Six Sigma
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Lecture No. # 40
Getting Results from Six Sigma

Good afternoon, this is the last lecture in this series of 40 lectures on Six Sigma from IIT Kharagpur. I am Tapan Bagchi, I am going to lead you through some of the key points to ensure that, you have success in your six sigma undertakings, as I show in the slide there.

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We will be focusing on the operational excellence in each of the steps that six sigma project is suppose to move through.

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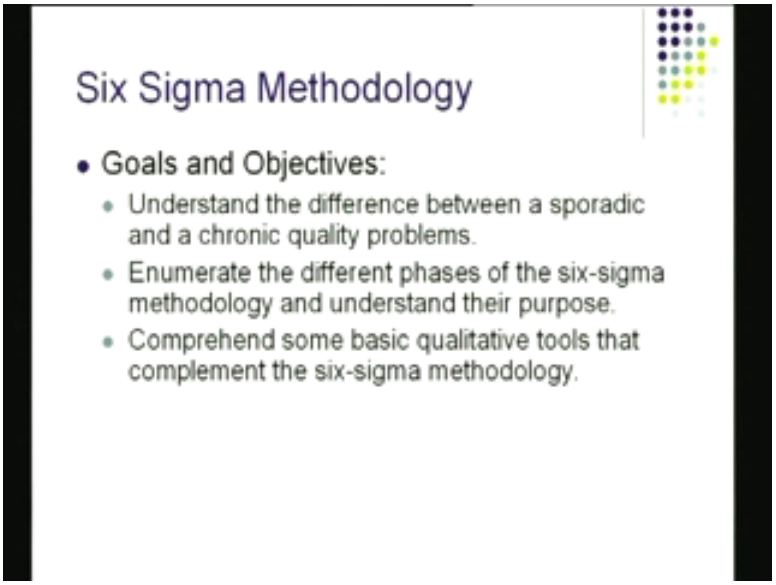

We have already reviewed that there are certain methodologies to be followed certain goals and objectives to be followed and these are going to be done in a systematic way I am going to lead through this in this presentation and I am going to actually point out some of the points which are pretty critical to keep in mind once you are moving through this particular causes.

Make sure the goals and objectives are clear to you, make sure you understand the difference between sporadic problems and chronic problems these are quality issues once in a while some things may go wrong, but there may be also consistent chronic problem these may come and go, but they are persistent they come back one after the other again then you have to enumerate the different phases of six sigma or some methodology which we done already and we will recover (( )) we will take another look at that in this presentation again complaints compliments of the basic tools basic qualitative tools.

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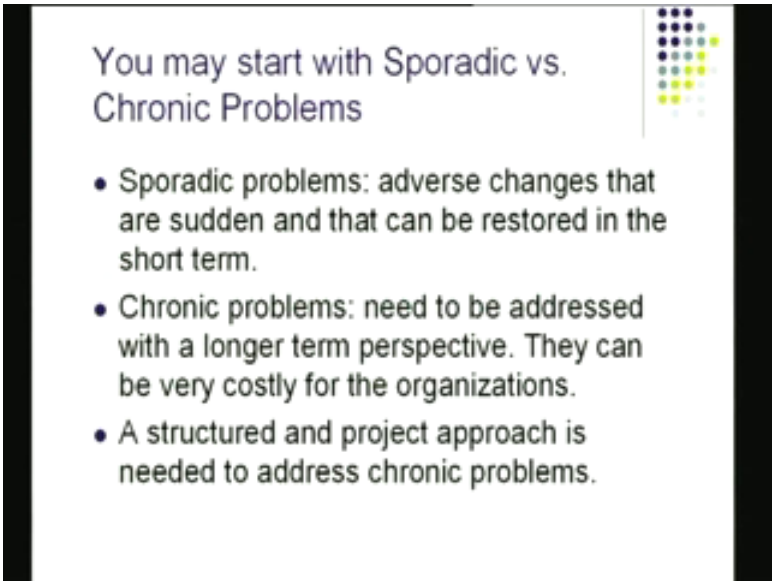

Which are used for this we are going to be reach out the problems let us understand the difference between sporadic problems and chronic problems, sporadic problems are adverse changes that are sudden and that can be restored in a short time these do not require a long term solution. Chronic problems on the other hand are problems which are intrinsic in the system and they must looked at from a long term perspective without doing that you it is not very likely that you will end up succeeding with your projects.

We need to have a structured approach and this have emphasized many times, we got to have a project oriented approach you set certain charters you define the scope of the project you look at the work break down structure you deal with this sponsor of this project which could be a process owner for example, and you are the expert presumably you have the you are you probably have a black belt or something like that and you are providing that the expertise to be able to solve the problem. You got to take this project oriented approach you project the whole mission and you take a structured approach and a follow through it as you move through the thing.

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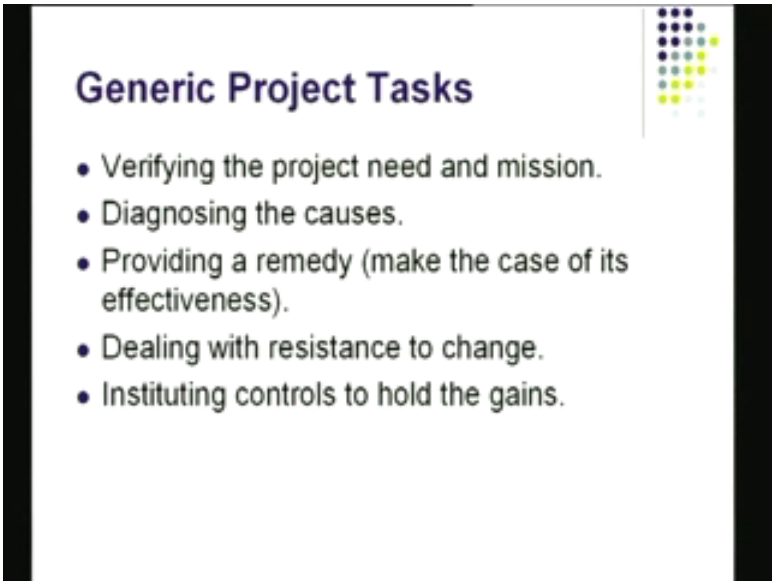

Only then you can tackle the chronic problems, certain generic project tasks are there these are to be there in almost every project that is there which is like first of all verify the project need and the mission of the project, that knows the causes these are going to be part and partial of the doing the six sigma project provide a remedy and of course, deal with the resistance to change this could be there, because there are best in interest they are already there people have been working in this area for a long time.

They have certain practices, that that I to them and you might change them so there would not be some resistance, because things would would change at the after this explaining this intervention things are going to change, then after all you got to institutionalize these changes you got to make sure they become part and partial of this institution, this again is required so these are going to be certain generic project task that will be there.

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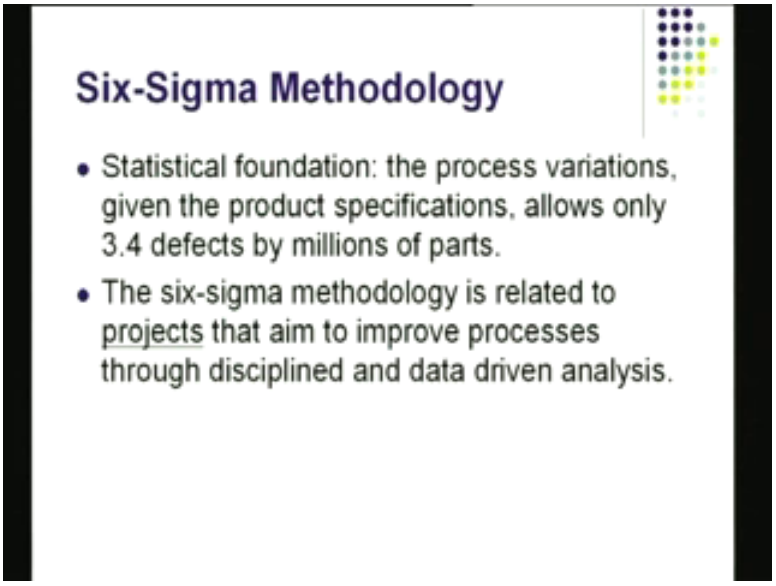

Then of course, you got to remind people of this six sigma methodology and more than anybody else you should remember what that six sigma methodology is the mission of course, is to try to reduce the effects to the level of three point four parts per million or three four three point four defects per million of parts any of those measures will be that is symmetric, this six sigma methodology is related to project that aim to improve the exciting processes through a very disciplined approach which is the DMAIC approach and it is a data driven approach it is fact based approach.

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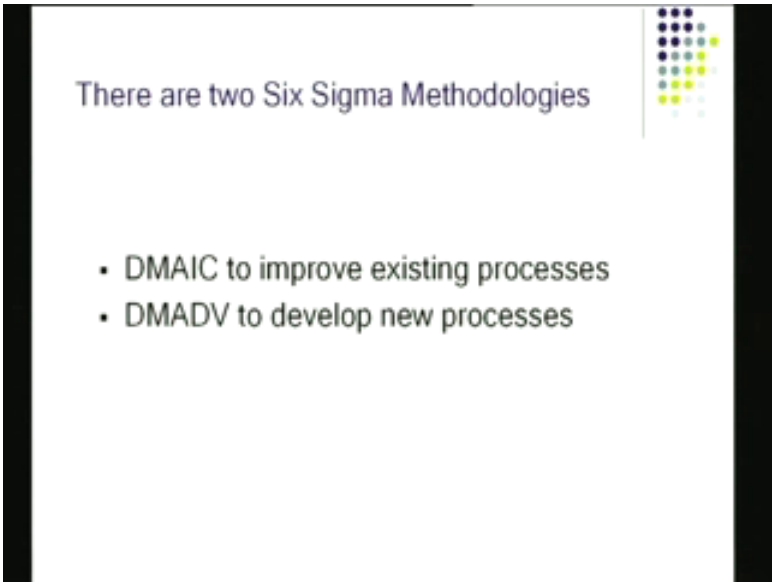

We will take a look at couple of couple of ways to achieve that, there is of course, the DMAIC process which is applied when you are trying to improve an existing process and if you are trying to develop a new process then you will be using a process that is very very related to DMAIC this is called DMADV, if the last stage you try to validate you try to make sure, that you verify validate the new process to make sure it produces the results that you want.

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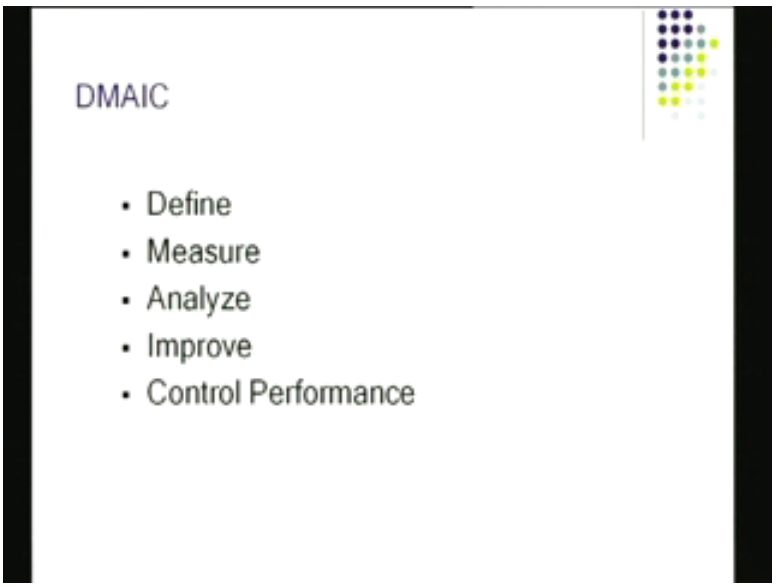

Just going over the DMAIC process again the heights that are pretty clear to you by this time you did define the problem you measure the gap determine what is expected and what they are getting. Analyze the causes for it then you try to look for improvement and this would be done most of the times using those are tools of quality improvement or these could be done by design of experiments, then of course, pulls you discover the new settings the correct settings for the process you will be basically putting the process putting the process under control so that it sustains this excellence performance- excellence in performance throughout the time.

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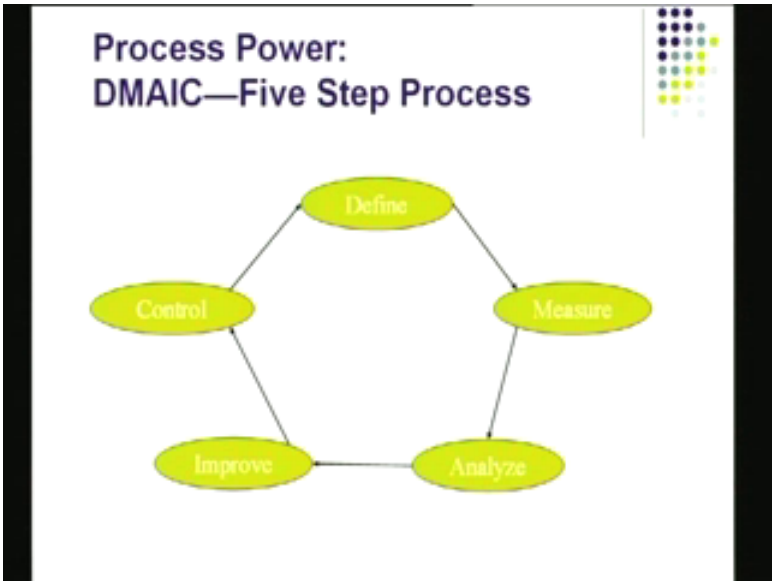

Again take look at the DMAIC process there are five steps involved in this process they define measure analyze improve and control, these are their specific task these are their specific responsibilities.

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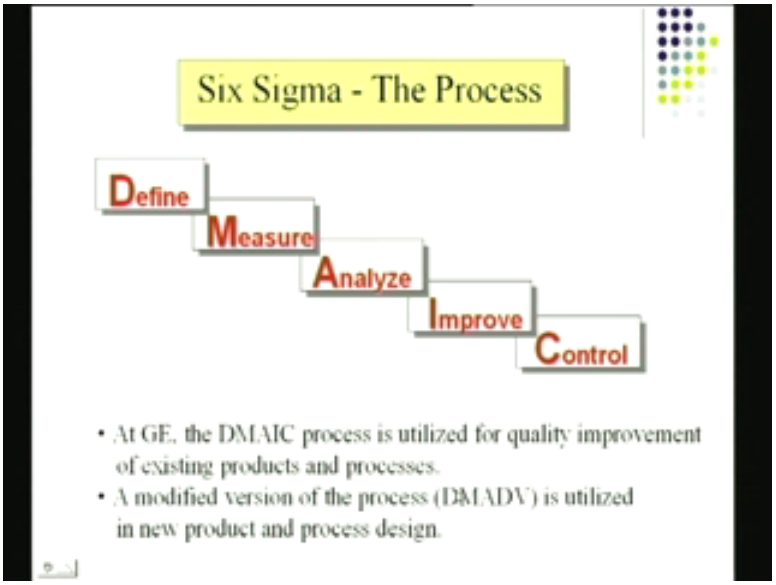

In fact, it turns out that the leading companies who assured this new new era the six sigma era for example, general electric as an example, they use the DMAIC process for quality improvement for existing processes also for new processes and also they use DMADV whenever they wanted to design a new product or a new process to produce

something that is that that would require you know the meeting of the stringent customer requirements those would have to be done under the six sigma logo.

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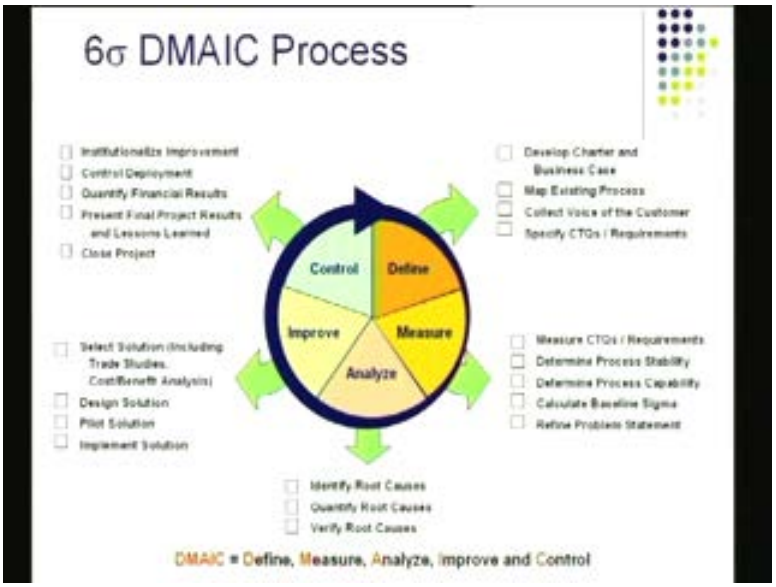

Let us take a look at the process itself the six sigma DMAIC process itself the very first step is define, you develop a charter a charter is basically going to be something like a measurement is more specific it is sort of you know kind of kind of clarify why are you doing it you make a business case for that project there. So every six sigma project must be made as a business case you map the exciting process you you come up with a flow chart, you define exactly what the stages are and you try to identify where the problems are and this you would be doing probably partly by walking the process or by looking at literature again you will end up with a with a process plan or you may basically talk to people and so on, so forth; or get people's help to make sure the mapping is correct.

Collect the (( )) of the customer these are the people who are interested in the performance of the process what are they expecting out of this process and then of course, make sure you define those CTQ's the critical to quality characteristics and these are the requirements, that the project must deliver, the process must deliver. Then of course, you got the measure step which includes measuring the CTQ these are very, very important measure the CTQ the critical quality requirements, determine the process stability also, determine process capability, this you know they measure it by CPK, if

you are forgotten about CPK, just look it up in a text book or go to internet and read about CPK this is a very, very important important measure metric.

Then of course, you calculate the base line sigma, so it could be that you know I am just going to draw a little line here to show you, what that is there is a distribution of the full process.

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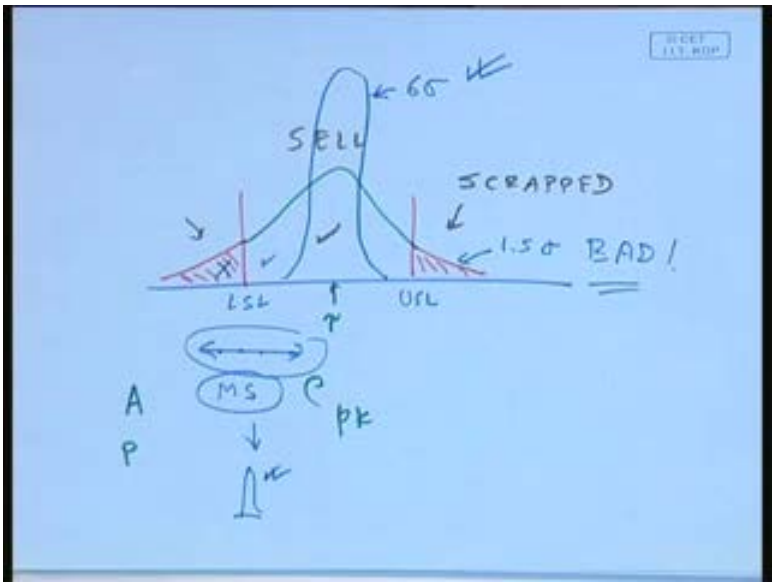

And I am going to show it to you part part green and part red, so there is some part that is going to be green and there are going to be these specification limits, which are going to be coming here and here and this part is the bad part, this part is the reject and also this part is the reject, you will in a process like this it is only Its only the part, that is in the middle this is the part, that I can sell and this part and this part these must be scrapped.

Now, as you know very well no these part or these parts are spent the same amount of labour, same amount of energy, same amount of materials and so on, for producing those results there unfortunately these do not meet my specification, my spec limits can can be remove very quickly as the upper spec limit and the lower spec limit.

Now, there is a metric there is a metric called CPK CPK this is process capability this metric basically talks about the overall performance of this process, which is firmly resulting from a lot of factors which are impacting the process and CPK gets you a a rough idea of what fraction of your production you can directly sell without doing any

rework on it or without or or also and also the extent of scrap that you might be producing in your thing.

So this is going to be your calculation of the process capability, that is going to move another step shared returning again you got to calculate the baseline sigma which basically, says a process which is like this the one, that I have on a screen here, this process actually has a sigma level that is way below 3 sigma, most likely this process is at 2 sigma level or perhaps at 1.5 sigma level and the process, that you would end up with after you done your six sigma work, it is going to be process, that is going to be six sigma and that is going to be whole contained inside this spec limit. So this is the six sigma process and the exciting process this one might probably 1.5 sigma this is bad, news this is bad, this is very bad and this is good, this is very, very good this is what we would like to be able to do.

So, we would like to start with the process which is like this would like to move it up to this and for this I need that DMAIC step to be able to go up from here to here couple of things you got to keep in mind, the first is that the average performance here, the average performance of the the output of this must coincide with the target that way I will have the accuracy of the process and the second thing is I must have I must reduce this variability and I make make the process precise.

So I need to have accuracy that is one criteria and also I need to have precision in every process that I do unless I have accuracy and precision my customers are not going to be happy, so this is something that I then define into a problem statement I define this into a problem statement and I try to find out is is my accuracy out of control or is precision out of control and then, I have to apply the appropriate tools to be able to do it moving on, I look at the analysis I have this variation I have this base variation I have to do something to try to realize that, variation or I have performance that is off target I have to restore that with the target, this also is something that I have got to understand and do It.

So, before I start my improvement the first thing I must do is to try to try to get a get an assessment of current performance this is for identifying the gap between what is expected by the customer and what your process is delivering, this gap is the one that actually holds your business, because if the customer wants this and you are supplying this there is no way this is going to be satisfying the customer there, so what I have to do

is I have to narrow the gap I have to really bring it right coinciding with the customer requirement that is what I have to do.

So, in analyze basically what we do is we try to analyze you try to understand, why this and if you remember if you remember our tools I am going to be showing you that tool again it is going to be the cause and effect diagram.

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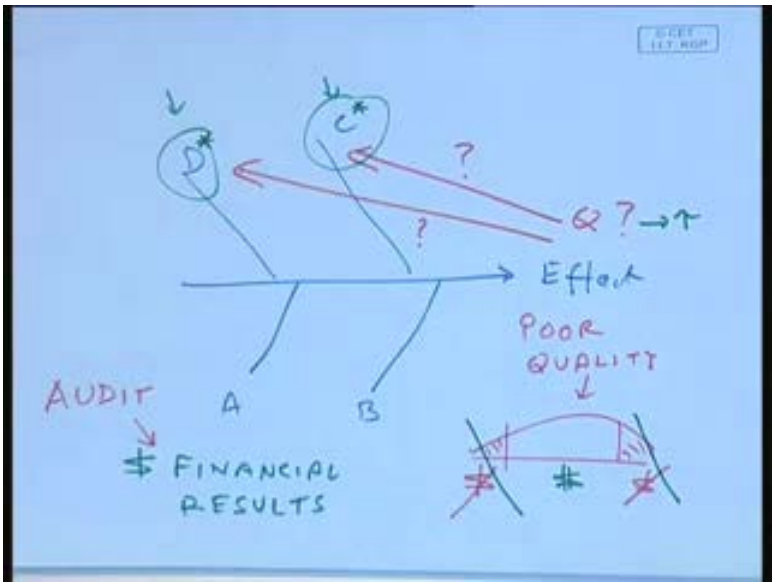

And if I could quickly draw that diagram here, I have the effect here and the effect is generally poor quality and this is caused by innumerous different factors, I will have to somehow understand, why how and why these factors are affecting that quality there, the effect is actually poor quality and poor quality has gives you high variability this is poor quality, the specs are here, but you are producing stuff that is out of spec and this is what I did like to be able to avoid. So to be able to do that, I have to understand one thing I have to understand how how these different factors produce this effect and for this I have got to do root cause analysis I have to identify the factors that might be doing this, so this is the part that is called your analysis.

Then moving on, we have got the improved stage and that is the part actually where most of the real real tough work in six sigma is done, this is the place where you try to come up with ideas you to come up with methodologies and these methods basically would lead would engage techniques such as design of experiments perhaps, regression perhaps, optimization and so on, and basically these are the steps that will make sure

that, the process improves that, the problems that you have identified in your root cause analysis those are rectified and eventually the process ends up with the six sigma quality or these three or four or five sigma if you are doing at if you are staying at one sigma at the base stage.

So, in the improved stage I will have to select this solution, I will have to design the solution, I will have to pilot the solution, I have to make sure I demonstrate on that shop floor and then, I have to implement the solution these things will have to be done right at the improvement state. Then of course, once I have got my improved state of errors In in my hand, I have got a good record of it I have got to make sure that, that new process or the new method gets institutionalized.

And then it stays there for this I need to institutionalize of course, that is something institutionalize these it becomes part and partial of the company part and partial of the shop floor, I control the deployment I make sure that the process variable the process different process factors, they now maintain the level at which they are set, when they are running at the optimum condition I have got to be able to do that I have got to quantify the returns from this.

So, for example, In this case in this case, as you see in the diagram there I have really in this diagram that I have on the on the thing there, this money is not with me, this money is also not with me, these moneys' are not there, the only money that I have that, I can call the results are of my business is this part. So this is my probably there will be some profit probably probably this this they they say on these goods probably it is just recovering my loss and because I have this loss, this loss and this loss (Refer slide time 14:35).

These are of course, your cost from poor quality losses I have got to remove them if I have done a six sigma project so that I remove them I do not have this and also I do not have this, then I have to put out the new financial results new financial results and this might require audit, so you do an audit, you do an audit to find out has this actually happen.

Do the audit to to confirm, that the results are actually been achieved and you are saving money or you are making money without additional profit, that is something that you have to be done, present the final project results to the people, who are the stake holders

and of course, you close down the project you release the resources and perhaps there is not the six sigma project waiting for you to take over.

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Let us look at some of the details again the DMAIC strategy, it is a strategy it is a it is a way that guides your long term action therefore, it is a strategy and it again agrees with the mission of the company. The mission of the company is able to outcompete the competitor it is It Is It will be able to you know grab the business from other people perhaps by providing better service and better quality products that is your mission, that is what leads to this strategy strategy actually spells out the steps and one of the key step say improving the quality is do it the DMAIC way, do your improvement do your quality improvement project the DMAIC way.

Now, what am I doing in define again to remind you I am defining the problem I am selecting a cost functional team, the team must have expertise in different areas and also define the charter team charter, what is it that the team is after because, from the charter I will define the scope of the project; then of course, In under measurement I would select this CTQ characteristics, CTQ are quality those quality characteristics are at critical to quality they are critical to customer satisfaction those all I have to select.

Define performance standards of these generally come from customer expectations, then of course, you validate the measurement system I cannot tell you how important the third point is on the measurement many times, what happens is when you measure quality or

measurement system is not good enough to be able to tell between good and bad, it can be as bad as that and this is something, that has to be checked before you get into a six sigma project.

So please make sure you look gauge r and r study if there are some measurements involved you do gauge r and r study and you take a good look at the training level at which people are performing their quality control task, quality control inspectors are they very trained to use those equipments those instruments and so on, so forth; do they produce good results, what about your overall gauge r and r variability is that sufficiently small, when you look at process variability. Suppose you are trying to measure for example, you are trying to measure this old lecture that I had there, you are trying to measure quality on this and suppose your measurement itself is widely variable let me just put down measurement variability there.

Let us see measurement variability at this wide, which means that I am if I if I measure the same object I can get a reading here or I can get a reading here, I can get a reading here I can get a reading here and so on,(Refer Slide Time: 17:46) would this sort of high variability I cannot really say, If I am meeting specs or If I am not meeting specs, I cannot do that with a measurement system that is as bad as this one.

So what I have to do is I have to make sure I convert this, I refine this, into a measurement system that itself has very little variation this is going to be a desirable feature of a quality management system, quality improvement system, so this is also, something that they must really ensure before you go Into your measurement in your measurement measure step in the DMAIC process.

Then of course, comes analysis, analysis basically looks at the root causes it looks at establishing process capability, so you really know how good or bad your existing process is I mentioned CPK that is like one of the key measures of how good or bad your process is, then you define performance objective, what what targets do you want to meet, what what kind of capabilities do you want to deliver, what kind of quality do you want to deliver, what level of customer satisfaction do you wish to achieve, what are your competition comparing the others, what are they offering to you this is something we got to be able to do.

Identify the source of the variation this also will be done by you and this will be done using the cause and effect diagram and doing your brain storming this is very, very important because, in order to do your improvement you are going to play with these parameters and these parameters must be there or three four, five, six any of them, they may be there, you may have to go up to each one of them, you may have to do the do the design of experiments designed experiments to be able to see you have identified factors you know exactly where they need to be set reset rather, to be able to deliver the optimum performance this is something that we will have to do.

Then of course, you got the improved stage which is when you scream the potential causes, you do not work with thirty five causes, you work with four or five or six and these seem to be the most promising ones and there are ways to do it one is of course, the orthogonal array experiment which is done with large number of factors, but a very sketchy type of a matrix type of system, where you did. Basically try to screen out factors that are really do not have much of an impact on quality and the ones you would retain are the ones that have got a lot of lot of impact on quality, that is something that is done at this screening level then of course, you will discover variable relationship you must have this cause and effect relationship.

So, I have that I had that effect here in this diagram, remember this diagram that I have there there is some quality problem there, quality is missing there, I have to link that to these factors I have to link that to these factors; today that is unknown through your investigation you will actually find out is quality affected by factor C, is it affected by factor D or it is not affected by B or A, then I need not worry about A and B, I need to then work with C and D and I need to find the optimal settings for C and D in order for this Q to go exactly where it should be.

Which is like to to take this to tau, I really have to drive this Q to tau the target, the target this is the point where the customer is happiest that is what I like to do, I would like to be able to do and that could be done by controlling these two factors, these are the factors which are the culprits of it. So I have to adjust this I have to adjust this once I have discovered the best settings for C and D, I have to make sure that the client uses those settings and for that I have got to have this controlled step and the controlled step basically says again please validate your measurement system.

Make sure measurement errors do not clutter up things and then of course, what I will be doing is I will be determining process capability this could be under the new conditions and you implement process controls you got to make sure that, the right value is for D should be D star and the right value of C which could be C star these are the ones that the plant uses routinely and this is a function, that you have to do as a as as someone who is in charge of sustained results from that six sigma project there.

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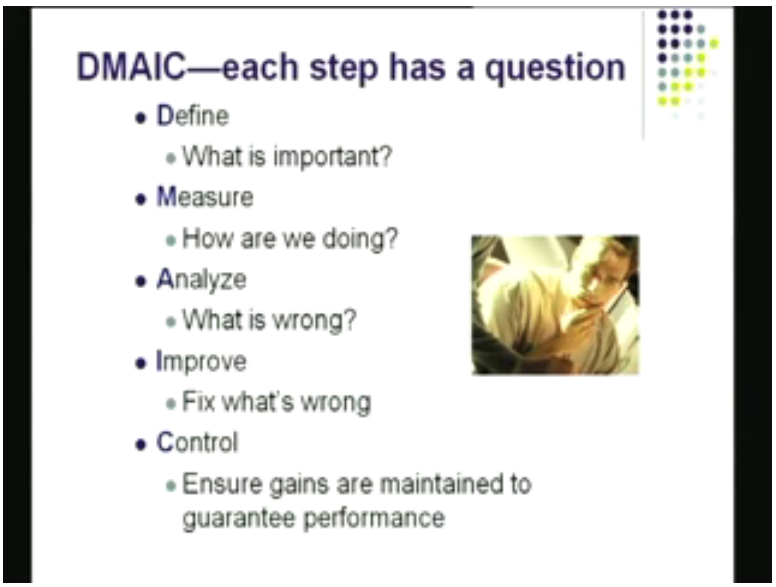

Again under DMAIC basically what you are doing is whenever you you are doing DMAIC at each step you are asking some critical question.

Let us, recall those questions again define says what is important? What is important to me? What is important to the business? What is important to the customers after all, measure says how we doing something is important, but how we doing what is our performance like this is where the process capability would come handy analyze try to find out what is wrong and this would require if use of the cause and effect diagram use of the fish bone chart and so on, so forth; to try to make sure you at least get the tentative list of factors that you will be playing with.

Then of course, fix what is wrong which means discover the relationship, between the input factor and the output, which is your quality? Which is the quality you desire? What kind of the relationship if you understand this relationship very well you would be able to set the input factors like I set here C and D, I set them at D star C star, those would be

the right settings to deliver my quality at tau this this would by my goal. So at fix what is wrong in the improved stage and in the control stage I want to make sure those C star and D star values they are sustained in routine production in the plant and that would be done to ensure gains are maintained to guarantee performance so that the customer stays happy.

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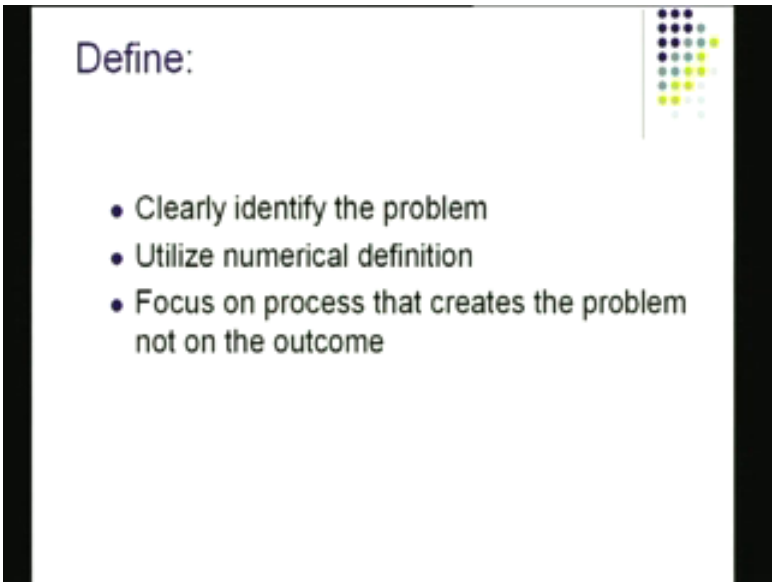

Let us look into define step a little bit clearly identify the problem, this is going to be very very helpful once you are into this define stage there utilize numerical information and make sure you quantify things to the extent it is possible, focus on processes that create the problem and not on the outcome, once you got the idea of the outcome then go into the problem itself get deeper into the problem.

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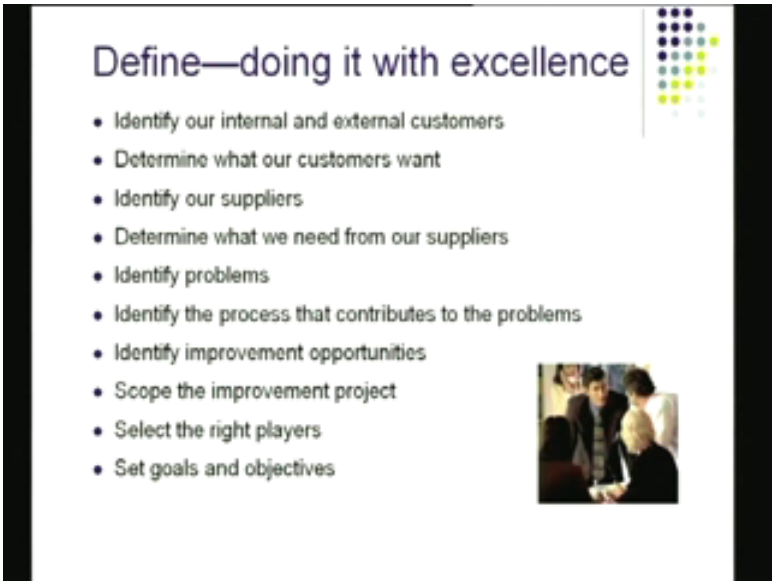

So, how do I do it with excellence? How do I do this define step with some excellence? Let us try to take a look at it, identify the internal external customer, because they are the requirements, determine what are customer wants, identify the supplies, determine what is needed from our suppliers, identify problems that may be there from suppliers themselves or the way we handle our material, once it gets in or the way it is mounted on the machine and so on, so forth.

So, those things would be rare identify process conditions, that contribute to problem this is like something you know perhaps when humidity is high, temperature is high or speed is too high or something like that I have problems. So when conditions are justified I have problems or when the workers tired I have problems or whatever it is or when the supplier is switches switch from A to B I have problems and so on, so forth.

So this is something that I will have to probably find out, identify improvement opportunities and this can be done once you have a general knowledge of the process and you are interacting with the people who are day in and day out with the process you will be able identify a lot of improvement opportunities with people there, these still stay in your mind tentatively as hypothesis these are guesses you will have to verify that as you go through the six sigma process.

You will be able to verify these improvement ideas, scope the improvement project that means you try to get some idea of how much improvement you can possibly achieve

which can be done by either looking at a benchmark or doing some trial and error type of thing, with that you will get an idea of what sort of leverage is there, what sort of room is there for you to improve, select the right players, these are the players who should be working that will be working on your team these are your team members for the six sigma project and of course, then you will set some stretched goals and objectives all this will have to be done at the define stage if you are doing it right you would really not have much of the problem.

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Measure the next step, the first thing is benchmark your process, you make sure you understand the capability of your process, you focus on CTQ these are quality characteristics that are critical to the customer.

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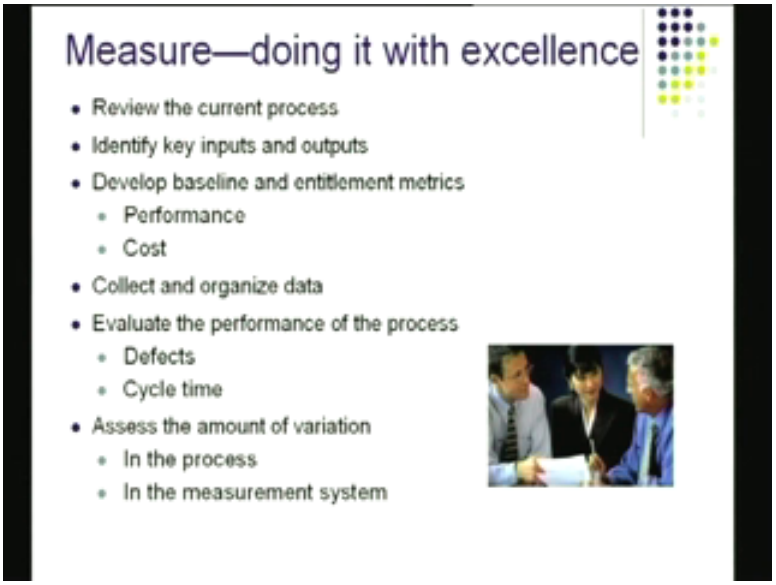

And how do you do this, how do you do these three steps really, really well, review the current process this is something that you will have to do by doing some flowcharting and so on.

Identify the key inputs and outputs this also is something that you will have to do without too much delay, develop baseline and the entitlement metrics this is like for performance and cost, there are certain entitlement metrics these basically say that unless I have this base line achieved or reached I will really not have business collect or organize data this also you will be doing under measurement and you could to do for example, one example is you could plot a histogram of the (( )) performance, that is something that could give you a lot of information if you produce a histogram of the output of the process.

Collect and organize data this is what we do there, evaluate the performance of the process look at defects, number one count of defects or fraction of defects or percent of defects that you produce routinely as there is and also take a look at your cycle time, because you know six sigma not only looks at reduction of defects, it also look looks at reduction of loses and one big loss could be production loss, because your times taken are far longer than they need to be.

Then of course, you assess the amount of variation this could be done variation could be in the process or it could be in measurement system both of these have to be as certain

unless you have done this of course, you stay confused forever you would not really know, whether your data is good enough to go into analysis or is it going to be something that is already at a high level.

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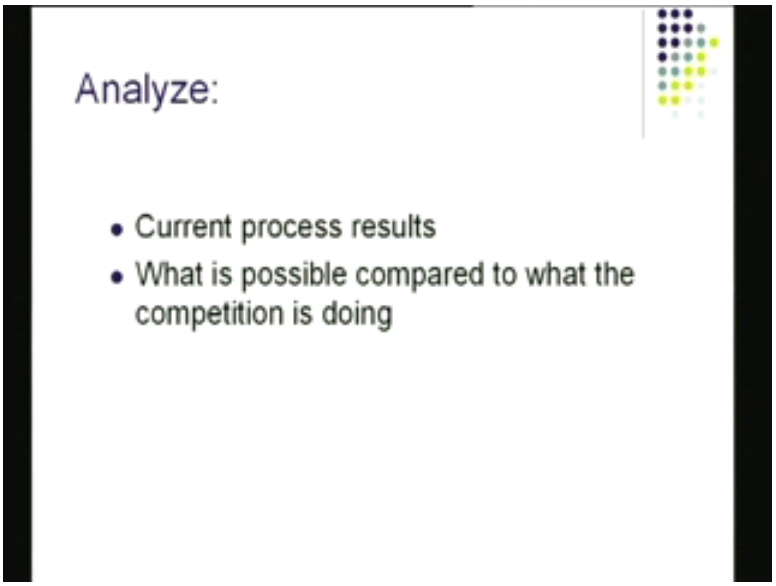

Pretty pretty accurate level or precise level to really not give a much trouble at all, this is something I would just adjust the mike for a second yes it is back and it is on my collar no problem there. Now, the analysis would be on the current process and analysis also will try to give in idea of compare your performance to what the competition is doing that will give an idea of the gap that is there.

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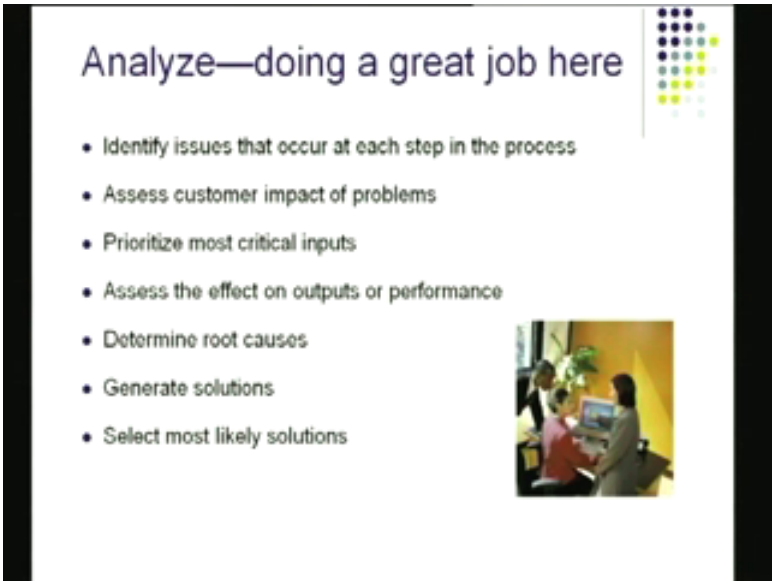

You do these things very well if you follow these steps which are listed out here identify issues that occur at each step of the process it shows me these are the problems that might occur people may talk about them, what are those issues? Assess customer impact of problems try to find out an idea get some idea of, what is if I ship out something that is defective? What is the impact of that on the customer and that could be just a next stage of production.

The customer need not be the guy who is standing outside with the wallet in his hand it could also be someone who is just a next stage of production it could be next person in the production line, that next work station for example, what is the impact what is the impact of my poor quality on them that is also, something that we would like to be able to do prioritize most of the critical input you make sure you you really start start with the big ones that have a lot of lot of impact.

First are those that probably do not have a much of an impact, assess the effects of the output on performance this is also something that we will have to get some idea of, determine root causes and for this I will be using the cause and effect diagram generate solutions these might come, once I have got the cause and effect diagram ready there a lot of ideas will start generating, will producing because, after analysis I will be moving into improvement.

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And select the most likely solution; I enter improvement which is like implement changes this is like after I discover the optimum settings, I have to be creative in these ideas to find new ways for doing things.

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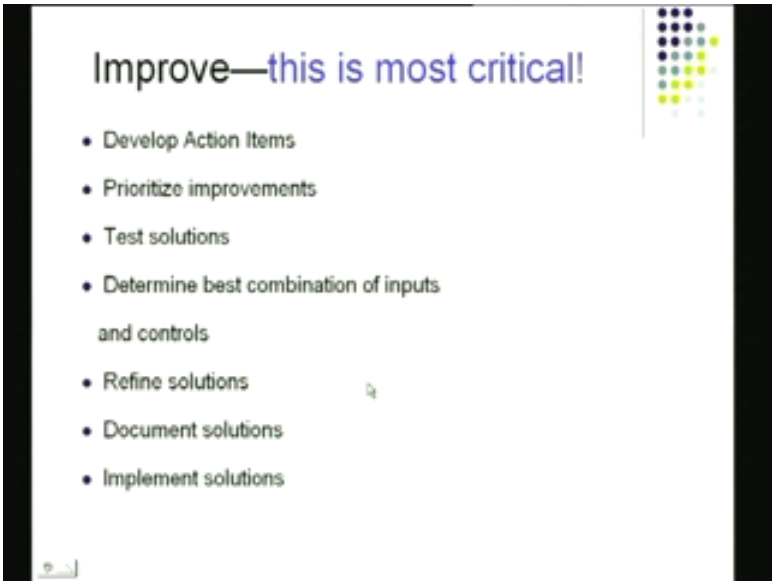

And how do I do these things properly develop action items what are the things on which I will be working prioritize the improvements, test the solution, this would be done most likely this would be done using some statistical methods. Determine the best combination of inputs and this would be done again by design of experiments and

controls refine the solutions and that could do again by design design of experiments DOE.

Document the solution implement the solution, I will tell you this that by far the training that the black belt people received those are most effective and useful at this stage the stage of improvement, because this is where you will be using a fare amount of statistical methods. Try to make sure you make an impact on the process, the process will be pretty complex and just by if you had told to me solve by common sense, then it would have been solved long time back, but because it cannot be done that way people have to resource to methods like such as design of experiments.

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The last part of course, is the locking in the success that you have and you demonstrated some good good levels of the process variables for the process variables and you got to implement measures that, you want to make sure that variables stay within the new operating level.

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How do I do them? Well, measure progress to make sure that you know have you if you bring in those changes they are actually produce some outcome, capture the and quantify benefits of the process improvement document the project this would provide the motivation for doing more six sigma projects, communicate to the wider organization what all things you have learnt. Because, so that other people can learn from this recognize the team's effort you got to make sure you provide incentives for those people, those who worked hard to make sure the success was there, monitor and manage the whole gauge whatever you have gained, make sure you are monitor them.

When the production when production starts on the routine bases when that thing is resumed, you got to make sure that you monitor that the the the output of the process there and you also got to make sure it holds there and of course, you try to adjust for continuous improvement this this is what we borrowed from total quality management; so there is some little TQM that is moving in here as you can see from this picture.

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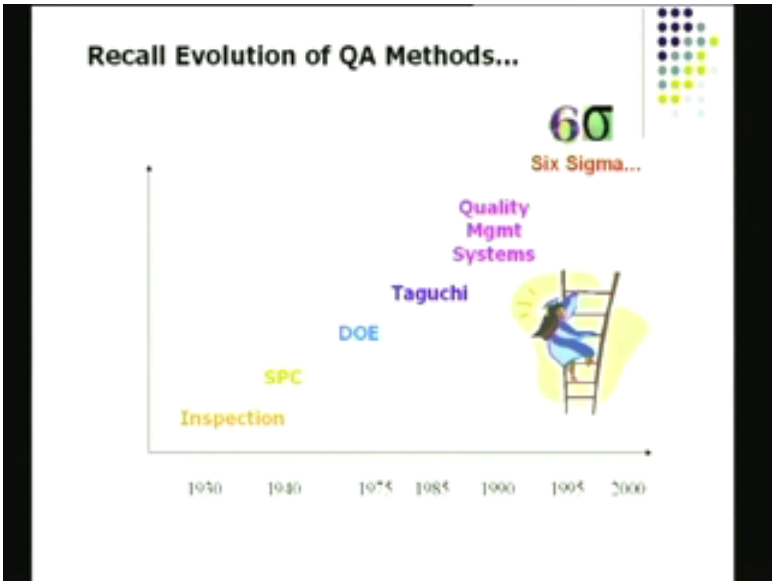

That I have here we come a long way we started with the inspection. Inspection was the first step when I checked quality only by checking or by inspecting the item that is all I did, all I could do at this stage was to sort items between good and bad that is all.

When people realized that they had to control the input which is like they have to control the process that produce those products and they got into this idea of process control which is uses the feedback root, data analyze statistic will become the feedback and that is what is used to try to keep the process in control and we use control charts and all these. Design of experiments was the next step in in this march towards perfection and that actually a basically is a tool by which you can identify it is a procedure by which you identify which factors cause the maximum impact on the output on that quality there.

Taguchi methods are ways to produce great designs and robust designs and keep production on target then of course, you have got quality management system these are required to make sure you have an overall management system to guide it all, because if you have this overall management system only then, the good processes will stay in place this is something that is part and partial of this.

You remember we did ISO 9000 some years back, about 20 years back we did ISO 9000, the goal really was to put a house in order that was the mission in ISO 9000, then of course, many other people they have felt that ISO 9000 was not sufficient and the automotive people they came along with the system called QS 9000 which brought in a

few statistical methods also including SPC also it is part of the routine, so not only your house would be in order, but also your processes will be in control.

Then of course, later on total quality management came along and that has those those five steps if you remember, top management direct involvement, strong customer orientation, systematic methods used for problem solving, everyone is involved and the theme is continuous improvement, these are the things that these are the things that that TQM pushes unfortunate the only thing that is missing in making sure the companies go with the the the the TQM approach is that the incentives for doing TQM are not very clear, reflected no point in t q m- no place in TQM even if you quantify the cost of quality, cost of poor quality you try to quantify as part and partial of in TQM program. You really do not work out something like that the six sigma does, six sigma basically launches every quality improvement project by first identifying the incentives for doing that project and it works out a it projects an ROI for doing that project and then, after the project is completed it verifies that yes the ROI it is have been achieved.

So, there is a direct dollar incentive for a management to support TQM six sigma project, which was missing in TQM; TQM basically told you a lot of things, that you should do and you had to take it on faith that these would be good for the company, but again managers because they could not see dollars in it directly, they did not see the dollar main effects they were indirect, but the dollar benefits was not were not visible under TQM program, six sigma took over and six sigma basically make sure, that every quality improvement that you start the very starting point would be quantification of the incentives for doing those projects.

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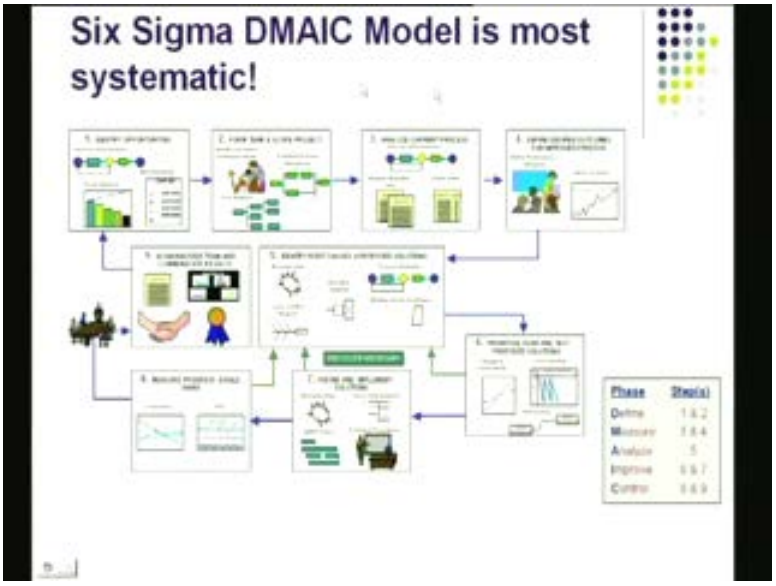

Six sigma DMAIC model is very systematic you identify the opportunities you do certain things there you form a team and scope the project, so you clarify there who will work on what what kind of expertise you sort of begin and what could be included in the project, what is not been included in the project, you will be analyzing project by doing competitive analysis and number of other things including including various tools which are there summarizing data and so on, so forth; to try to understand the you get a good idea of what the process is doing, now you define the desired outcome this is also part and parcel of doing good DMAIC.

Then of course, go after root causes you would try to work with the cause and effect diagram and number of other ideas, such as brain storming and flowcharting and so on, so forth. To try to understand you are in the phi you pin point the root causes, then of course, at this point you prioritize the plan and try to do design of experiments and you discover what we call the factor effects.

The factors effects are done right here, if you are you might remember and you can actually go back and revise and and view the view the lectures on design of experiments one more time, that will tell you which factors are important, which factors are not important and the factors that are important in the in delivering quality what should be their optimum settings, these are discovered by doing DOE design of experiments.

Then of course, you will refine and implement the solution and you will put down some monitoring device such as, control charts and so on, so that you basically keep keep an eye on how the process is doing after you gone through it all and of course, hopefully you would be making more money, you would be getting awards and so on, so forth; so it is a pretty systematic process, six sigma direct us up to the very systematic process.

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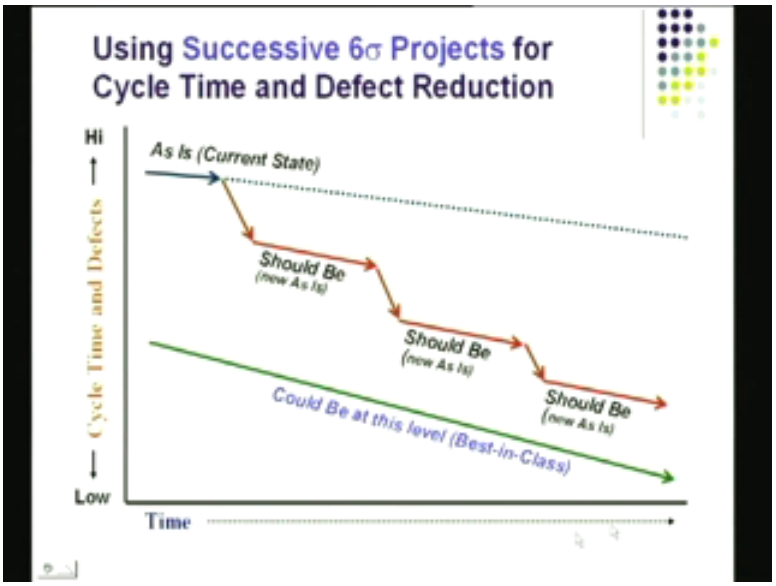

And as far as as far as DMAIC, the impact of DMAIC is concerned you look at cycle times, so you look at look at defects, this is the low end of cycle time, that is like small cycle times and low defects, this is the high end of it. If you start here and if you keep doing six sigma projects, your march is going to be like this and you could actually reach the level eventually if you put enough effort into it, that will be in class perhaps, best in world.

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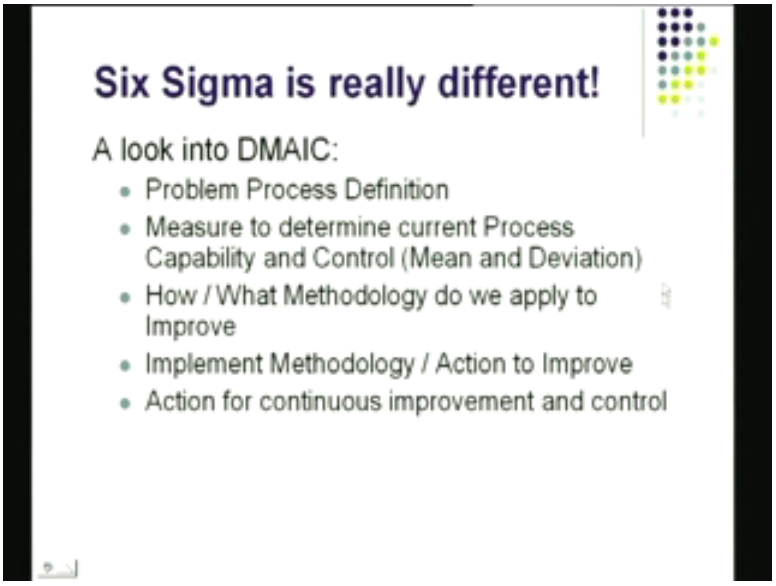

Six sigma therefore, is really really different, it is very different from the traditional way of trying to manage quality, trying to monitor quality and trying to improve quality, it is said it begins with the problem and a process definition, it uses measurements, it uses a systematic methodology which has been proven out it influence that methodology to make sure actions are there to try to improve this, it incorporates continuous improvement and also it very much looks for to control.

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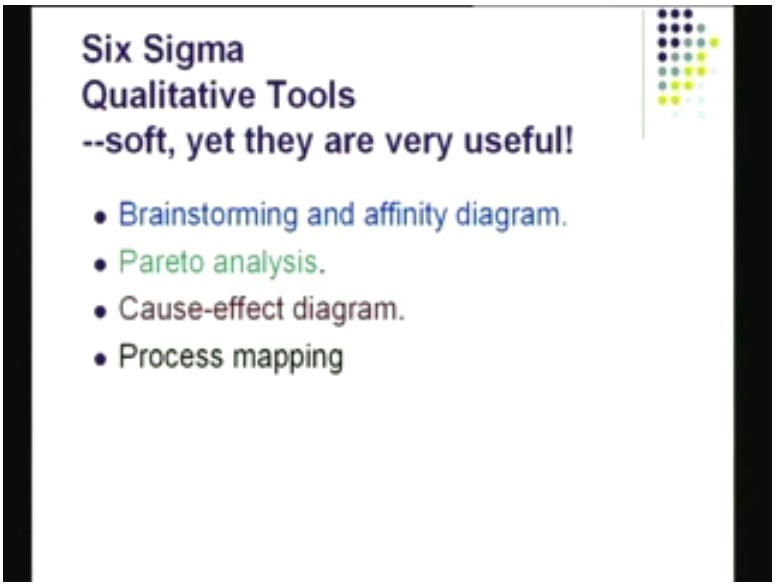

What are some of qualitative tools used in used in six sigma, brainstorming and affinity diagram these are one pair to analysis, which tells you which things are important which things are probably important not so important, so you got if you got various types of customer complaints which are the ones that are more frequent first attack those.

Then of course, you got the cause and effect diagram that is a very, very important tool and I just cannot tell you how much I love this this little tool here, which again I am putting on this diagram here, on the on this paper; this is the cause and effect diagram and this basically helps me helps me to brainstorm look at the quality problem and try to speculate where, what different causes could have caused this then I can begin my then I can begin my march toward improvement.

Then of course, I have got process mapping which basically talks about, what are the different steps through which the process moves, the quantitative tools are many and I have listed out a few there, statistical testing which is a tester hypotheses when I comparing the output of a of a machine before and after reconditioning for example, or before and after a technology change or a tool change for example, you would like to be able to compare two two outputs and in fact, it could go like this, if I show it on a picture to you, that is an exciting process was like this this is some quality characteristics.

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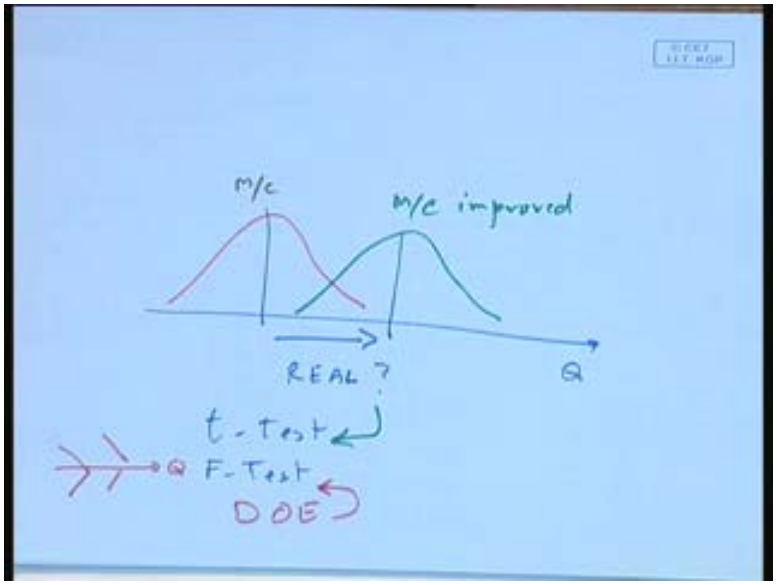

And the aimed process was like this and I improved the process and I have a new process, now which is like this, now what I am interested in knowing there is some

variation here, there is some variation here, what what I am interested in moving is Is this movement real, is this change real and this can be answered by for example, the t test in statistics.

So, it is a statistical test or of course, you could also do the f test, t test is used when you are trying to compare when you are trying to compare for example, machine output machine, this is machine, the old machine and this is machine, after the improvement has been made, so this is the machine improved and your mission is going to be hopefully this produced an impact is that real, that I can find by doing the t test.

And of course, if I have got a system that is affected by multiple factors for example, if I had to start with, if I had the old process with a little cause and effect diagram and many factors impacting quality, I can actually use this technique called DOE design of experiments and DOE uses the f test, so there are certain statistical tools, that are available to you to answer virtually any problem that might be there in regard to data or in regard to the output, that comes out of machine for example.

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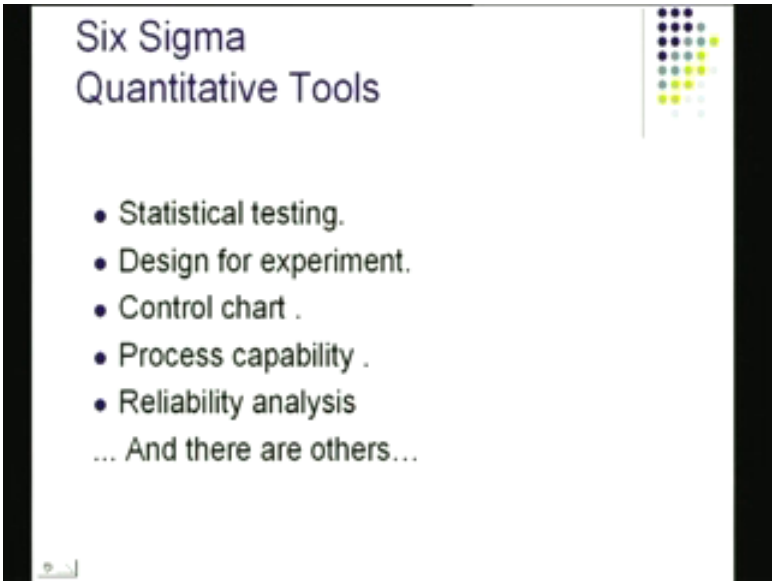

So, those methods are there, statistical testing is there, design of experiments is there and of course, control charts I am going to give you an example, there process capability is this basically tells you, what fraction of your output is acceptable to customers and indeed if you are you know quite if you really are running at quite quite a tight process;

then of course, you have got reliability analysis these are the different statistical tools, that are quantitative tools within six sigma.

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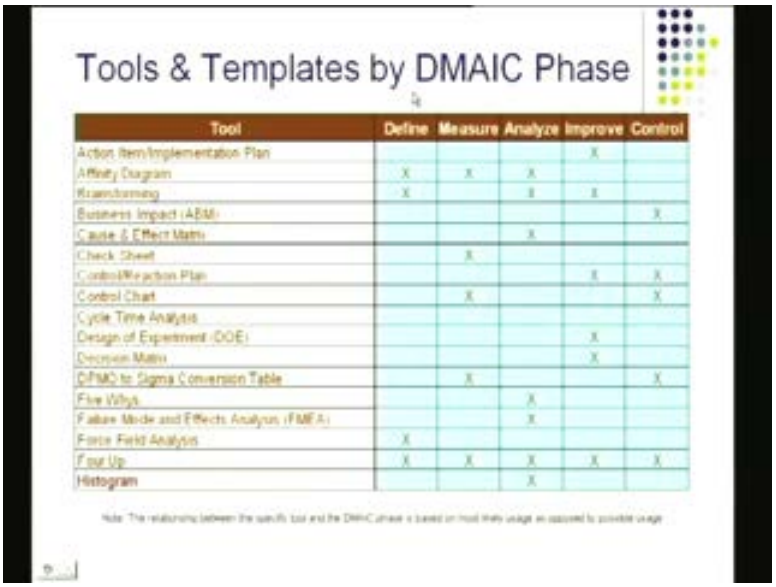

Tools and templates and I have given giving a slide here, which actually lists many different tools and it shows you the stages of DMAIC for those tools are used, so I have affinitive diagram, brainstorming and I have got force field analysis and four up, these are the ones which I used at the define stage. Let us go right to improvement then of course, I have got implementation plan, I have got brainstorming, I have got controls, I have got a basically, then I have got a design of experiments, I have got decision matrix, I have got a four up, these are the methods which are utilized.

These are the tools which I utilized in the improvement stage, we get controls, I have got the business impact, I have got control and reaction plan, I have got the control chart, these are going to be there and of course, they are going to be some of the methods also which are to be utilized here.

So basically, it is not true that, you use all the tools all the time, that is not true, there is an appropriate nest for each tools to be used at a solving stage and that is shown here.

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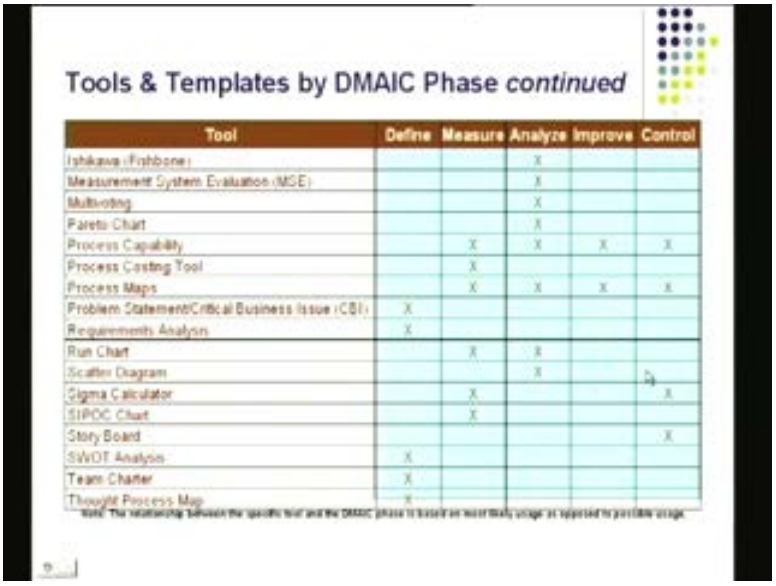

If you look at the DMAIC process, there are some more tools there for example, the Ishikawa diagram, measurement system analysis, motivating multi voting, this is also there then of course, pare to chart is there, process capability there, notice a lot of these really are focusing on analysis and as far as improvement is concerned I have got CPK process capability there, I have got process map, these are going to be utilized in improvement and control is fully utilized first for example, this six sigma calculated that could be there and the story about these are these are various different tools which you utilized at the stages which are shown here.

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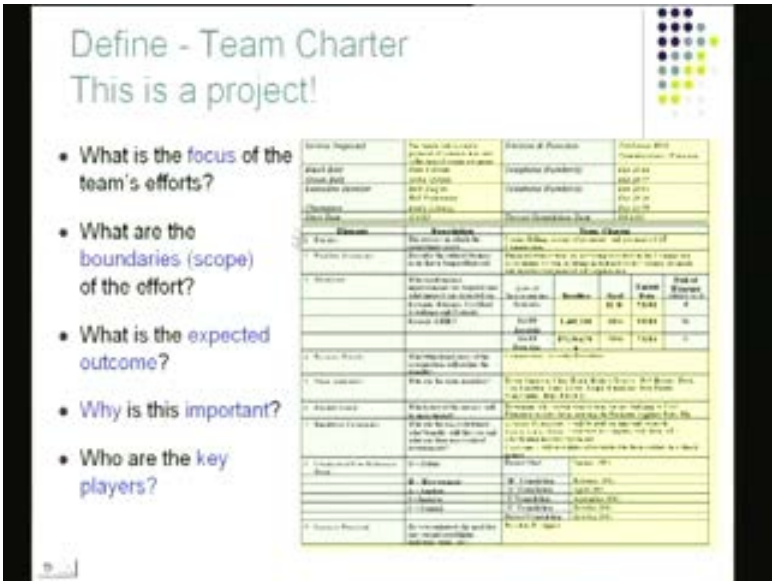

Now, the team charted how do you actually identify the charter, I have given an example basically, when you ask the question, what is the team's charter? It will identify what is going to be the focus of the thing, what are going to be the boundaries of the project that is like hopefully will, what will the project include? What will it not include? What are going to be the expected outcomes? And why this is important? What what what is going to drive the motivation for it and who are the key players? Will be providing the basically, the expertise for it and here is the work sheet and you can read this and you will get a pretty decent idea of how does one go about defining the team charter.

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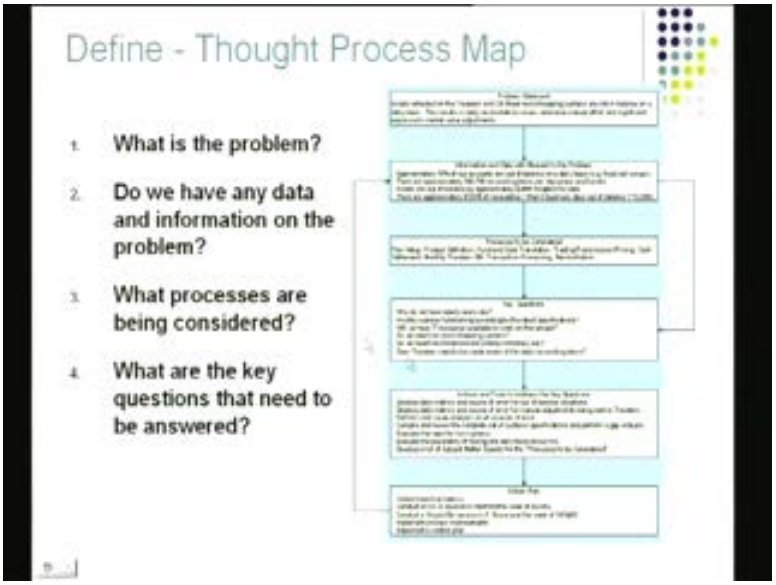

Then walking through the process, the thought process itself, when you are doing define is, what is the problem? Do you have any data information on the problem? Just think of this, think of being at the defined stage and you are asking these questions, what is the problem? We have any data or information to be able to say shut some light on the process.

What process is being considered? This also has to pin down and what is the key question that needs to be answered? These are queries, that you might like to answer and here is a here is a way to lead your path lead your path in the define process.

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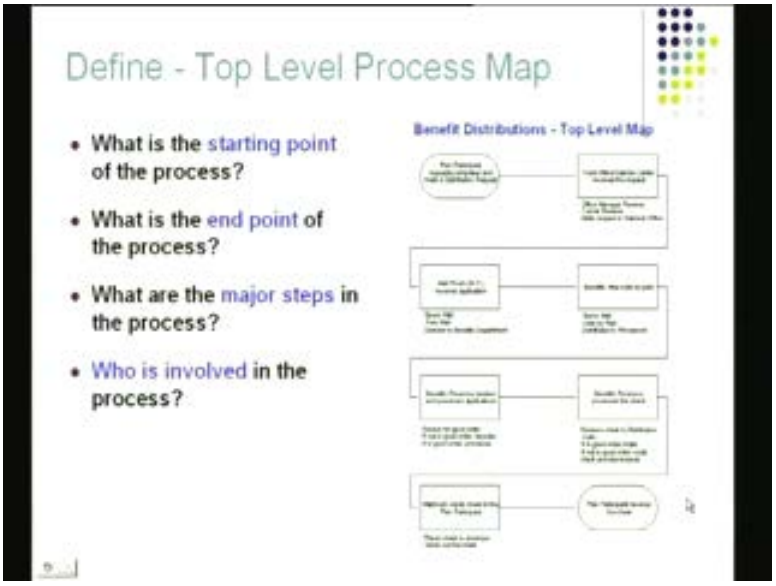

You could start with the top level process you will have a starting point and end point unless some major points in the process map, there is a top level process map.

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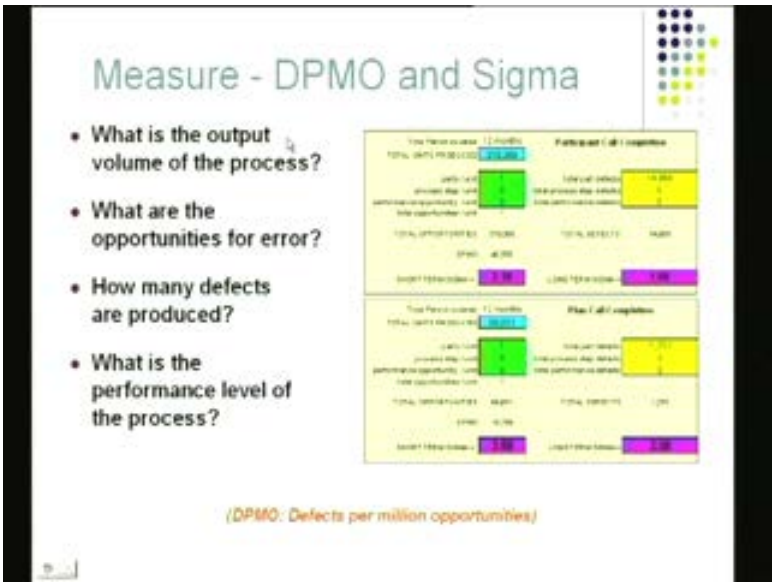

Then of course, you will have to measure things, so what is the output what is the output volume of the process? What are the opportunities for error? Because I have to I have got to come up with a DPMO's I have got to know, so many parts, so many defective parts per million opportunities, so I have got to have an idea of that, how many defects are being produced and what is the performance level of the process? Under the DPMO

measure and that is shown in the calculation which I am showing on the right hand side of the block.

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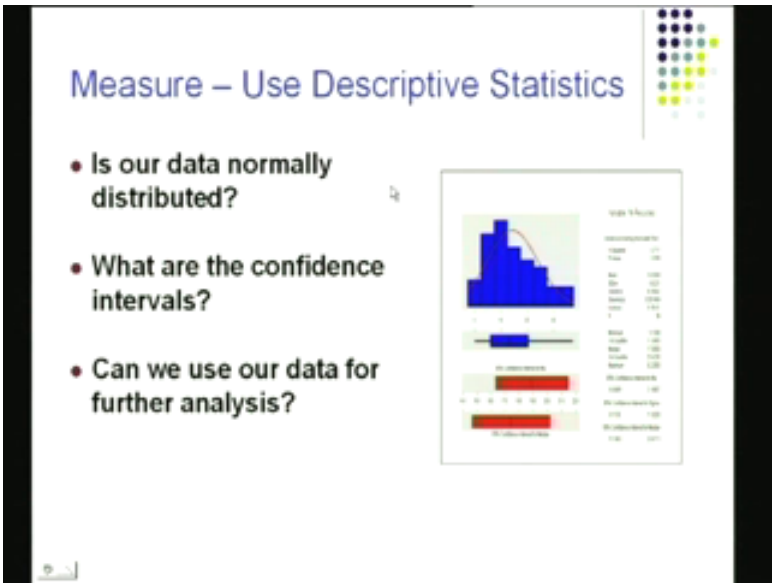

Measurement of course, you can use descriptive statistics very well is the data normally distributed, that I can find out by drawing the drawing this histogram for it, what are the confidence intervals? And that also can be found at once I have got the data there, I can find out with 90 percent confidence what is the what can I say about the output coming out with 90 percent confidence and can I use the same data for further analysis? This will be these would be the various descriptive uses of the data.

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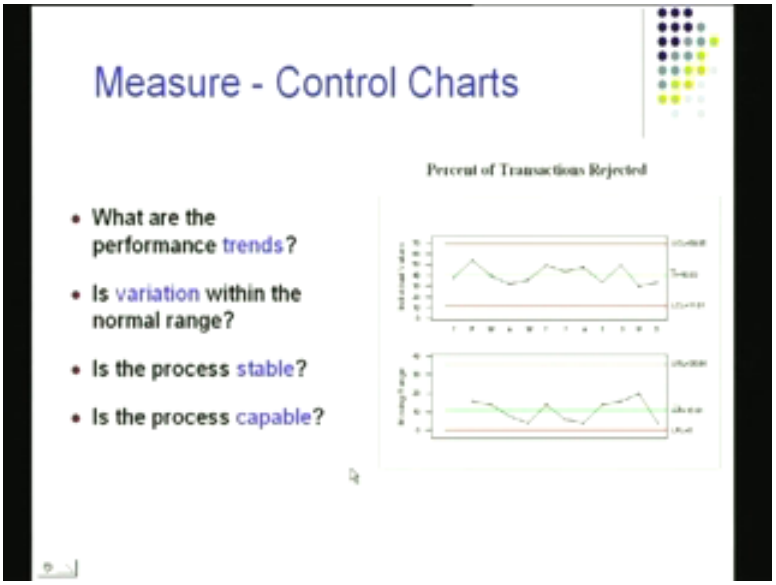

When I am doing control all I I would be using something, like I will be looking of a trends in the process, I will be looking for variations in the process, is the process stable is it stable and those can be had, those can be found out by looking at the control chart of the process.

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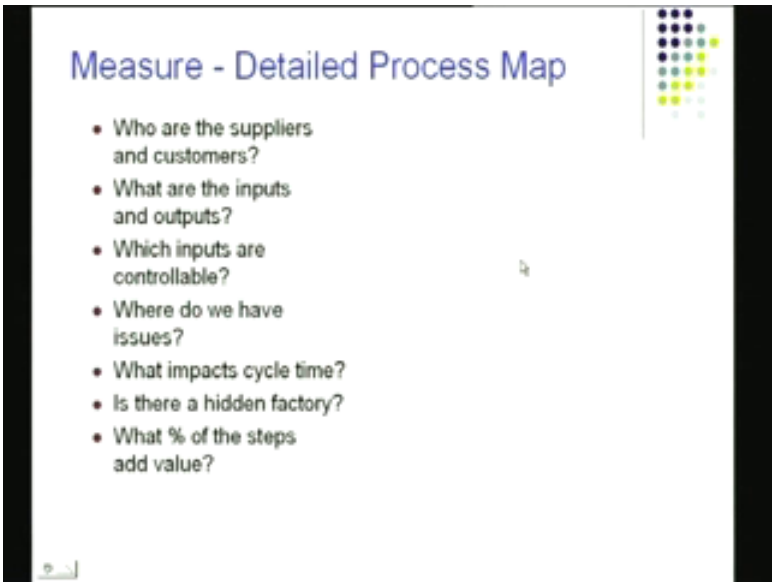

Measure of course, something in his very important, this I have got to map that process completely, so in fact, I will probably list out all the steps in the process and that would like this eventually I will end with a map like this.

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That basically you starts with the inputs goes till the process steps, when it comes out with an output and this, process stops right of the, starts right at the beginning and it winds itself, throughout the business process on the physically process of the system itself and it goes on and on and so on, so forth.

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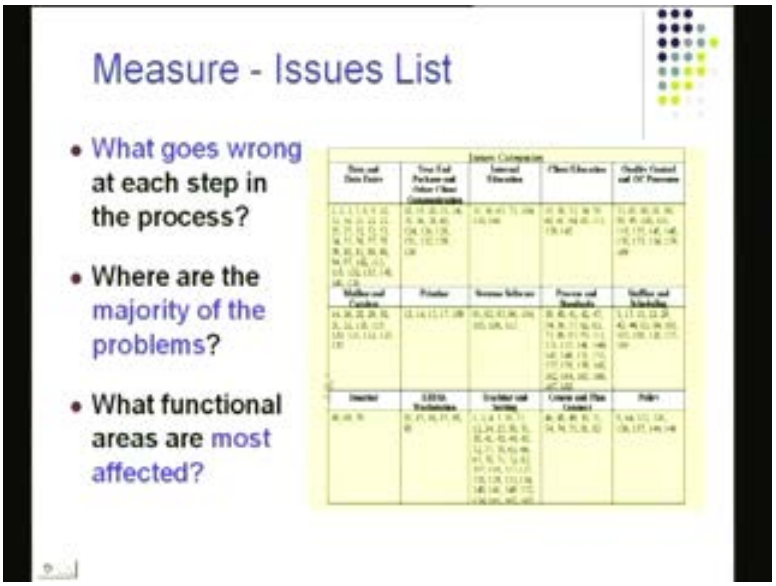

Measurement system would really look for, what goes wrong at each step of the process? this is very important, but these are the some of the things that you might have log books to look into, for you to be able to look into what are what are the majority of the

problems? This could be one done by pare to analysis, what functional areas are most affected? And these are the ones that will probably have a lot of work.

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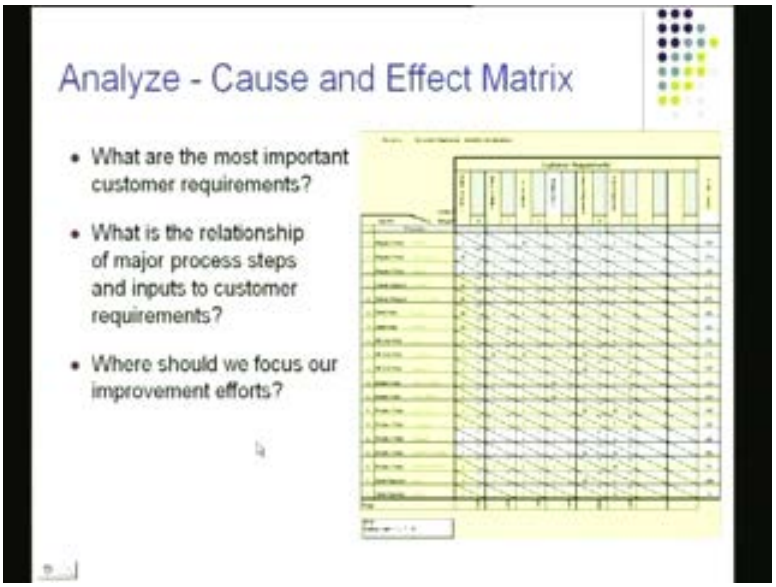

That is finding out because, quality is not moving very well, the cause and effect matrix and this of course, leads to our cause and effect diagram.

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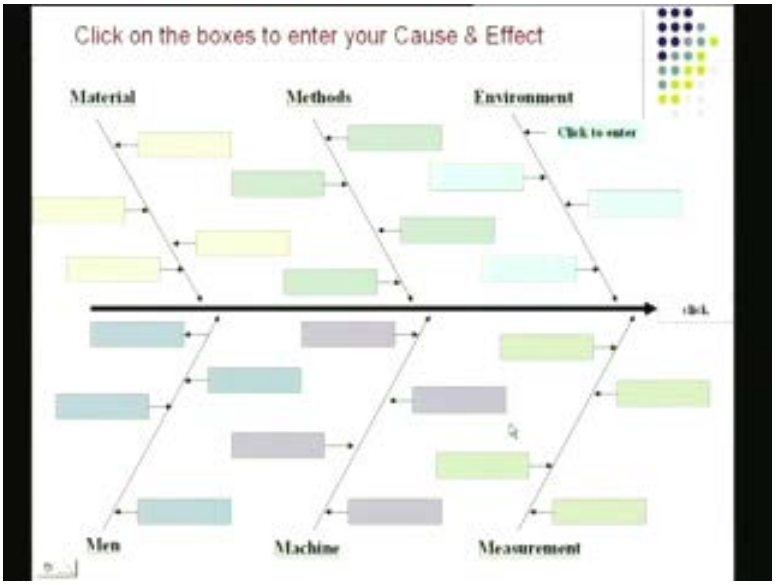

This Ishikawa diagram this is a very, very important tool.

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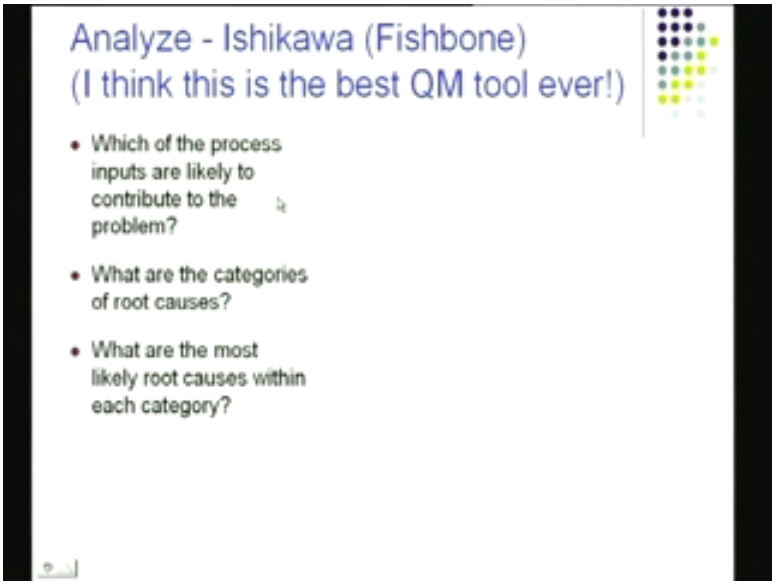

This actually indicates what processing inputs lead to the problem? What are the categories of these rules man machine you know materials and methods and so on, so forth; that is something that could be done and that can be done looking at a diagram like this and you can put down, the methods first put the these captions around, then start filling in factors in the environment factors in the method factor in a materials and so on, and you will end with capturing most of the things this is like an example.

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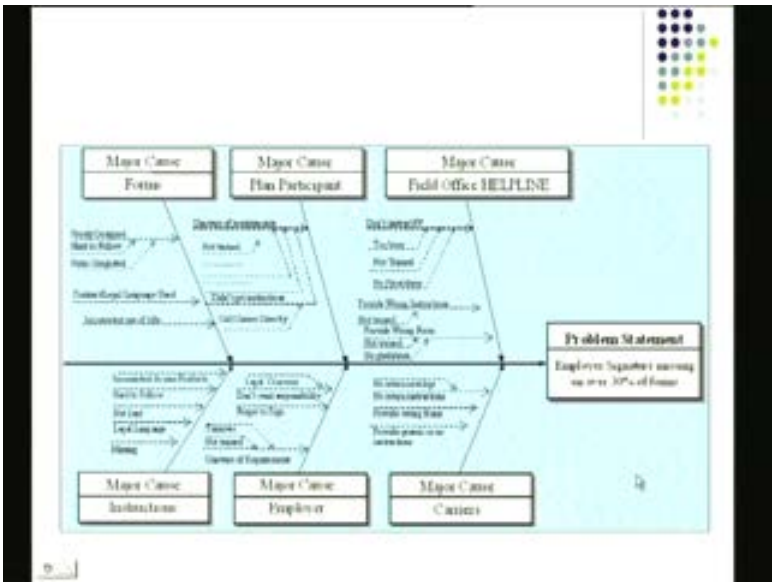

This Is like an example of you know real cause and effect diagram that is generated by someone who is try who is trying to analyze it particular problems.

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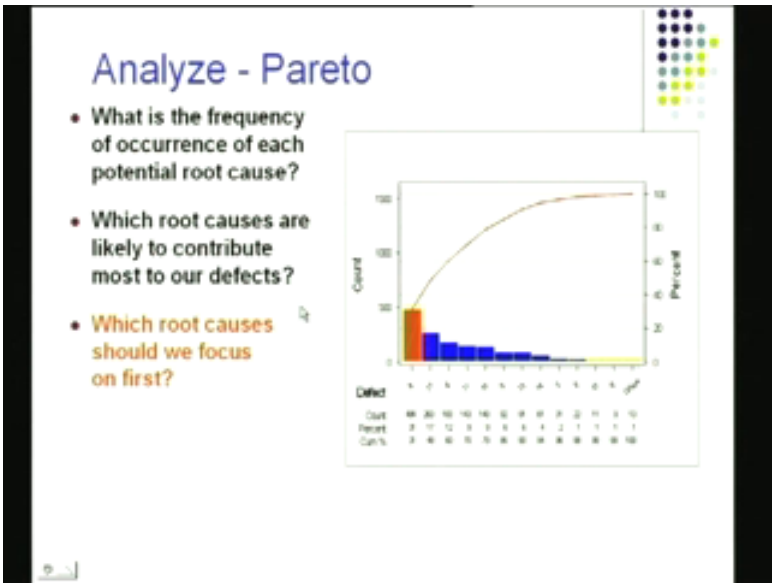

Analyzing analyses of data output data by Pareto, which route causes really should be focus on first, because then I look at the can the kind of defect, that I am looking at and look at the one that is most critical, that is someone, that is the most critical this can be had very easily once I do my analysis using a pare to chart.

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Then of course, there is a process for a FMEA.

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FMEA is away to try to predict how a process or a product may fail and FMEA is a very routine procedure, we spent one lecture on FMEA, so we would go back and review the FMEA process one more time to our aspects are looked at if there is a failure that is likely, how likely it is going to be, what is going to be consequence? What is going to be impact of it and what is going to the likely impact on the customer of that thing, this is done by the FMEA work sheet and once you have done, that you identify RPN the highest RPN that is the Risk Priority Number and that basically tells you this is the aspect of your design or the process, that need some action right away as quickly as you can.

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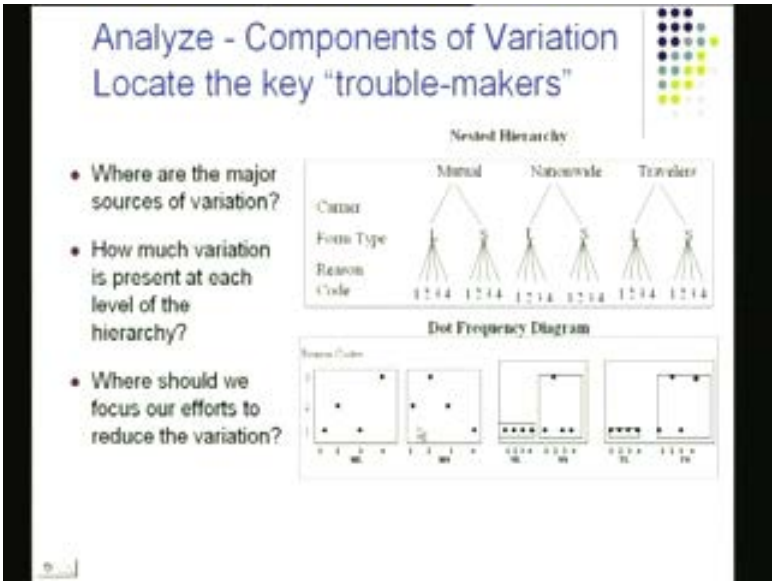

And there are other methods also which where where again you look at the sources are different variability's, this could be done by collecting data and you try to find out there are several sources, that could lead to that could lead to variation and where would these come from that can be done by doing, what we call look at the components of variation and looking at the key trouble make maker that can be done.

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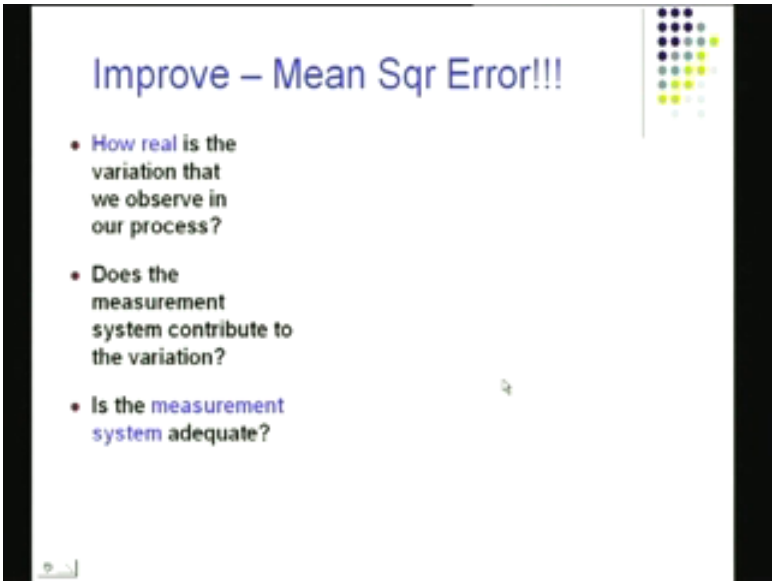

Improvement would be one one way to do that, would be to take a look at the mean square error this like very, very important and this is done at the with the measurement system you try to take a look at the measurement system itself.

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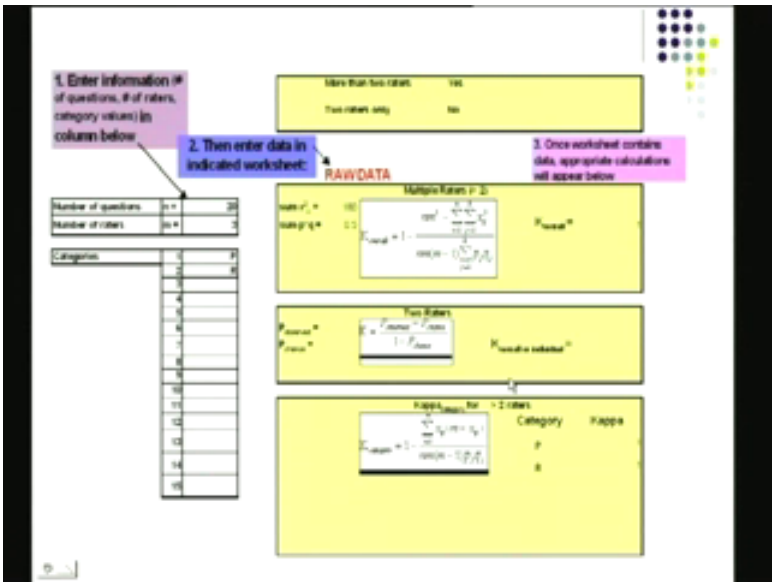

And there are certain procedures available I have given you the method for gauge RNR studies and those are the methods that are utilized to try to make sure your measurements system, has the capability to be able to do your do your do your basically to to enable you to conduct first first of all data collection, then measurement of the performance of the process as if is, then again at DOE or even after DOE ones you are doing controls then you you got collects some data, you got to be able to analyze those data. If the data are of poor quality then of course, everything goes out of the windows you got to make sure your measurement system is in good place, so do have gauge RNR as one of the key steps in your six sigma study.

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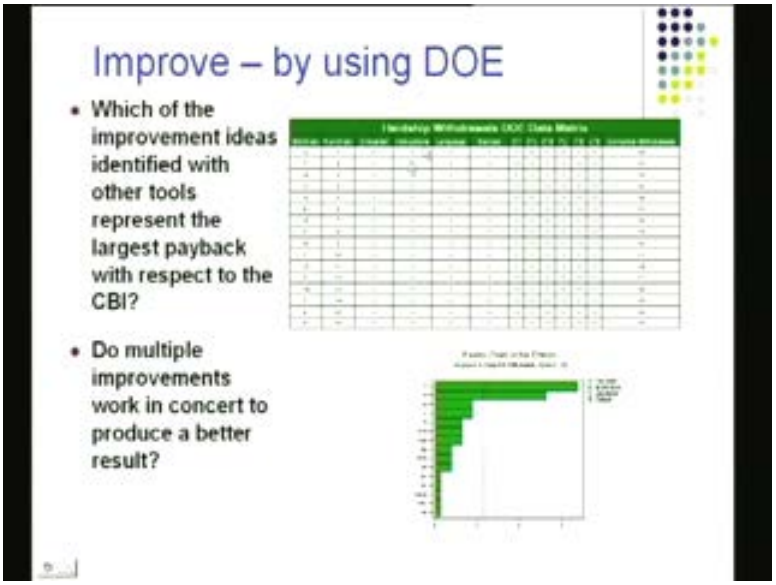

Improvement comes along by this dear friend of ours called design of experiment, which is a very discipline approach in which you vary multiple factors, you vary multiple factors together and you look at the output you look at the output of the factors, when you have manipulating these factors will look at the output look at the output and you analyze the output in a way, where you can find these factors effects you might remember some of the curves I showed you, where different factors they are led defend extents of impact.

We did that Nissan logo falling off problem, there again we plotted the impact the various things like glue, you know sticking strength on so on, so forth. The thickness start a form and so on, so forth; those things we looked at the idea was conduct your DOE and make sure identify the factors, that are causing most of the problems in the output, then you locate also the optimum setting for those factors. So in our case, it turned out glue really did not matter that much, but the addition area was a very important one as far as Nissan so logo mounting problem, was concerned.

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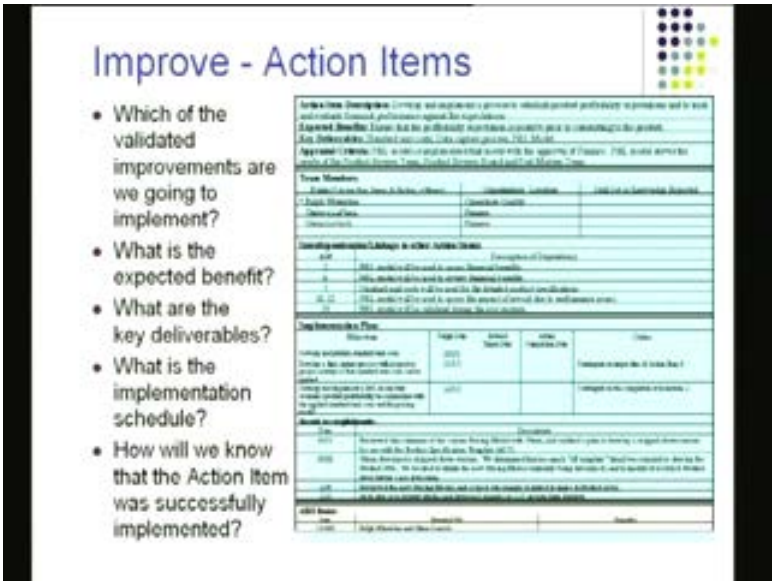

Improvement option of course, we will follow through DOE, because you identified the different factors that might of caused the problem, you should quantify some of the things, what are the expected benefits? What are the deliverables? What is the implementation schedule?

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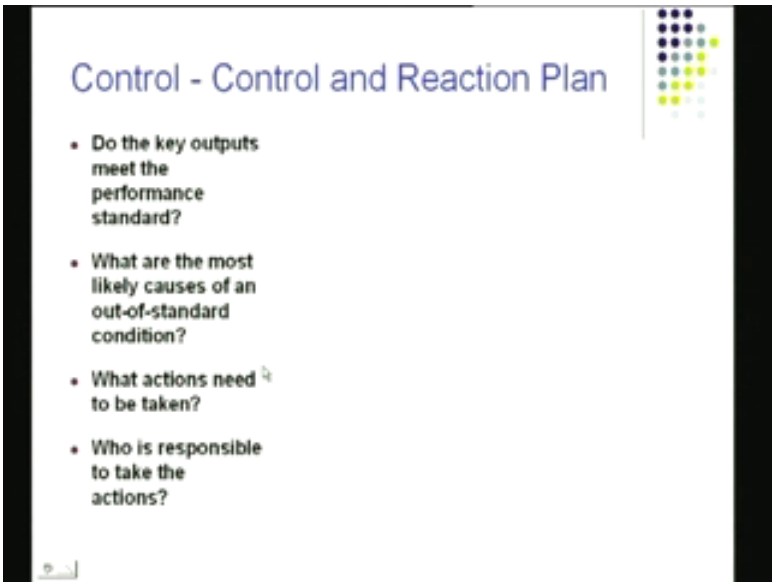

Once you got the new plan in place, you got to think of controlling things, do the key outputs, now this is like after the results do the key outputs meet performance standards, what are the most likely causes for an output, going out of standard? What actions are to

be taken? Who is going to be responsible? So, for example, when you put the control actions in place.

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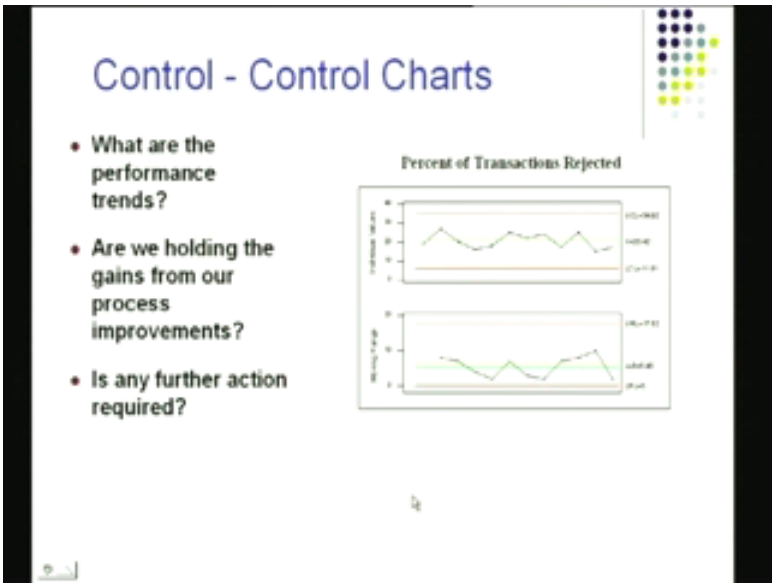

Where you got to control charts in place, you got to make sure you got to make sure the control actions restore the process in it is statistically controlled stage.

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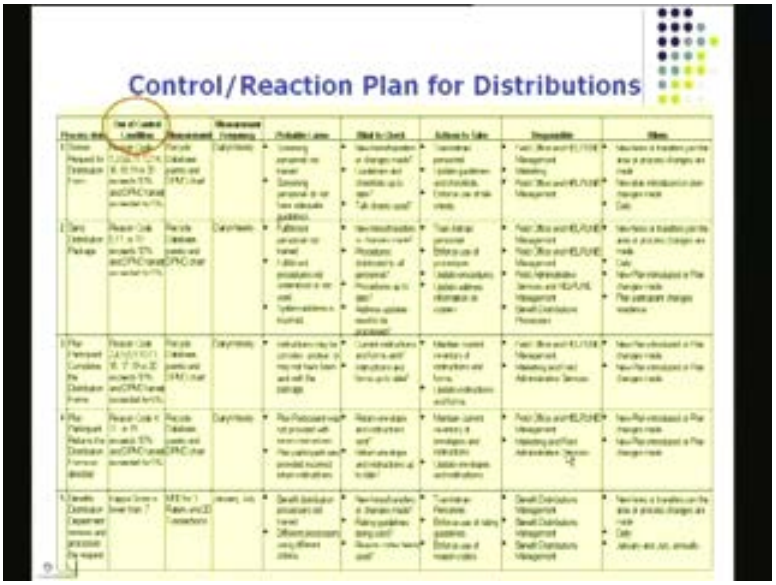

So control reaction plan is part and partial of.. the you have got to make sure, whenever we got a point out of control you bring out the reaction plan.

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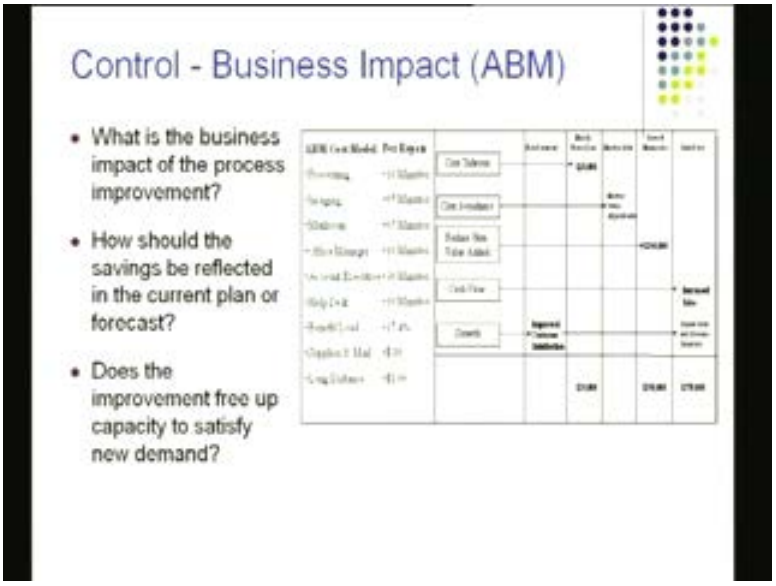

And it takes an action there, control action will also going to be looking at the business impact on your process there, so there are going to be some measures there that might include cost cost counts, cash flows growth impact on profits and so on, so forth.

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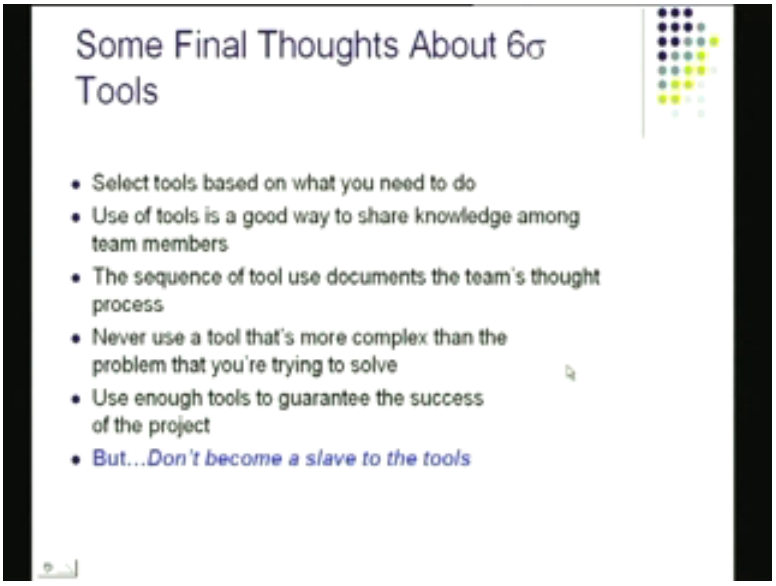

Some final thoughts were six sigma tools, because some other things that really one has to keep in mind.

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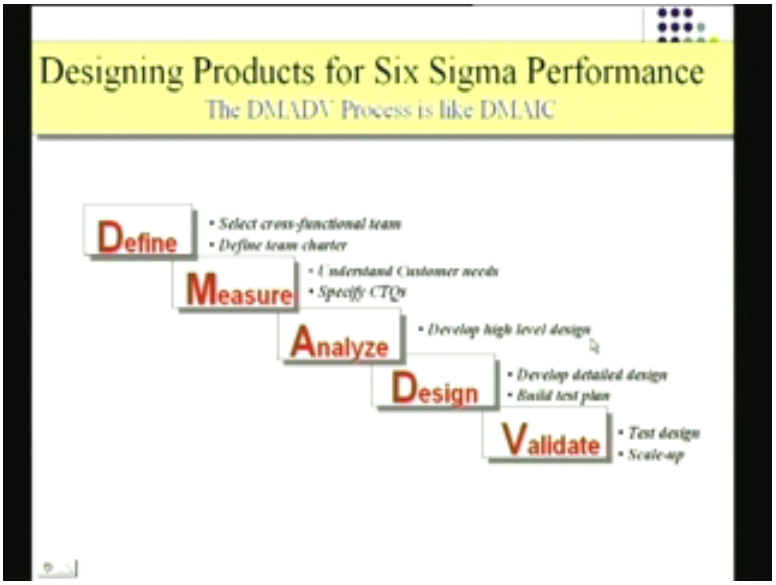

We got to make sure.

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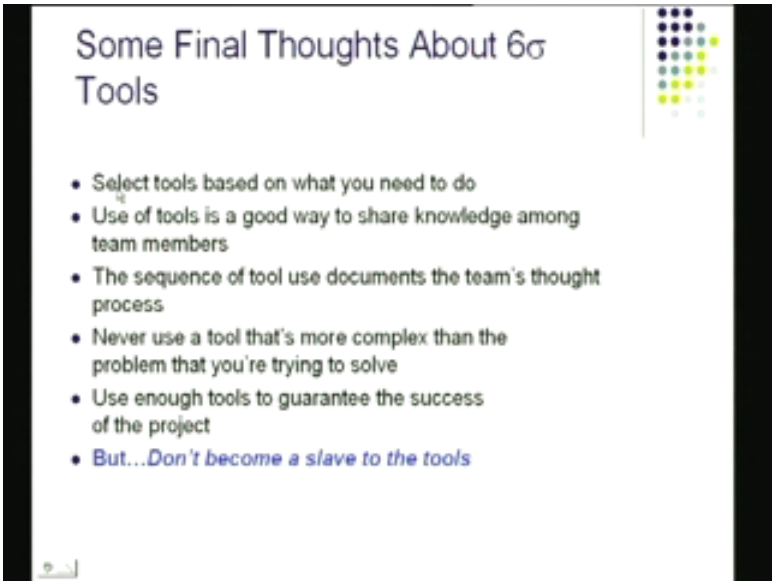

We select the tools based on what you want to do, we also use the tools in a good way to to make it becomes use of the tools is the good way to share knowledge among team members, sequence of tools use documents, if sequence of tools use documents of team thought process. So, if you using certain tools basically the sequence the tool you are you are using you are using DOE just to begin with you are doing a lot of data collection and so on, so forth. So you are using simpler tools, then you get the cause and effect diagram

and then you go to DOE; so If you show this use of the different tools there are actually becomes say great way to find out how the team progress into this.

So if you make a six sigma presentation, if you start off with a DOE people would have many many questions they would like to know, how do you really think of DOE to the best way so this is something you got to keep in mind, never use a tool there is more complex in the problem that you are trying to solve.

So, DOE is not obviously the answer when you can fix it in a in a many different ways and so do not become slave to your tool and of course, we got to make sure we have a method to design from products also to lead to the six sigma process and there again, we will using the define methods there, the last step define measure analyze design this is where it depart from the, because of it was a improvement we got design here and validate.

So we had improvement and control, now under design designing products for six sigma we got design and validation these are the step that walk in.

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And what is a design what is design for six sigma? What is DF DFSS? Which a customer driven process it is predicts design quality up front before you get into this it looks at CTQ's it looks utilizes cross functional capabilities, it drives quality measurement and predictability hand in hand, it utilizes process capability information to make sure the

designed decisions are right you are using the right process for the for the purpose and it monitors process variations, that is this is something there is done by design of experiment.

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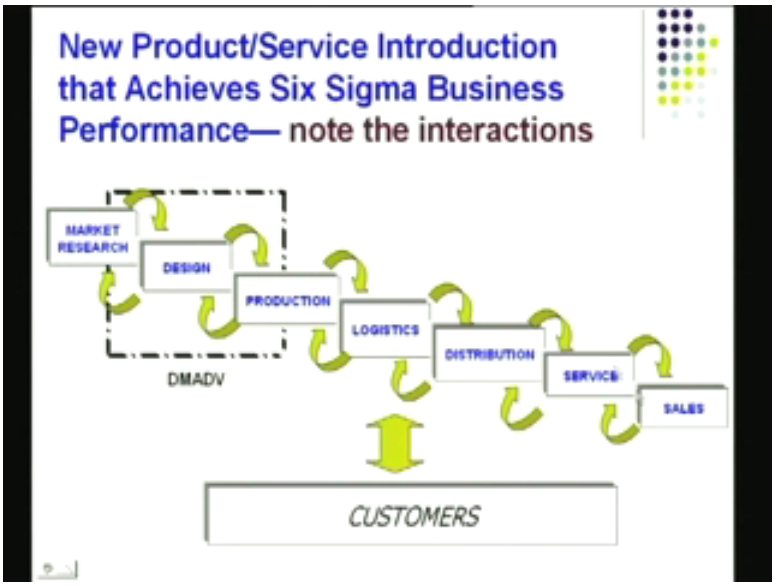

And basically if you are introducing new products you should be moving this way which is like you start with the market research, at that point improve at that point include QFD point in improve include the corner analysis, that will lead to requirements, that will lead to the design once you designed the product you lead to the it will it will lead to some decisions about the process, so you will move slowly into production.

Then of course, you will move into logistics to make sure the products get out to the customers location, then of course, you will have to worry about the distribution and of course, obtain delivered this going to be some service and same support these are going to be there and and please keep in mind six sigma is not focused on manufacturing only, it can also help in a big way as per as services are concerned.

And if you look at this total span of things, if you look at the total span of activities, you can take a look at any aspect of it and you can approach it using DMAIC, because there are many internal customers throughout and internal customers should be treated with the same respect as people who come back and pay you money and talking of money; let us make sure that we at some point in time will remember, then after all we had doing all these things to be able to eventually deliver some money to people.

So, you got the make sure you show them the really money there, that is what your after so your team should remember, that in the end you got to produce this extra money beyond what you produce under routine business, hope you enjoyed it thank you very much and good luck with six sigma.

Thank you.