Six Sigma
Prof. Dr. T P Bagchi
Department of Management
Indian Institute of Technology, Kharagpur

Module No. # 01
Lecture No. # 36
A Case Study of Defect Reduction

Good afternoon, we resume our lecture series on Six Sigma right now.

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This is the follow through of lecture 35, which you must have written as before me, I ended up with this slide I ended up with this slide that says DMAIC is the step by step disciplined procedure, that defines measures analyzes improves and controls a process, that is currently producing defective goods, that was where I left.

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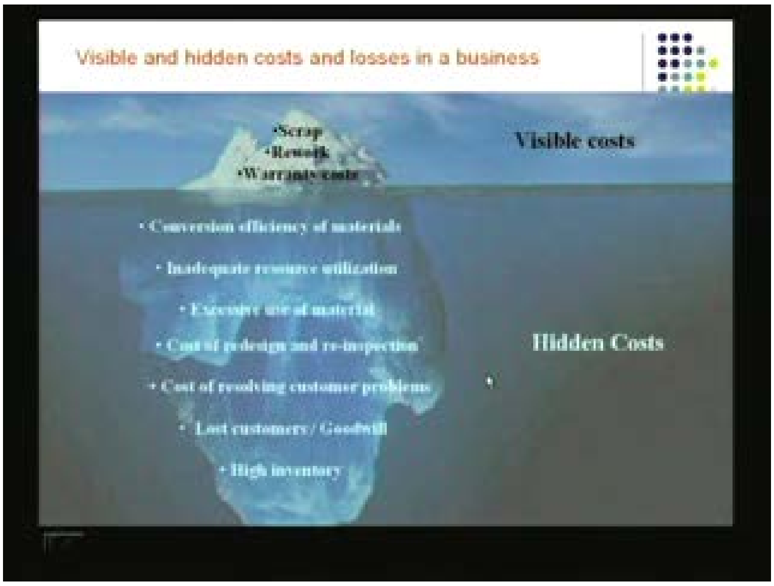

Let us now get into this, let us try to find the incentives. Take a close look at this slide what you see is an iceberg. In fact if you look at the total amount of the, what we call costs of poor quality. Generally speaking what gets measured in the company are the scrap, rework, warranty services and so on; these are the visible cost, these are the ones that get really recorded somewhere, probably in the in a plant report this might be being recorded.

But, these other guys these are just they just a hidden likes an iceberg most of it is inside water, only the tip is visible. And if you look at the inside, there are things like conversion efficiency of material, that also can be poor a quality is poor. Inadequate utilization of resources that is also, something if quality is poor excessive use of materials, cost of redesign and re-inspection, cost of resolve resolving custom problems, lost customers, good will gone, high inventory all these are also consequences of poor quality.

Unfortunately these are not visible but, when it comes to doing a six sigma project, you got to get deep into these things, you got to get into inside that iceberg, you got to find out items there that can be eliminated. And these are the one that will have a bottom line impact on your on your on your company's balance sheet, that is like something that you got to pin out, if you are able to do this successfully; you will end up with a very good project, very good six sigma project.

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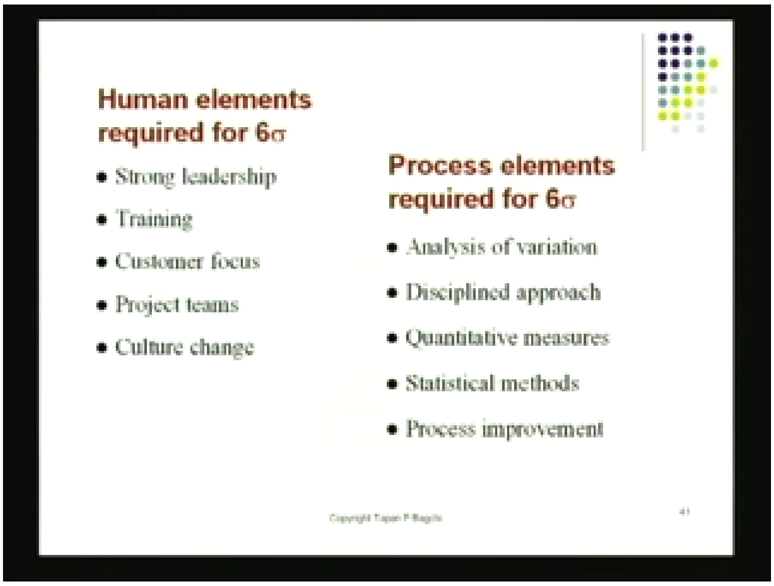

So, the incentives are going to come from this, what are some of the other things that you require? There are certain thing, which are like the human elements, certain parts of it which are required. For example, on the human side effects strong leadership is required, good training is required and it just goes without saying, if people are not trained in statistics, they are not be able to do a six sigma project successfully.

Customer focus, find out we find out the CTQ's, who are the owners of the CTQ's projects team have to be put in place. This got to be a overall cultural chain that also is something that is got to be there. On the process side analysis of variation this is to be done, a discipline approach has to be taken to try to impact the process, quantitative measures, have to be there you should be able to a measure them on a scale, statistical methods have to be used and of course, process improvement is the mission.

So, in fact all of these things they must be there, if these things are all there together you are bound to succeed with the six sigma project. So, make sure when you are doing a six sigma project bring up this slide and use that as a checklist to make sure, you got you you really taking care of each of those items to be able to move forward.

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What was the impact on the cost of poor quality? You saw that iceberg motorola had a iceberg like that, very huge iceberg. In fact their market share had gone down from being 90 percent to 10 percent, because the Japanese products, the Japanese handled mobile communicative devices. And they are very different from our cell phones, they were not like cell phone they were high powered you know transistorized wireless communication devices.

And motorola had the virtual monopoly, there their market share was like 90 percent but, because of poor quality, because quality was something that was side line they focused on production and supply. They ended up losing that major market share to foreign foreign wireless walky talky makers and that came down to something like 10 percent. Then, they mounted this six sigma approach and look what they were able to do with their cost of quality, cost of poor quality, that came down for something like being 15 percent, 1986 to you know about 10 years time it came down to what all most one third of that, that was that resulted from they are very aggressive, attack on this whole problem with this six sigma methodology the DMAIC methodology.

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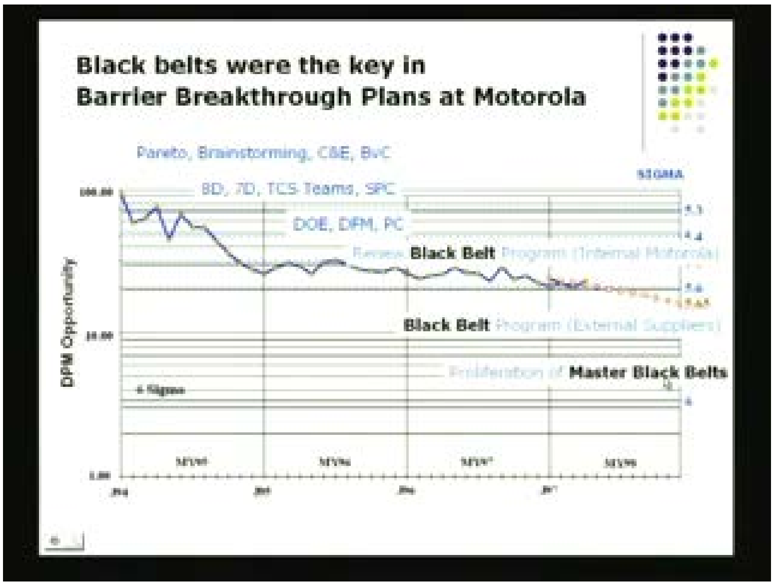

And these kind of giving an indication of the quality level that, that is why they started, they started out here that was like 100 defects per million, that was a pretty high level of defect; that is like something that is not to be tolerated. This is one of your wireless sets would be defective per 1000, that is a pretty high level, they did the they did the they started the work with pareto brainstorming and so on and so forth cause and effect diagrams and so on so forth.

Then of course, they started to bring in other techniques and they had teams put in place they had s p c installed on the floor and so on, that happened in the 90s. And in the 90s late 90s they brought in design of experiments and design for manufacturing process control, these things they brought in and they also brought in at that point around 1995 they brought in the idea of the black belt program.

This was internal to motorola at that point there, then of course, they also externalize this thing they started consulting with other people there, because they showed success there. And of course, the march continued and when they brought in the master black belts their sigma level. Six sigma is out here for that part parts per million but, they were able to reach in the 90's but, before these before the before the 20 th century was over, they were already at 5.65 sigma level that is a pretty high quality level.

So, you got probably you know 7834578 defects per per million that was this is was motorola's march toward quality; so it started with something that was fairly nominal quality to a level of quality that was certainly much much better than, what they what they have started with.

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Who are the experts you require to be able to succeed with six sigma, you certainly require a six sigma champion. This is the person who really undergoes a lot of training he understands statistics now, after he goes through the training, he understands that and he is also taught how to manage projects, because remember we also need project management skills when you are doing this.

And this champion is going to be acting as advisors, he is going to be advisor and he is also going to managing the, he is going to be basically mobilizing resources to be able to support the project. Then, you got master black belts these are the people, who conduct this six sigma training they also do lot of job training experience, they actually have this they even got master black belts. These are the ones who really get trained on all the statistical method and they become basically the the major stake holders in six sigma projects, they are the major power houses for expertise, then you got green belts who also became involved.

So, in fact it turns out, you got the champions six sigma champions, you got master black belts, then you got black belts and green belts without having these people together, you cannot really do a six sigma project. In fact if you think that, just by learning a little bit of you know graph plotting and so on; and calculating averages and sigma you will be able to do a six sigma project. Just absolutely please push that out of your mind you should be able to do design of experiments, you should be able to do regression model, you should be able to do data analysis. Unless you are able to do these things, six sigma is certainly beyond your reach that is something you should not try.

Let me now get you get in get into a live case, this is the case that you know the the the problem occurred with the Nissan company.

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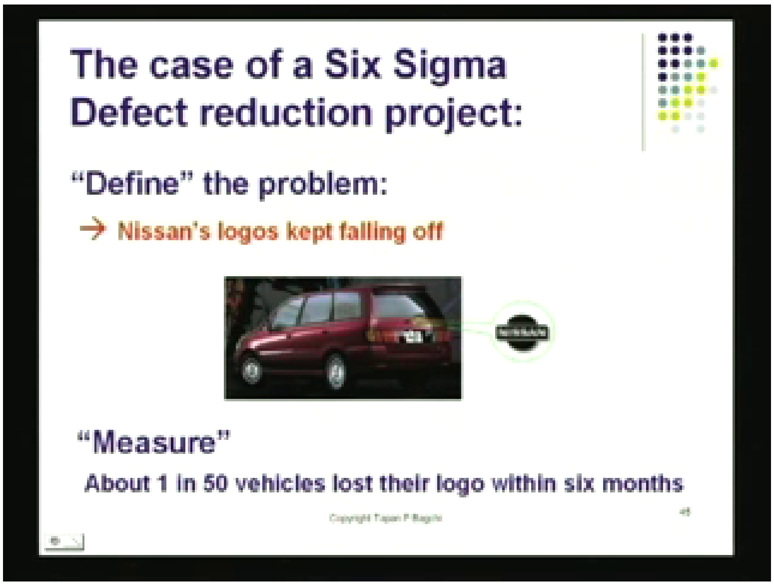

You know when you look at a Nissan vehicle on the back of it like many other cars you see a logo. Now that logo actually is not welded to the car, it is actually stuck with glue a certain things done with that logo there; so the logo might be might be like this and the logo is put on the put on the things some glue is applied. And the the logo is put there and that is how really stays there, what we have to really do is we have to really see if indeed there is anything wrong with this where would you begin you begin with customers. The complaint was that Nissan's logos, they kept falling off and these of course, the if they would be lost on the road they would have to be replaced with a new logo what was the extent.

So, the first thing that was done for this project was, it was a defect reduction process project, the first thing that was done was define the problem the problem was Nissan's logo's kept falling off. Then some measurements were done how many how many of these things was this the very rare event, it was found that 1 in 50 vehicles would lose their logo, that was the extent to which to which they could identify the problem.

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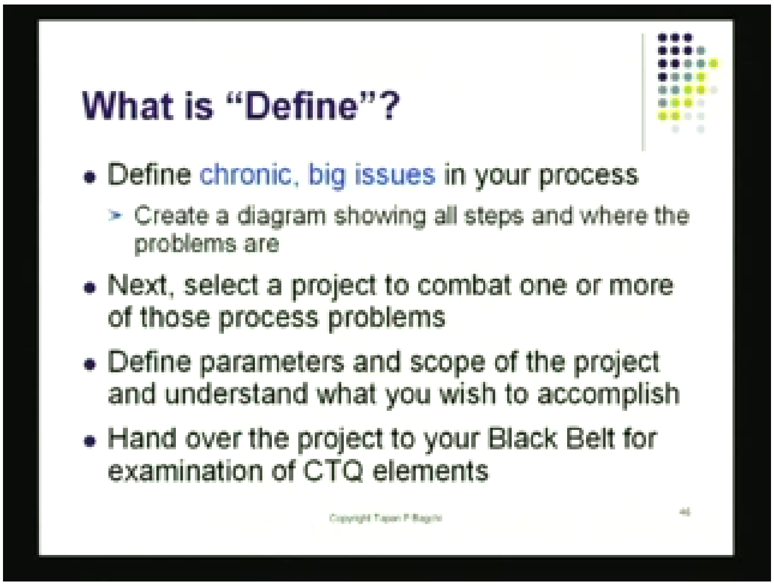

What exactly is they define you know I mentioned that define step there, define chronic and big issues in your process, create a diagram showing all the steps where the problems are this is something you got be able to do.

So, when you are doing define this is the first step in DMAIC, you must define the process itself and and locate exactly where the problem is taking place. Select a project then you of course, select the project to come back one or one or more of those process problems there define the parameters. And the scope of the project and this again is definition and you got to make sure of course, you put your finger on the right CTQ. And your black belt should examine that to make sure that you are actually is the right kind of CTQ, that can be now attract with a with a project there.

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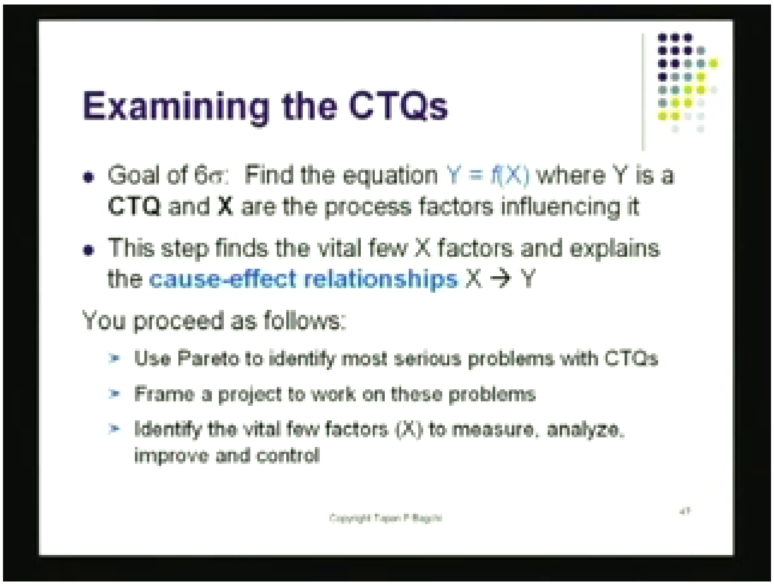

Examine the CTQ, CTQ's are those quality characteristics that really have an impact on customer satisfaction. So, that is like your Y, Y is a CTQ Y is a C T Q and X are those process factors that might be influencing that I have to locate the correct X; so that I can Y drive this Y to the targeted value or to a level or defect that is acceptable to the customer.

So, I have got to establish this what we call, cause an effect relationship between the control variables and the C T Q as it is measured, how do we do this? We use the pareto to try try to identify the most critical C T Q. That is the thing that customers are generally unhappy with I frame a project to be able to do this, for that I will have to really you know define the chart of the project, have to define the scope of the project.

I have got to define the work breakdown structure, I have to come up with C P M little network, I have got to worry about resource management of and how to do risk analysis all those things will have to be done they are like part and partial of any project. And six sigma being a being launched in a project mode it will have to be done, that way then you identify the vital few X to measure analyze improve and control, that is going to be the measure of your six sigma project.

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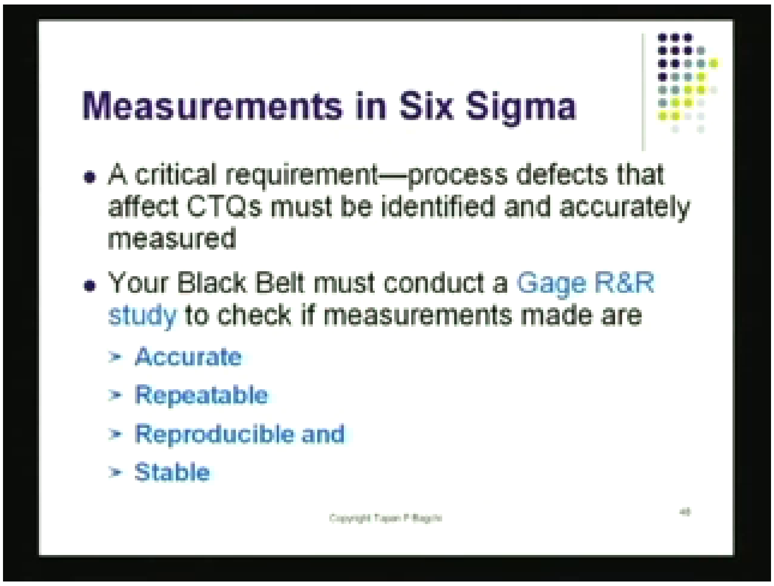

Measurements in six sigma, now what kind of measurements do we want to make, we got to measure these CTQ's any instrument you are using and this it goes without saying if a instrument is poor, if the gauge that you are using, if the gauge is poor there is going to be the the the data that it produces is also going to be poor.

So, you may have a perfect identification for the CTQ but, if you are not able to measure if you are not able to measure those CTQ quantitatively, correctly, accurately, repeatably, repressively and stable. If unless you are able to do those things, if your measurement system that takes the CTQ, makes a direct measurement and produces data, if this system that is in between this is measurement system if this a. If this does a poor job there is no no hope at all that you would be able to do ultimately control the final process, because you will be working with garbage, you will be (( )), you will be working with data, that has a lot of measurement error. So you got to make sure you do this measurement system analysis and one of the key things there is doing gauge r and r this is something, that we should be able to do.

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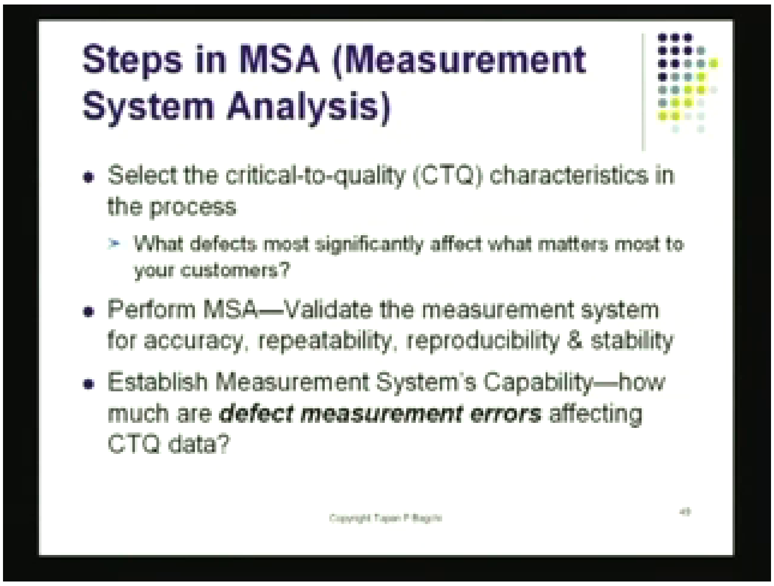

So, what are the steps in this measurement system analysis, you got to select the CTQ that is like something, you could should be able to do, then you got to be able to do the M S A. M S A is measurement system analysis you validate the measurement system, you make sure that it is, it produces accurate data, it produces repeatable data, it produce a reproducible data and it produce a stable data.

Once you have done that, we got to also make sure that I establish the capability of this measurement system, it by itself should not introduce so many errors that, that parts per million. When you are trying to measure it those figures are wrong, it should not be like that so it is a very important step.

In fact before you are going to your improvement step, before you start making measurements and so on, that you make sure that, the measurement system, that you applying to produce data out of the system, out of the process that measurement system is worthwhile look here.

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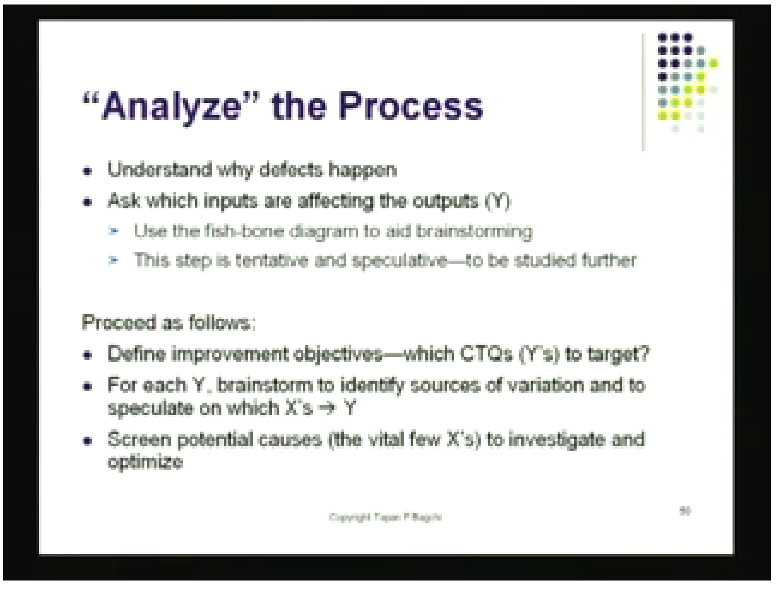

Then of course, comes the analysis process, analyze the process understand why the defects happen this is the place, where we are trying to do group cause analysis. These CTQ's are the Y's, the CTQ's Y is the proxy for CTQ, the critical to quality characteristic.

What we are really after, what we are really after is identify those X's, the critical X's that have the impact on Y, those are the vital few X's. If we control them, if you locate them and then if we control them to the correct value my Y or my C T Q is going to be again, it is going to be in control and I am going to have fewer defects, that is something I should be able to do.

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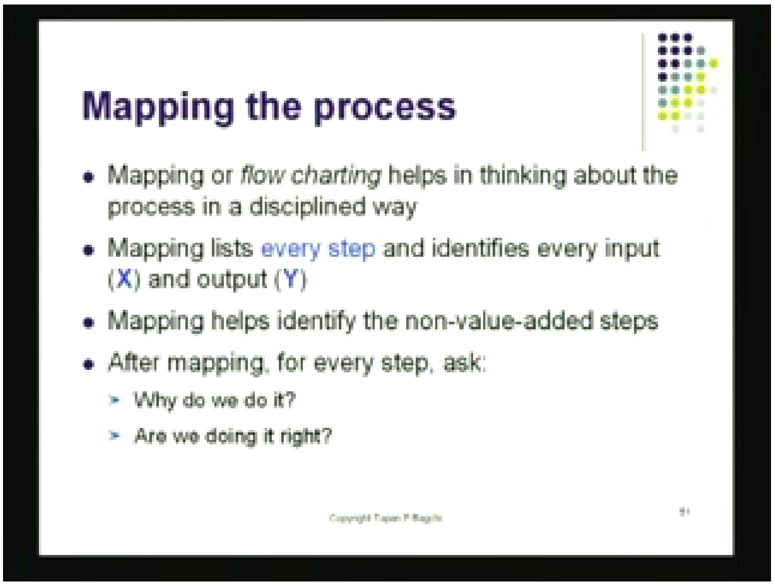

How do I get there with the first time is of course, I have got to map the process mapping is essentially flow charting the process, I flow chart the process, I start from the input side. And I end up with the output side, that is what that is what something I should be able to do, I must map every step of it in going from X to Y, that is something that we should be able to do it, while I am doing it I have I have also got got to keep an eye on non value added steps.

For example, we should probably ask, why am I doing this step in the full process and am I doing it correctly, is that training's there is the tool's there or the tool's there you know the the different equipment, that I need and you know to test equipment so on, are they all there for me to be able to do that, all the tools there for me to able to carry out those things.

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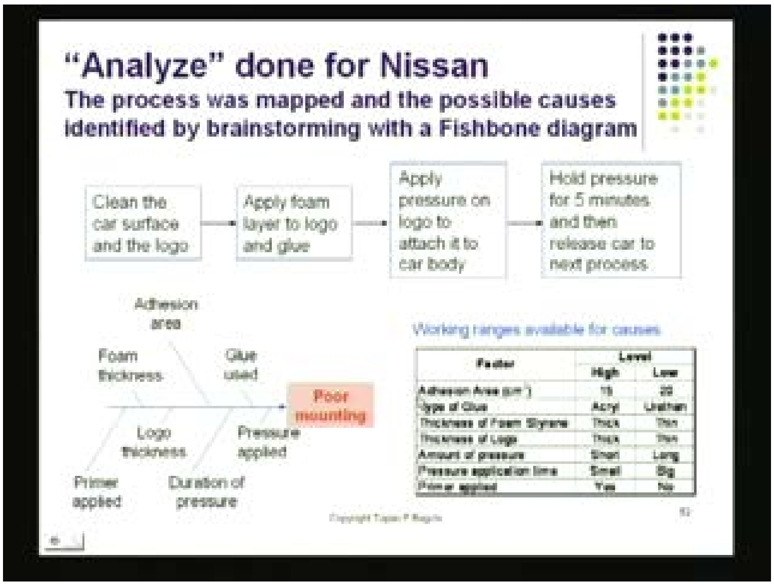

Now, this would be done once I have got the mapping done and I am going to be give you an example, here is an example the same Nissan problem, we took a look at the process. And what did the process show us the charting of the process, showed that the first thing that was done in applying, that logo on the back of the car the logo was not welded.

The logo was not welded to the car the logo was taken it was cleaned up obviously and also the surface of the car was cleaned up, then a glue was applied some curing time was given a foam was applied and some glue was applied. And then this thing was pressed on the body of the car and the people who do it well they of course, would positioned very correctly and they had hold it for the few minutes. Then of course, they would let it go that is that the glue glue the glue has cured and of course, the logo should stay there.

So, the steps of the process would be clean the surface of the car, apply the foam layer to the logo and glue, apply pressure on the logo to attach it to the car body. And of course, hold the logo, hold pressure for five minutes and then release the car to the next process. These are these are basically from left to right, this was the mapping of the process with this map in front of us a brainstorming was done.

And all the factors that could have that could have lead to poor mounting see, that red box there it shows poor mounting as the effect, various things that could have caused it those are listed here for example, foam thickness could have caused this, addition area the area over which you apply the glue that could have also caused this, the glue used that itself could have could have probably caused who are mounting.

The primer applied the primer that was applied on the surface of the car, that also that also is something, that could have caused the logo's falling off. The thickness of the logo and perhaps it is weight also, the duration of pressure and I did, I hold it for 5 minutes or 2 minutes or 1 minute. Then of course, is the amount of pressure, that I applied in in in making sure that the logo is held close to that held tightly against the body of the car, that is also is something, that could be a factor, that could be contributing this.

Now, this was done this this was done at a speculative level, no one really knew what the correct answer was for that of course, we have to get to the next step, which could be to try to identify, what are the working ranges for these different factors. And those are shown here; these are the working ranges, if you look closely the addition area this is like one of the factors we see there. Type of glue used thickness of foam thickness of logo amount of pressure applied, pressure application time, primer applied, these are here the working ranges.

So, I have some changes there, it is not that I cannot really change the addition area, the working range turn out to be 15 square centimeters to 20 square centimeters, I had that variation there, may be we were at 15, I do not know that at this point. But, obviously when we take a look at the process, when we when whoever was doing this project, when he took a look at the process he might have found out exactly where where things were as they were today.

But, because this working range was available, were we using were they using was Nissan using the optimum combination of all these different factor settings, were they actually doing that, how would you find that all and this is where you bring in statistical methods to you need designed of experiments.

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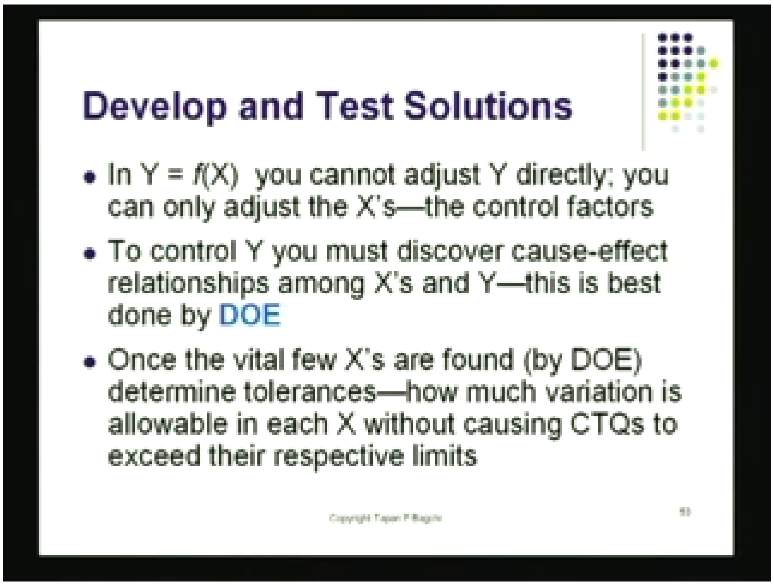

So, if you now see the the the the the progress of the six sigma project, you would probably find that now, what they are trying to do is, they are trying to establish the Y equal to f X this leadership Y is Y is the response. Which in this case could be the gluing strength or the amount of force, that is required to push off a logo of the back of the car this could be Y that could be the response.

And the X's are those different factors that I showed you, the different control factors and to combine all of them and to look at the effect, we had to do this the this trial had to be done in the design of experiments framework. And that would lead to finding the vital few X's, that would have the largest impact on Y which is the gluing strength.

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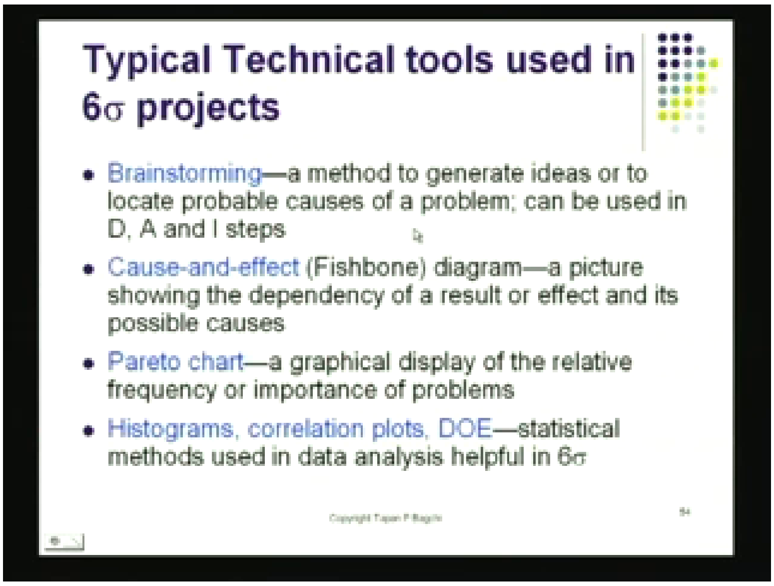

How was that done? First of all of course, the factors were you know people did brainstorming and they utilize the cause and effect diagram to be able to do that and I showed you that. Then of course, the pareto chart was used to try to basically, find the relative frequency or different problems and then of course, histograms, correlation plots and DOE these will be used to try to establish the leadership.

Now, let me just go back to the picture here for a minute (Refer Slide Time: 19:50) and show you what is going on the first is the mapping, this takes you from left to right for the full process. Brainstorming was used to try to construct this fishbone diagram and then there settings were settings were established by looking at the process itself.

So, this was actually to try to understand first of all try to understand, where the process was and even before this if you looked at they pareto thing, people went back to the problem their problem statement (Refer Slide Time: 20:21). And then looked at other problems that also could be custom complaint, they found that many customers did not like this this logo business falling off. The logo falling off the back of their car in most as situations other with most of the other things, they were pretty happy but, they were not very happy with this.

So, if you did a parade to analysis, you find many complaints came from from from this issue, the issue of the logo falling off and that is why, this became one of those targets for this six sigma project. So, we had the mapping done and we also had the working ranges identified and we also understood what is it that, we will have to do, we did the we applied the different techniques, that meant to be used there.

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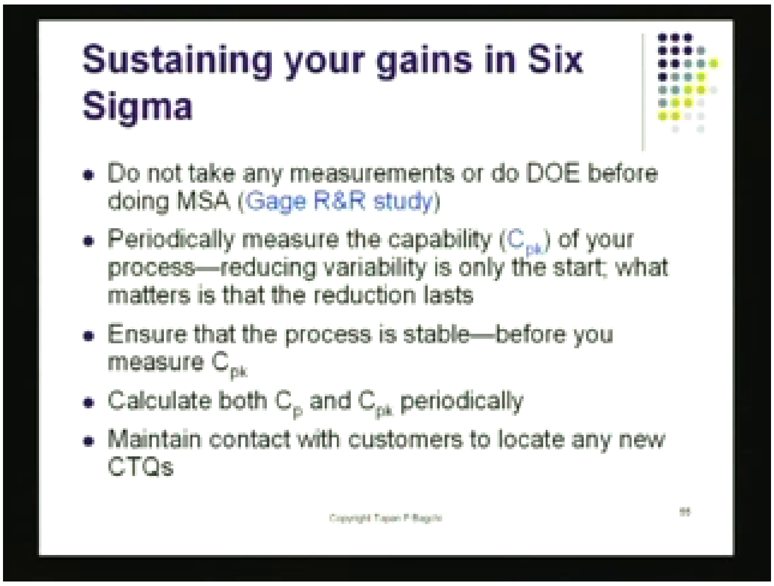

And of course, we had to make sure that, we if we are going to measuring some forces, we had some device they had some device that they applied on the side of the logo, this is a mounted logo that was already cured and declared to be ready.

So, force had to be applied on it to take the logo off and that that force have to be measured by some some device, some gauge there, was the gauge measuring numbers correctly that also had to be established by doing, what we call MSA Measurement System Analysis. And many times of course, they might if this was like a routine process they might also workout the C P K process capability. Now, that C P K in this case turns out to be 1 in 50 getting rejected that is a pretty high level of rejection.

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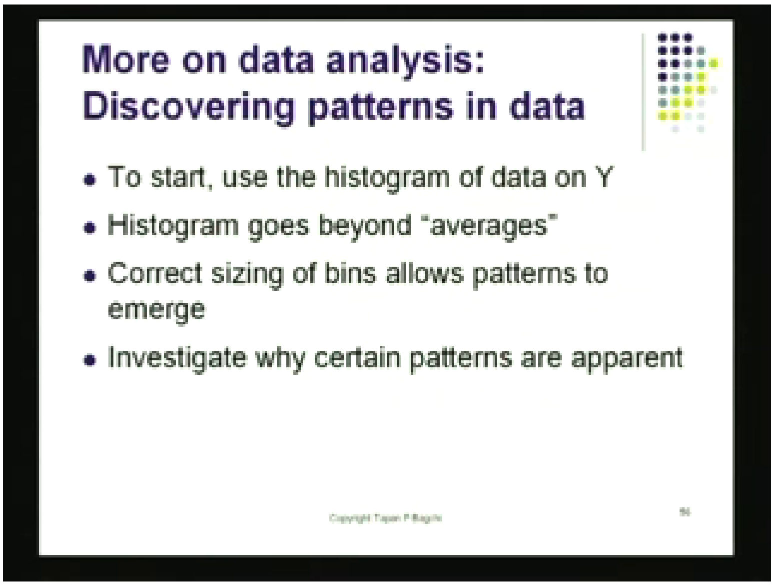

Now, we slowly move toward data analysis, basically what we would like to be able to do is, we would like to be able t see some patterns on the data and one way to do that is if you got multiple variables.

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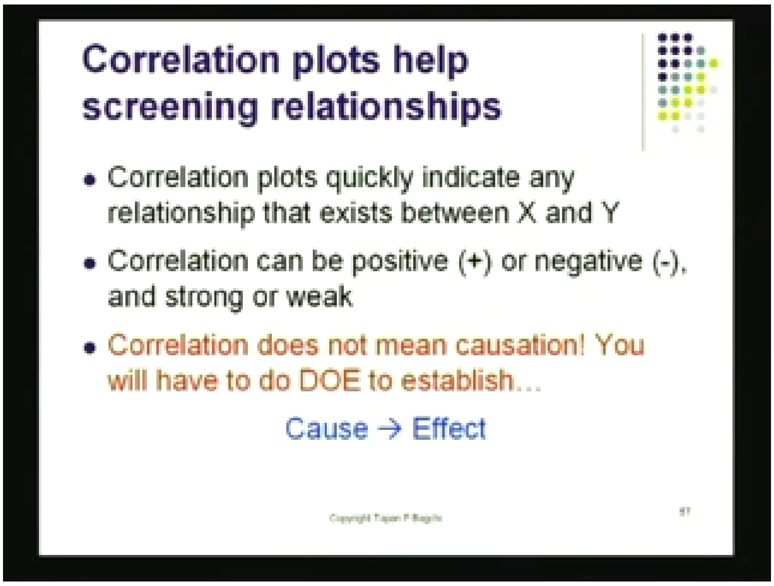

You would try to take a look at some correlations and see with those correlations can we at least speculate about some cause and effect of the thing. This is something that will be verified by DOE but, when I plot, when I make the correlation plots do I get a positive relationship or do I see a falling relationship, a negative relationship, if such the indications are there on the what we call correlation plots; it would give us a pretty decent idea. That perhaps I have located one or two factors that might become a causing that effect there one or two X values X 1, X 2, X 3, remember I had those factors, there in fact I can show you those factors again, those factors were the one that were here.

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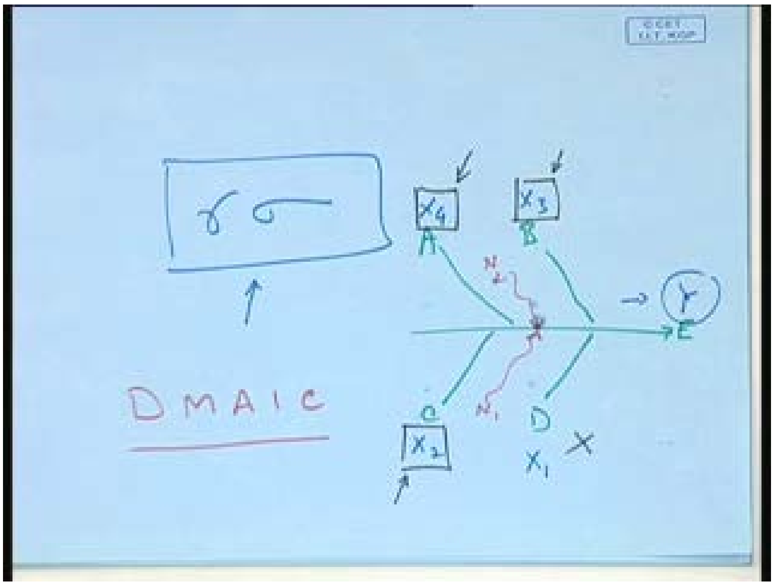

So, what I would do is I would basically do a plot of X 2 versus Y, X 1 versus Y, X 4 versus Y, X 3 versus Y. And see which of these through a strong correlation that would show some sort of a linkage, some sort of dependency between X 2 and Y or X 4 and Y. Once these correlation was sufficiently strong. I could use those as candidates I could use those as candidates in my D O E, in my design of experiments.

I could combine these factors in a metrics like structure, which I am going to show in a minute to try to your sort of (( )) can I uncovered some sort of dependency, between these X's and the Y's, this is something that I would like to be able to do with my DOE.

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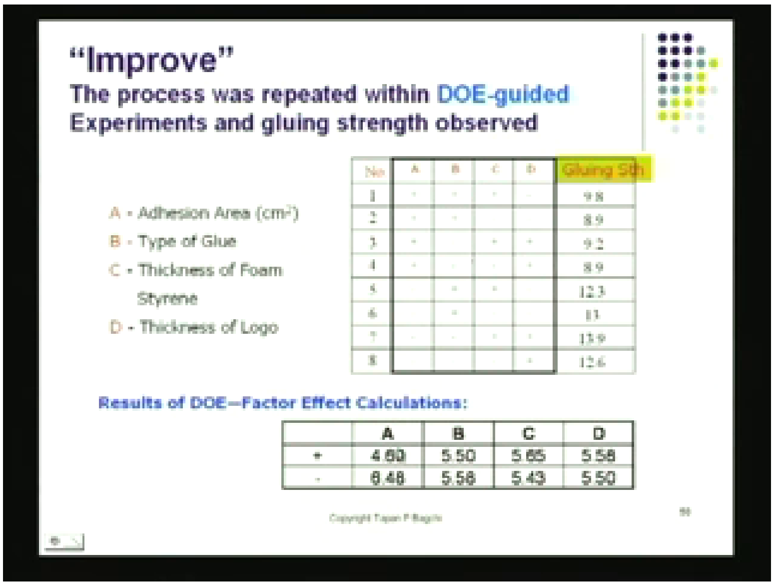

So, coming back again to the slides, I now have my DOE guided matrix, these this is my experimental matrix, if you look at little closely you will be able to see the pluses and the minuses under each column. Now let me remind you, what this matrix is this matrix actually is A scheme by which I will be conducting my prototype experiments. So, I will be building up few, I will be mounting a few logos, under this setting A set at plus level, B set at plus level, C set at plus level, D set at plus level remember, now D set at minus level remember.

Now, each of these factor we just chose four of them for illustration, remember now each of these factors had a working range. And let us just go back and take a look at them (Refer Slide Time: 24:25), the working range for these factors there here are the working ranges.

So, there is a high level, I may call it plus and there is low level I may call it minus, so for area I have 15 at high as I call it plus and 20 as low and the acrylic versus urethane this is also is like this could be plus and this could be minus. And thickness could be plus here thickness could be minus here, thing would be minus and as for as the thickness of the logo is concerned, thick is plus thin is minus and so on.

So, I do that, once I do that it becomes very easy for me to show that, on my matrix here as so the first matrix, will be done like this factor A set at plus level, factor B set at plus level factor C at plus level, factor D at minus level. I run this process I run the process now A set at plus level, B set at plus level, C set at plus level, D set at minus level. And I check out the resulting gluing strength and this is actually the sum of two two, so you are you did sample one, you did sample two, you added up this things; so there may be some slight variation there, so added up to take care of the fluctuation there.

And I did the same thing this was my experiment number 1, I would similarly, do experiment number 2, experiment number 3 and so on, so forth. When all these experiments are done remember this side of the matrix is an orthogonal matrix, it is an orthogonal matrix, it is a orthogonal design scheme. Experimental design scheme that is what I utilize to basically, show you this matrix on this side it has got 8 trials, it is got 4 factors that are being varied, according to the settings here and these are the resulting numbers.

So, the first experiment, which is done at plus, plus, plus, minus it give us a gluing strength of 9.8 pounds, then 8.9 pound, then 9.2 pounds and so on, so forth. And this guy gave 12.3 pound, then 13 pound, 13.9 pounds and 12.6 pound; you might think this is the best setting, we do not know that yet, because it is possible there may be other effects and not just a additive ahead that is that is that is causing this.

So, I would like to be able to probe this a little bit more, so what I did what we did was what was done was the factor effect calculations were done and then we try to identify the effect of each of these values there. Now, notice here, addition area, which is the first one plus was low area, it showed lower strength, it showed in fact lower force required to move that move off that that logo of the back of the car.

And when area was increase increased it required a higher level of force to move it off the back of the car, so this is like what we would expect, same thing was looked at with factor B that was the type of glue, it did not seem to have much effect, C also did not seem to have much effect, D also did not seem to have much effect but, area certainly had a large effect and let me show this to you graphically.

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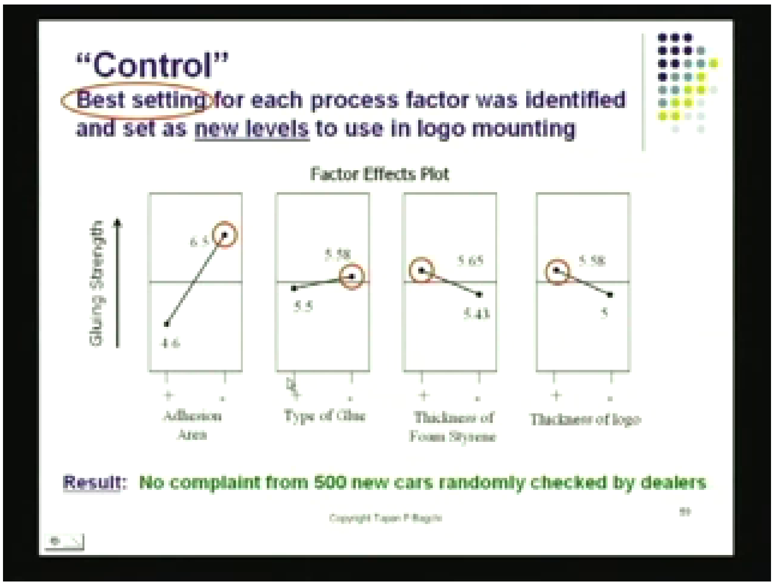

Graphically the picture would look like this yes of course, when addition area is changed from this low value to high value, which is like plus to minus, if you go by the by the working ranges, that I displayed earlier. You will find that gluing strength goes up quite a bit, it goes up by all most 50 percent, when you move it from low area to high area, that is like setting of addition area, from plus to minus, what about glue type it did not does not seem to have much effect.

So, you could use either glue you could use either level of thickness that also would not be a problem, either level of logo thickness that also would not be a problem. But, of course, if you really wanted to optimize the process use these settings for your commercial production. Minus setting which is a higher area for higher higher area a larger area for addition area, glue type minus, thickness type plus, thickness setting plus for this styrene foam and thickness setting plus for the logo. And these would then be your optimum setting there minus, minus, plus, plus that would be that would be the one that would be your new setting for the process and you should then feel comfortable to release these settings.

Now, to your to your plant and you can probably tell them please go ahead and change the original settings by which you are applying this logo to the back of the car, both that down to be use these new settings there. And make sure they have means by which, they can control these factors and they can keep them there, because every car as, the cars keep coming by you may actually have some variations in these input variables, these process control variables one has to make sure that, the process control variables stay exactly where they are found to be optimum.

So, that is like something that one will have to do, this is something that cannot be ignored it happens, so many times that you identified you identified the optimum settings. But, it do not have the the proper process control devices to be able to keep those process control variables there, if they are not kept exactly where they should be behold it it may turn out that the process will fail this is something that you do not want to happen that is why it is very important.

And DMAIC make sure that you have a control step, you end up DMAIC you end up with these things (Refer Slide Time: 29:58), you have define you have measured, you have analyzed you have improved and you have controlled. This control one is kind of critical because even if you done all the other things right, unless you keep controlling place, your process is going to wander of to some some optimal value. And you will not be getting the kind of P P M defects that your shooting for that is something, we got to keep in mind.

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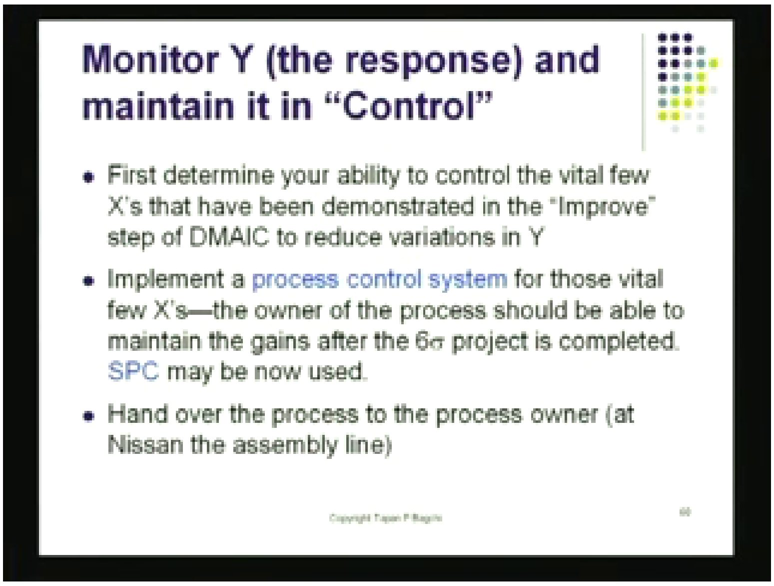

So, this is very important for us to be able to be able to do that you got to monitor the output, so basically what you really should do at this point, is you got to keep track of this output as it comes off. So, occasionally what you should do is, you should take a car on the side and you should try to take that sticker off that, that logo off you should try to do that, you should probably measure, you should probably get down to the level of doing destructive testing.

Which is like you really peal it off peal the logo off and measure that the force that is required to take it off, this way you would be assured that, my process is running at the at the setting where I where I set my process control system. Unless is this done of course, it is very possible that the process would have drifted and then you would end up with defective products again. And defective cars, when they go out with with logos that fall off again, there will be unhappy customers and they may not really recommend those cars to their friends, that are something you got to watch out against. Once this is stabilized you can handover the process to the process owner, that is the assembly line you could do that that is not going to be very difficult.

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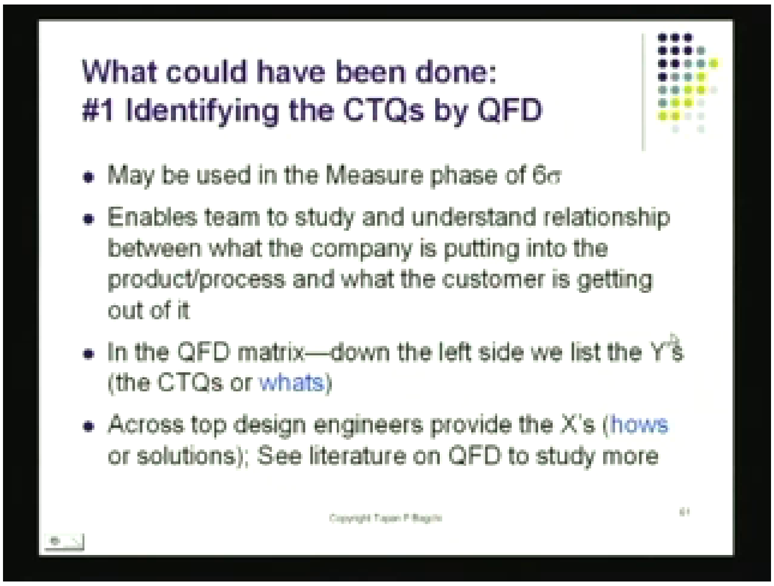

What things could have been done differently, suppose you are doing this as a top notch company you are really a six sigma company. And you have this these defect complaints coming to you, what what would you do differently, let us take a look at all kinds of things that you could do, the first thing you should try to do is, you should try to identify the critical to quality characteristics using QFD. Remember QFD, quality function deployment, this is something that actually takes that it it would involve interaction with flotation customers. Perhaps real customers and we using what we what we really try to do is, we really try to make sure that, the team understands what is it that, they are really after, what are the C T Q’s.

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Remember this diagram this diagram house of quality on the left hand side on the left hand wall, I have got the CTQ the critical to quality characteristics. These are the one's these are the one’s customers are going to be really requiring, they are the one's who are going to be wanting to see these. And therefore, what we have to do is for example, in the dry cleaning case, we wanted to make sure that, we understood what the customers wanted there, they wanted, the there the dresses to be completely clean, they wanted it perfect dress, they wanted to make sure there would know delays at the counter. They make sure that there were quick quick turn around, they wanted to make sure service was friendly and of course, they also give us some priority.

So, even in the logo case or any automotive application for example, you will be doing the same thing, you will be interacting with the customers, you will be making preparing a list like this and you identify these CTQ’s. You try to make sure you have some measures on them also, because you can only control those things that, you can measure if you cannot really measure a certain things. It is just going to be a feeling just going to be qualitative feeling and that will be just good bad, may be type of thing and you cannot really do much quality control using that. So, see if you can convert or at least you can get a proxy for the C T Q’s that is measurable on some sort of scale and the moment you bring in the of measurement you got to make sure your measurement system analysis is complete and the data that you produce is repeatable, reproducible, accurate and of course, stable those things have to be made sure. After you identify the CTQ's by this quality function deployment, this the this (( )) house, you got find solutions you got to find out, then how am I going to deliver that.

So, in fact you recall the house of quality for the dry cleaning shop to deliver these things, if you got to have the the experts tell us we must do good training, we must have good dry cleaning solvents, clean dry cleaning solvents, there we must have properly functioning filters, we must also have no rust in the those lines, that bring the fluid into the into the system, the press pads must be form.

And I have got to we also have to make sure the overall quality of equipment is good and we can do many other things. So, this is something that I would start with if you in fact go back (Refer Slide Time: 34:19), and say how good I would have, how would I have started this; I would have probably done a step number one, I would have identified the C T Q's, by doing Q F D that is something that I would have done; so, I would have gone through this step.

The next thing I would have done is something called design for six sigma, I am actually getting pro active now, I have a tentative design I have a tentative design in place. What I am really trying to do is, I have to identify and address weaknesses of that design this is where we have to actually ask the question. How would this fail? How would this How could this design fail. For example, if I have got anything I have got a simple product here, I have got a pen in my hand, in what different ways could this pen stop working, that is the question I have to ask and I have to construct this engineering work sheet, that is called the F M E A Failure Mode and Effects Analysis work sheet.

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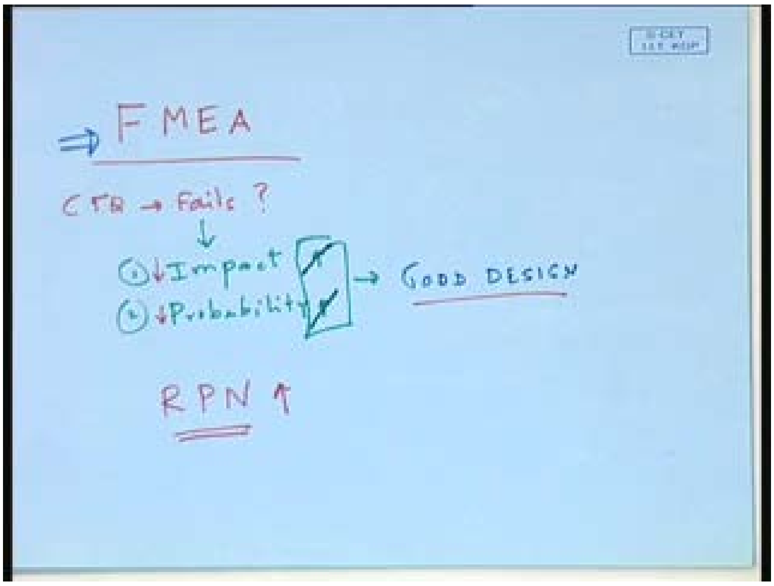

So, that work sheet will be called an F M E A worksheet and what this one really does is a ends up it looks at two things, how it might how might a C T Q fail, C T Q are the C T Q that fails. How might this happen to be able to do that, I answer some questions I first of all I try to find out, what is the impact of this failure? This is the first thing I try to identify; the second thing I try to identify is, what is the likely hood? What is the probability of this failure?

If there is some item, that has high impact it is also got high probability, that become something critical for me, I have got to do an I have got to do some analysis beyond just doing plain and simple f m e a for it I am going to take steps. Now at the design state to try to make sure this gets canceled, this impact produces and also the likely hood reduces. Unless I have done that, I will not end up with the good design, my good design will come when I have crossed this and I have crossed this (Refer Slide Time: 36:33) I have got a good design.

So, doing F M E A doing f m e a will lead to a lead to a good design, that is something I should be able to do, so this is something I would have like to do if I was doing this place in fact if that had been done. If those trials had been done then these logos would not be falling off in the field that is something that is very very important and this, what is called design for six sigma. You are really designing things in such a way that it will lead to high level of customer satisfaction, lead to very few defects, this is something that requires a lot of effort.

Of course, it requires a lot of prototyping and so on and so forth. You might use DOE, if you use DOE you would be doing this very efficially, this is something that is routinely done for all critical products. For example, a engineering products, a lot of electronic products, that we have around us when they go through the design shop, the designers before they really start fabricating prototypes.

And all they will have the schematic or they will probably have a sometimes even a mathematical model or perhaps they have a some build something there, they start asking the question. How might this design fail and what will be the impact, will it stop working will it really will it will it lead to a critical defect or a functional defect or perhaps just a cosmetic defect. What sort of defect will it cause, that would give me an idea of the impact then you will also ask, when this product is used in the field, how likely is it to fail.

So, this is now the issue of not the impact but, the likely hood the product of these two quantities, which is impact multiplied by the likely hood of failure, this is the quantity that is called RPN Risk Priority Number. RPN and the higher the RPN, the more dangerous, that designers the more likely the design is going to be the the use of the design going to be dangerous.

So, what we have to do is we must identify the various modes of failure and calculate their R P N and whatever turns out to have a high R P N, whatever mode of failure turns out to have a high R P N. We got to take steps so that, we can reduce it is impact and also we can reduce the likely hood of that failure, there if you do that, we will end up with a good design; unless we are able to this, that design is not really satisfactory as up this stage.

So, this is something I should be able to do at the design state itself, so I would have done this differently, I would have probably gone through this and I would have probably located, then that the logo might fall off because, of improper sticking or not enough area or not not the right kind of glue or the logo being too heavy or whatever it is I would have probably discovered, that if I done F M E A. That is something that apparently was not done when this was done.

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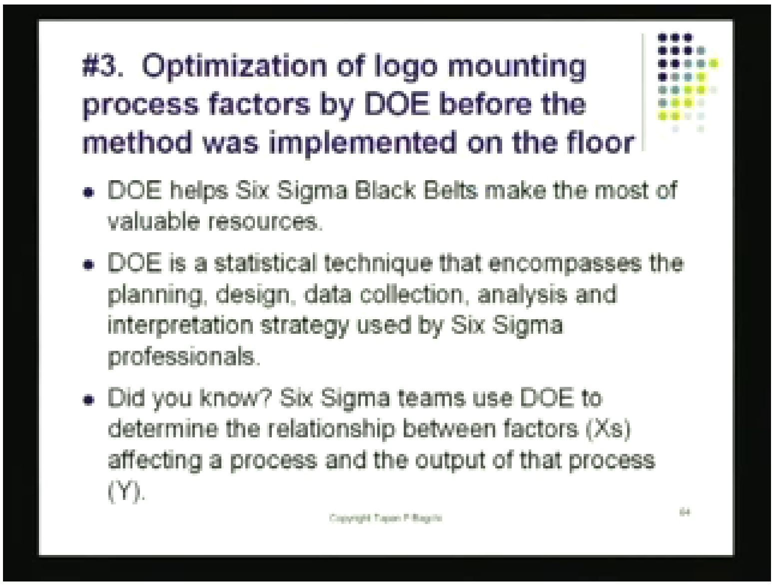

The third thing is is should have actually optimized the mounting process itself. Then again my old friend design of experiments, design of experiment D O E comes along there, I have these different process factors, that I can play with and I can construct this matrix I can construct this matrix. And with the help of the matrix, I may be able to conduct certain special experiments, that would lead to an optimum process, because here each of these process factors, that are like made to work together, those factors would have been set at their optimal levels this discovery.

Of course, would take place through D O E and again you know perhaps, trying to over sell you this idea of D O E, so there is no better method available today, not known to man, we do not really know. We cannot really do one factor time trials, those those are bound to fail because, many times factor effect the interact you cannot really do a study of one factor.

Here, another factor there third factor is here, fourth factor there and I hope that when I put whole thing together, it will all work just fine it just does not work, that way many times, there were interaction very complex interactions in systems. Particularly those that are complex system, that are around us further, we got to do this DOE got to be able to do this.

So, if you did process DOE for this process, there we would end up optimizing, the mounting process itself and that would have lead to perhaps say, process that would be guided by the black belt people and that would end up with you know, the correct choice of the X's and their settings to give us the best Y that is possible.

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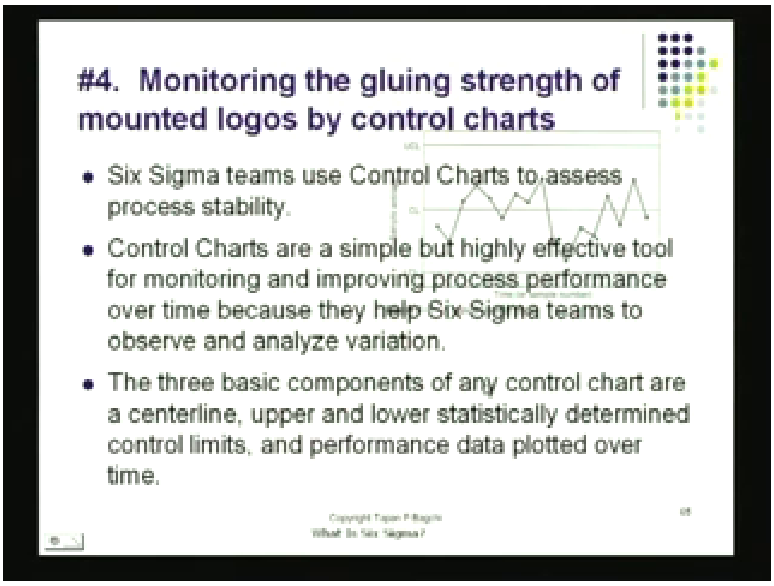

Then the last thing I would have also probably done, before I let this go would be would be to in a focus on the control system and perhaps plots (( )) charts and the (( )) charts could be done two ways. If these could be utilized two ways, you see a chart there in the background, there is the trace of the level of perhaps the gluing strength, these probably I i I measured, these probably I measured as a take of a few samples of that, production line there and do this.

This obviously it does not have to be done on the full card, you could just take a a surface a sheet material that has been polished like the back of the car and you can take a logo. And you could probably mount them you could probably you know push it through the process of mounting, as if you are really simulating the real process. While doing this you are recreating the process, that would take place on the production line and here you can play with the different factors and I can conduct his matrix experiment and you can get the factor effects and so on.

If you do that, you have to identify the correct setting say, if you identified the correct setting for gluing strength areas and all those things. Those could change while the process is going on, so what you have to really do is you got to keep keep an eye on them first of all the output, gluing strength being the output you could plot a control chart for

Y, the gluing the the first with which can take the glue of the of the plate of the a metal of the metal sheet that is there.

So, you got the metal sheet there, then you are applying this I I will pretend that this is the logo, I will pretend that this is the logo and I will put there I will try to push it off and this of course, I am doing with some device, where I can measure the force. Once I am doing tha, I will able to generate some data. And that data I can plot you see the control chart there you see the control chart heading there, that is the that is the kind of chart I would like to be running alongside production that is going on there, this is got your upper control limit, lower control limit and so on.

We reviewed of this thing when we were doing our review of SPC, so this is like something, that I could do at the output level. I could do the same thing at the input level also because I have got these X 2, X 3, X 4, there were the three variables that I wanted to control. And I have to keep them at the at their target value there, this is something that I could also do and this is something that I actually could do quite easily by doing this.

So, this is also something, that I should be able to do it is its like it goes without saying that, with such good controls in place, I end up with nothing except good products.

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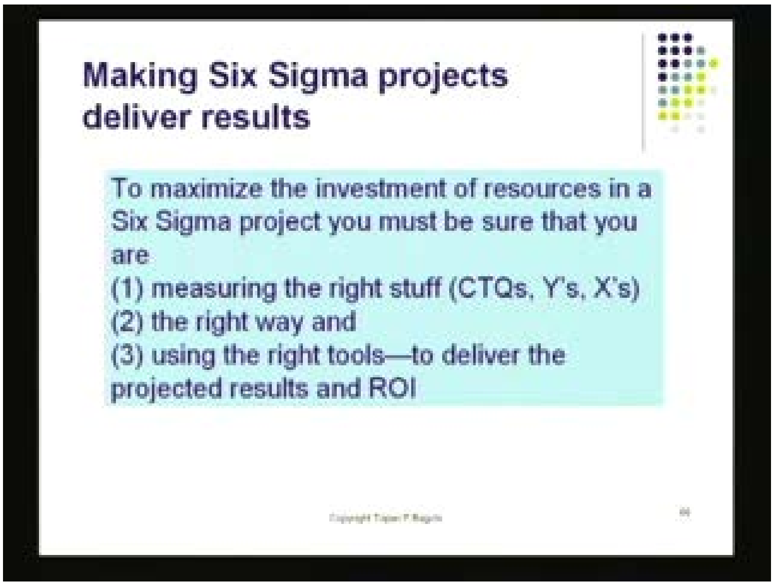

How is it that I am going to be delivering good results out of six sigma projects, just take a look at some of these things and we will come back and revisit some of the things that we have done so far. in today's two sessions.

We want to make sure that six sigma projects, that we do they deliver maximum results and the the the aim really is because, we we are putting in some resources, we putting in it is an investment of time and resources to conduct these improvement projects, we really should be able to do this very, very well we should be measuring the right stuff. So, you should start with the customer and we get the CTQ's from the customer, CTQ's are those characteristics those quality characteristics, that are important for the customer this is something that is very, very important then of course, the Y, Y is the proxy for that CTQ.

See, in our case the problem really was that the logos were falling off this is what the observe this is what the customers observing the logo fell off. So, in fact the measuring that we had was we had so many so many logos, that fell off what is it that was the good proxy for this it was the gluing strength, it was the first for which we could take the logo off the back of the car. That would be Y, how would Y be controlled, what would what would be different influencing factors you remember.

Those factors that, we had on the fish bone diagram those with the different factor that could be affecting Y, I had to do DOE, one had to do DOE to be able to find, what exactly is the link between the X's and Y's. And remember what we did, we ended up with plotting graphs like this (Refer Slide Time: 45:29), these were the graphs that we used. And these show the relationship between Y, which is gluing strength which is on the vertical axis and X this is like X 2 this is X 3 this is X 4 this X x 1 and so on, so forth. these are my process control variables and I see their impact.

These plots I could not have made, I could not have made this these plots if I run my experiments willy, nilly it is only, because I ran these experiments in this matrix frame work. I was able to run my trials and I was able to plot those plot those graphs there, was the data is presented like this, was the outcome of the result is present presented like this.

Almost anyone can actually point at the superior settings, the best settings, so in fact it is really worth your are trying to do DOE, if you do DOE if you use this matrix frame work, which is like this one and of course, to be able to do that the first thing, you should be able to do is you should be able to do the cause and affect diagram. So, this is what is start with you got the mapping mapping done and that mapping will inspire you to construct this cause and effect diagram with the problem at the end here. Then some of these factors probably are causing this thing, so you would like to conduct some experiments with them, so identify their working ranges, so you got some choices there.

Now, let me tell you what different types, how many different ways you could run this process, there are seven factors here, seven factors here these seven factors each can be set at two levels. So, if you look at the total number of combinations by which, I could combine the two settings.

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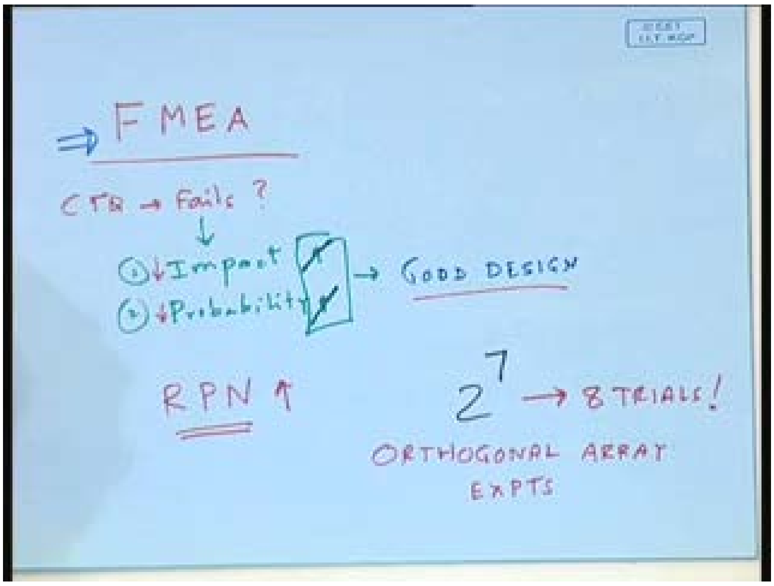

For each factor, they are being seven of them is actually 2 to the power 7 2 to the power 7 is the number, these many different ways I could actually conduct this process I could run this process. And those would be the combination of the different working ranges that I have there but, this is just way too many, there is no way I would be able to find money to conduct all these trials. And somebody could say well run all those trails if those are the possible trials go ahead and run them the problem is I will never have resources for that kind of think. In fact if you proposed a six sigma project using to be using, these number of trials nobody going to found it for you.

So, what do we there, we apply we bring in the knowledge of statistics, we bring the bringing the the knowledge of the master of black belt. And the master black belt says when you do not really, have to run these many trials instead, what you could do is you could do orthogonal arrays you could run orthogonal array experiments, that would reduce these 2 to the power 7 trials to 8 trials only.

And this is a remarkable saving, this is a remarkable saving your coming down from 2 to the power 7 to 8 trials, while using this approach to do your D O E, this is the frame work for conducting your D O E. And that is we see when you look at the matrix here this matrix here this matrix here is an orthogonal array and this is good enough for me to calculate my factor effects and this is good enough for me to plot these effects there (Refer Slide Time: 48:55).

So, whatever I wanted to do of course, I am not really reaching the ultimate optimum, I am not reaching there, because that would be one of those 2 to the power 7 combinations that are possible. I just do not have the resources for that but, just see what this simple method is done for me, it is cut down the number of trials from being 2 to power 7 trials to 8 trials only.

And I have been able to find pretty decent practical answer, that is something I have been able to do, this is very important something we got to remember. If you run into a situation if you run into a situation when there are many factors involved there are many factors involved in a process and it turns out that you will have really a very large number of trails to be done.

For example, in this case 2 to the power 7 trails think of either consulting with the master black belt or use your own training, pull out a text book on statistics and start paging through those pages on orthogonal array designs and so on and so forth. And most likely you will not have to use, what we call the full factorial design, use the taguchi type of design or use the orthogonal array design, those are going to cut down the number of trials that you need to run drastically.

So, here we cut it down from 2 to the power 7 possible different trials, so 8 trials only and we got very descent practical answer, after the changes were made carts will monitored the the output was monitored. And the dealers they sampled randomly 500 different customers, not one had a complaint after the new process was put in place, that is a remarkable improvement that is a remarkable improvement; from 1 in 50 low walls falling of they got down to the level; 0 in 500.

And of course, this was a sample so most likely the population of the carts they had probably much better much better performance in the field also.

What was so many things that we did just just try to recall some of the key steps there, this is going to be if you start with the motivation, the motivation is going to be your cost of poor quality. And where would you find them just go back to what we call the iceberg, go back to the iceberg some of the problems are pretty visible, some of the problems are visible and they are the visible parts those are going to be the scraps the rework the warranty. Here also it turns out that most of the time what we what we really observed a scrap is reported and rework is possibly reported in the work book in the log books and warranty is also, some times reported, these are the these are the only visible one's.

Now, many companies may think that this is the only consequence of poor quality but, low and be hold, because you got unreliable machines, you got materials that are not of good quality, because you got production stoppages and so on, so forth. Because of that you are really loosing a lot of money, you are loosing the productivity of the capital, that you employed in a company.

And that is going to be the body of this look at the body of the iceberg (Refer Slide Time: 52:20) I have got conversion efficiency, in efficiency there I have got in adequate resource utilization, I have got excessive use of material, because quality is poor cost of redesign. And re inspection that also is there, because quality is poor cost of resolving customer problem that is also is going to cost the company. Some money lost customers and good will loss that also going to be there and high inventory.

You may not believe this but, when I did my masters theses in Canada, systems are pretty unreliable those days and there were production units, that would like set up one after the other and so on, so forth. That will solve the production stages and one of the problems that I was asked to work out, was to kind of estimate the amount of inventory that, you require between two unreliable production systems.

So that, one the stoppage of one would not affect this stoppage of would not affect the operation of second one, in fact this inventory that was to be there in between would act like a buffer between, two unreliable systems. So, one going to split in the other one this this inventory could absorb some of the problems, that might be occurring with the feeding one and also with the break down one. In fact this this buffer sizing really became an masters theses problem.

And what was the what was the system that has working with unreliable systems are (( )), so I had two unit that one unreliable and are supposed to work out the size of the of the buffer today. Today even if one conceives a problem like that, he will be thrown out of a college, because today we are talking six sigma, we are talking about perfection, we are talking talking about the level of quality, that is right up there with the with those that are best globally that is what we have to get to.

So again to come back to iceberg (Refer Slide Time: 53:59), when you have to justify your project take a good look good look at your cost of quality. And try to see what you can do to try to improve the cost of quality that is there and can you walk through the DMAIC face, can you actually do that if you are able to that (Refer Slide Time: 54:18) if you are able to do that you are settling on that winning path, I hope you had an understanding now and also illustration with that Nissan project that we looked at.

Where they were defects and there were problems and there multiple factors, that could be affecting it but, with the DOE with the frame work that was DMAIC and DOE put in place for improvement, the improvement step was there, we are able to take very good care of it. And defect levels came down from being one complaint for 50 cards to none in the 500 that were sample randomly, that is a pretty good improvement.

And I hope fully you get inspired by by this to adopt the DMAIC procedure that is like one, if any other practioner and certainly whenever you are trying to do an improvement use the DOE frame work, use the design of experiments frame work. And there to in particular try to apply first the orthogonal array frame work, that is something that is going to save your lot of time, a lot of resource, we will continue thank you very much.