setting are given by what I have described in the earlier exercises and then measured the response as the gluing strength of the logo sticking to this car body. So, there was glue applied to this and the then the logo was pressed on this and they measured after the drying time, they measured the strength of a particular setting of particular combination of area, the type of glue used, the thickness of the foam used and the thickness of the logo after doing that then of course, they computed what we call the factor effects.

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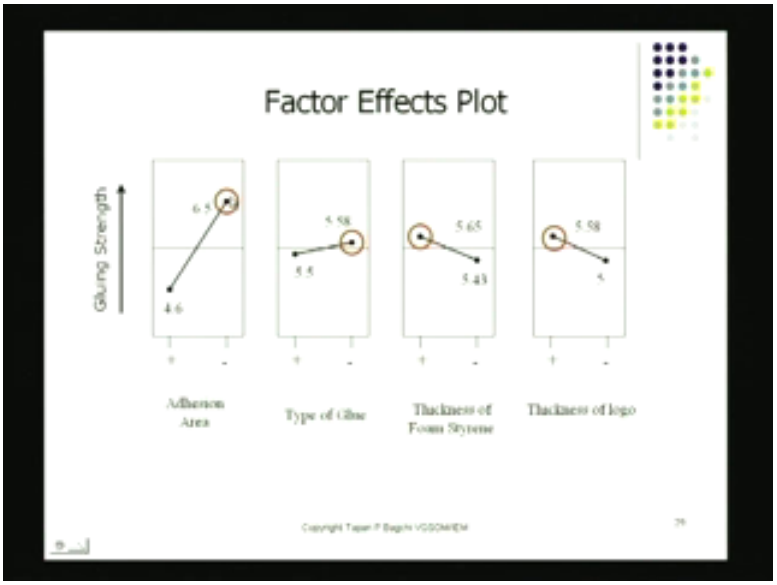

And the result is just amazing they did some plotting and these are the plotting of the factor effects and you can see very well that factors such as type of glue, thickness of foam style. And the thickness of the logo did not seem to matter at all when it came to gluing strength and it seem to be most affected by what we call adhesion area, as area was enlarged the logo stayed on for a longer period of time.

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And that was the one of the things they were really looking for. QS 9000 of course, is the certification system that must be utilized now by all automotive parts. Many of them are using DOE, many of them they are optimizing their processes and they are using design of experiments to try to make sure they get to the optimal answer in the quickest time possible. That is something those guys are doing this is something that is not been easy, but once you have the orientation of DMAIC which is like define, measure, analyze, improve and putting control. Once you apply this framework for your approach and you are doing this on the foundation of TQM and so on.

If you are doing all of those things together, you are going to be one the winners and this has been the cutting edge, this is been really the hall mark of companies like Toyotas for example, the Toyotas and the Hondas and so on. They are the once who are utilising these techniques and they have started literally from the ashes and they have reached the top in market share and customer satisfaction in the automotive world. So, the picture is pretty clear here and the message also is very clear, if you stay this way you are bound to

succeed, you are bound to out compete others, you are also going to be in the same market place looking for the same bucks from the hands of the customer. That is something that has happen in the world of supply chain also. And as you saw we told you the stories starting from the raw material, the intermediate process and so on. As you squeeze out the fact that is there, which is like if you squeeze of inventories the problems will become visible and that is really the secret, ones the problems are visible you will go after them. And you will be using techniques such as DMAIC, such as T Q M, such as S P C, such as 7 tools and so on and definitely it is going to lead to better profits. We will continue with our series in the next lecture onwards thank you very much thank you.