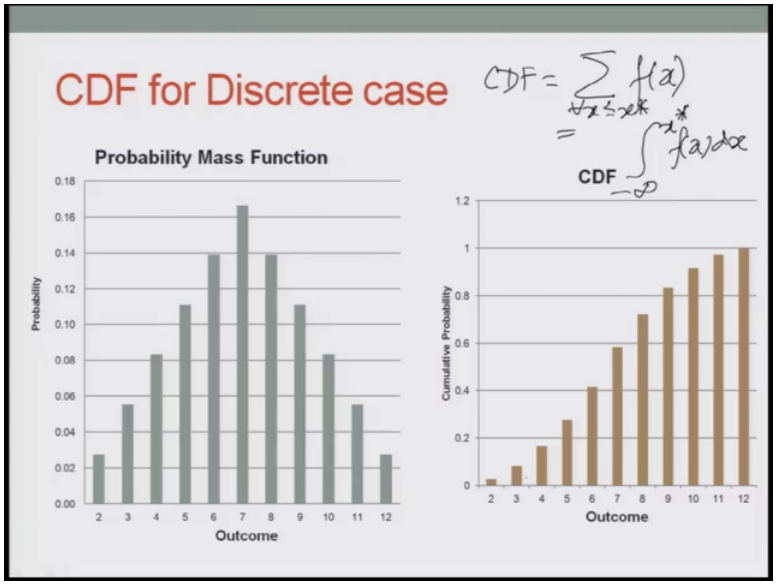
Total Quality Management - I
Prof. Raghunandan Sengupta
Department of Industrial and Management Engineering
Indian Institute of Technology, Kanpur

Lecture - 07
Six Sigma Overview

Very good morning, good afternoon, good evening my dear friends wherever you are; welcome back to this 7th lecture in Total Quality Management. As you know my I am Raghunandan Sengupta from IME department IIT, Kanpur. And this course of total quality management which is of 20 hours and 40 lectures each of half an hour. So, as you know that in the (Refer Time: 00:40) end of the sixth lecture, we were discussing about probability distribution functions, probability mass functions, density functions, and how normal distribution I did stress on normal distribution how it will be utilized and we will come in to the details more later on.

(Refer Slide Time: 01:13)



So, let us start with full energy in the seventh lecture. So, if you remember, we were discussing about probability mass functions, mass why the word is because number one the x are discrete. And if you remember I did mentioned to very distinct examples one being when you are basically tossing a coin or when you are rolling a die. So, the die are all faces can come up unbiased numbers are marked 1 to 6, or a, b, c, d whatever it is and the coin has a head or a tail or a black and white color based on that which you can do

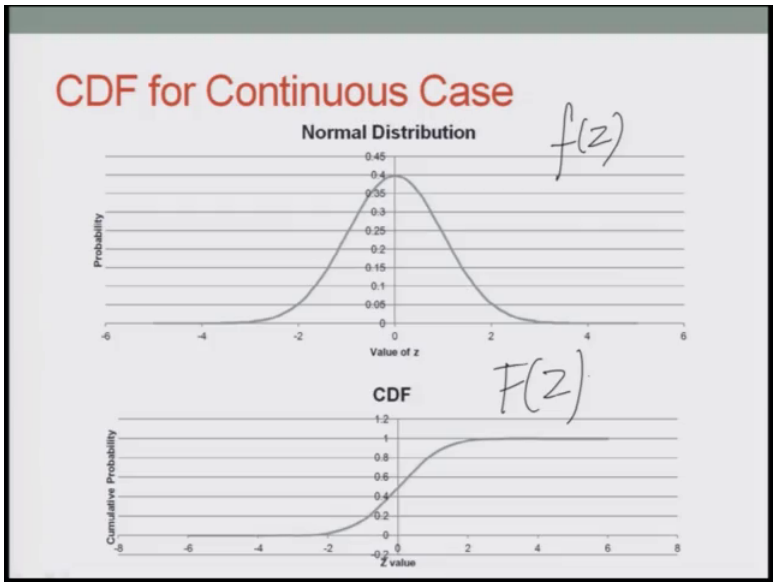
the experiment. And continuous can be where x is continuous within range; and for the normal distribution, it is from minus infinity to plus infinity other examples which can be considered at continuous for x being measuring the height, measuring the length of a tie rod and such examples.

Now another thing why it is mass function because the x discrete values are such that the probabilities are concentrated at those points. So, it is basically known as probability mass function. So, I have this in the left panel in the slide, I have basically the probability of mass function; it looks like a normal distribution as it should be the histogram is a normal distribution. And if I add up all the probabilities because we all know I will just highlight it very simply that the CDF, value which I am writing is equal to in the case if it is a discrete value, it will be the sum of all of f of x f of x means the probability mass function.

And the CDF and this would basically be for all x being less than equal to sum x star based on which you want to find out the CDF value. And in case if it is a continuous one it will be integrated from minus infinity considering this is the minimum value of x till the value of x star wherever you want to find out the CDF f of x d x. So, this is the probability density function and based on that you find out the CDF values.

So, on the right panel, you have basically the corresponding CDF of the probability mass functions. And if you notice it is basically sum of all the probabilities as you proceed from the left to the right. Left means the minus infinity value or the least value for the probability mass function.

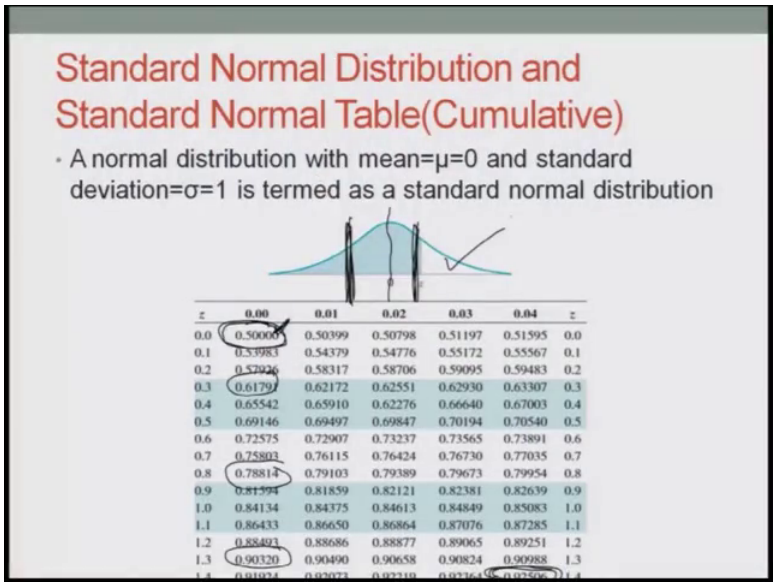
(Refer Slide Time: 03:42)



So, now if we come to the case of the normal distribution, which will be utilizing quite rigorously: so you have the z values, if you remember I did mentioned that for all the discussion all the of the normal distribution, we will be considering the standard normal deviate for which the mean median mode values are all zero, standard deviation or variance is basically one. And based on that we have we will see that we have the tables such that we can do the calculation accordingly. So, here in the top figure which is the normal distribution PDF, we have the x, z values along the x-axis and the corresponding probabilities being measured along the y-axis. So, this is the distribution which we have where I am basically covering my this pointer.

Now, you may see if the values decrease exponentially on to the left and decrease exponentially onto the right, but technically the values should be between minus infinity to plus infinity. Now, if I have the corresponding CDF value for this probability f of z, f of z means the standard normal deviate, which I have for the normal distribution. So, this is basically capital F of z. So, then in that case the CDF value is given which also would be utilized later on for a calculation. I am just giving you a feel that how the distribution for the normal case looks like the PDF value and the CDF value such that you can understand how we can utilize the tables in order to do our calculations.

(Refer Slide Time: 05:29)



z	0.00	0.01	0.02	0.03	0.04	z
0.0	0.50000	0.50399	0.50798	0.51197	0.51595	0.0
0.1	0.53983	0.54379	0.54776	0.55172	0.55567	0.1
0.2	0.57926	0.58317	0.58706	0.59095	0.59483	0.2
0.3	0.61791	0.62172	0.62551	0.62930	0.63307	0.3
0.4	0.65542	0.65910	0.62276	0.66640	0.67003	0.4
0.5	0.69146	0.69497	0.69847	0.70194	0.70540	0.5
0.6	0.72575	0.72907	0.73237	0.73565	0.73891	0.6
0.7	0.75803	0.76115	0.76424	0.76730	0.77035	0.7
0.8	0.78814	0.79103	0.79389	0.79673	0.79954	0.8
0.9	0.81594	0.81859	0.82121	0.82381	0.82639	0.9
1.0	0.84134	0.84375	0.84613	0.84849	0.85083	1.0
1.1	0.86433	0.86650	0.86864	0.87076	0.87285	1.1
1.2	0.88493	0.88686	0.88877	0.89065	0.89251	1.2
1.3	0.90320	0.90490	0.90658	0.90824	0.90988	1.3

So, here as I mentioned this is the table which is the standard normal distribution, the standard normal table which is the cumulative one. Remember, why it is cumulated one I will come within another one minute. So, this is the normal distribution with if you remember I did mentioned quite few number of times in the last class also, which is the sixth lecture and today also few minutes back, the mean value mu of z is 0 that be because why z is the random variable. While the standard deviation for z, the standard normal deviate is basically 1 and this is termed as a standard normal distribution.

So, if you look at the table and also with respect to the diagram which has been drawn here. So, this diagram shows some light shaded portion till a value of z where my pointer is. And the portions onto the right of z is basically white in color, white is that I am going to come within few seconds. So, the first column of z are the standard normal deviates realized values and the values inside are basically CDF value. So, I will highlight one point which will make it very clear to you.

Now if you consider the z value at 0, so if and also if you consider the overall sum of the probabilities or which is the CDF of the standard normal distribution or any distribution from its minimum value to the maximum value then the overall area inside or underneath the curve is 1. Now, as mean median mode for the case for the normal distribution is equally distributing or dividing the normal distribution in two equal halves. So, if it is 0.5 and if you basically pay attention to the value which I am circling it means that for all the

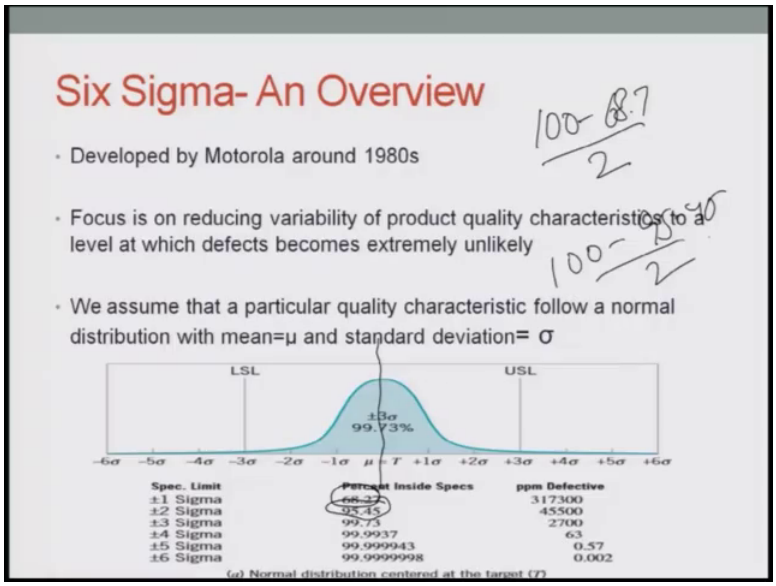
sum of the probabilities starting from minus infinity to 0. So, hence the shaded region means when z is basically at 0, the overall area from minus infinity till zero is equal to 0.5 as it should be and this is the value which denoted here.

Now, similarly say for example, if I want to find out the value of the CDF value from minus infinity to say for example 0.3, then in that case the overall area is basically 0.61791. In case if I want to find out the overall CDF value for minus infinity say for example, 1.3 then in that value the case is the CDF value is 0.90320. And in case if I want to find out the value of the CDF value from minus infinity to say for example, 1.404, so in that case the overall the CDF value is where I am circling which is 0.92506.

Now remember one thing as 8 the normal distribution or standard normal distribution equally equal to both to the left side of 0, and right hand side of 0, because it is a symmetric. So, hence if I want to find out the value of the CDF value starting from say for example, minus infinity to minus 0.8 in that case minus 0.8 would be someone to the left. So, what I would do is basically I would find out the value from say for example, 0 to 0.8 which would be on the right hand side.

Now, 0 to 0.8 would be about 0.78814 overall area inside the curve is 1, so 1 minus point 0.78814 would give me the area on to the right that means, starting from any value greater than 0.8 till plus infinity. So, as it is symmetric that value would be coming on to the left hand side hence the overall CDF value from minus infinity to value of minus 0.8 would be one minus 0.78814. So, you can utilize this table which is given here in order to do all the calculation for the normal distribution and the standard normal distribution.

(Refer Slide Time: 09:47)



So, coming to this the six sigma concept I will very be very brief in this discussion because we will be encountering and coming to the concept of six sigma later on also. So, it was developed by Motorola in the 1980s and it basically focuses on reducing the variability of the product, quality characteristics, what are the quality is. Say for example, it may be micron thickness of the paint, it can be say for example, length of the tie rod, it can be say for example, weight or of any particular product which you are manufacturing it can be say for example, the level of noise the overall machine produces.

Whatever it is the characteristics is based on which we are trying to study, how good or bad the machine is or how good or the bad the services are, it can be translated in the cases of service sector also. Based on the fact there is some quality level quality characteristics assign to that metric which you want to measure using the concept of six sigma and the corresponding concept of standard normal deviate.

So, again continuing where we just left; so six sigma basically focuses on reducing variability of product quality characteristics to a level at which defects become extremely unlikely. Because if you are able to reduce that is obviously, the per percentage or per million or per thousand number of defects, obviously would reduce which would mean the amount of variability with respect to the good items being there would obviously, increase I am basically using the negative connotation. In the sense if it is if the quality is improving it means the overall variability of good products would increase. On the other

hand if quality is being good is the manufacture goods or the services are good; obviously, it would mean the variability for the bad products is basically decreasing that means, there is very less likelihood or less chances of a bad product coming.

So, continuing the discussion we assume that a particular quality characteristics whatever it is as I mentioned follows basically a normal distribution with certain mean mu and a standard deviation sigma. So, if there is a mean mu and standard deviation sigma obviously, we can convert that case into the standard normal deviate where the mean now become 0 and the standard deviation becomes 1.

So, in this case, if I have been able to convert the concept or the characteristics of any quality metric, which you are going to measure from the normal distribution to the standard normal distribution case. And basically try to implement or bringing the concept of six sigma, then the graph would look as it is shown in this slide. Whereas you can understand the middle value would be the mean median on a mode which is a value 0; and on the left hand side and the right hand side you will basically go as per the concept minus 3 sigma on to the left from my side.

So, basically you are going towards minus infinity and plus 3 sigma on to the right which means you are going towards plus infinity. Such that the overall length of dispersion which you are trying to consider from 0 on to the left and the right the total length would be 3 sigma to the left 3 sigma on to the right, so the overall lengthy is basically six sigma hence it is basically concept of six sigma.

So, if you consider the overall characteristics then it becomes very simple that how you are going to basically find out the level of defect or level of percentage of good products which you are going to consider. Now, with this let us refer to the table which was shown and I will strongly urge all the participants, all the students who are trying to basically do this course at least pick up the standard normal table and its corresponding distribution. How it looks like keep it with you as we progress along with the course, because that will give you a lot of information.

Now, if you refer to thus the table then it and if you want to find out the level of say for example, confidence which you have corresponding in that fact that if you move minus 1 sigma onto the left, and plus 1 sigma on to the right, then the overall percentage specification within that bandwidth which means the overall area between the bandwidth

of mu minus sigma till mu plus sigma the overall coverage of area is 68.27, which means that any product which is following between that bandwidth is good. And if I basically continue doing my experiment then out of hundred about 68.27 percentage of those good items would be in that bandwidth.

And the rest which is 100 minus 68.27 would be equally dispersed on to the left on the right such that the total number of defects if I have 100 such amount of goods which I am picking up would be 100 minus 68.7 divided by 2. Why 2, because they would be some goods whose specification would be less than mu minus sigma and some of the goods specifications would be mu plus sigma onto the right. In case if I basically want to increase the level of confidence or level of tolerance, so I am using this words interchangeably, so they would become more clear as you read the book go through the notes or go through lectures.

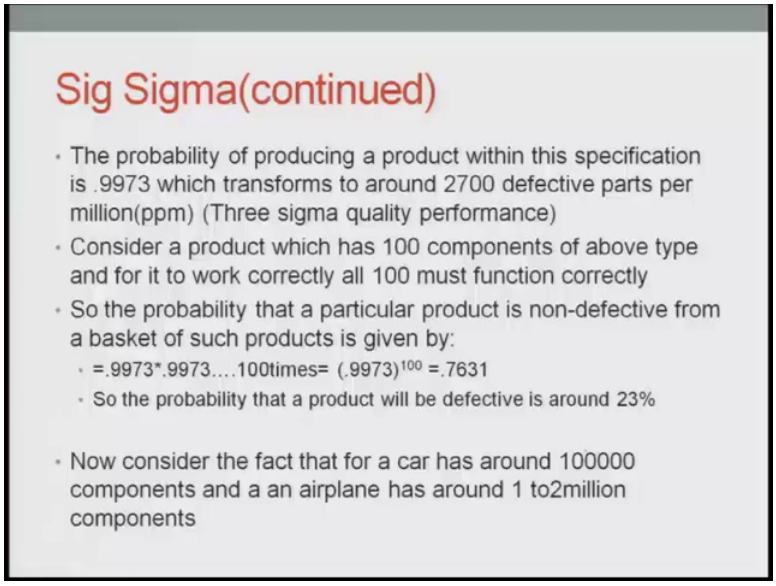
So, if I go minus 2 sigma on to the left and plus 2 to sigma onto the right then the overall coverage in that bandwidth of mu minus 2 sigma and mu plus 2 sigma the overall area comes out to be about 95.45. So, the number of defects which specifications which is mu minus 2 sigma less than that and mu plus sigma and greater than that would be now 100 minus 95.45 divided by 2. So, you can basically find it out.

And if I go to three sigma plus minus 3 sigma, plus minus 4 sigma, plus minus 5 sigma what I am reading is basically the first column here, plus minus 6 sigma then the corresponding percentage inside the specification level basically increases from 99.73, 99.9937, then 99.9999943 and the last value is 99.9999998. And if I translate on to the parts per million defect then the values which are there on the right most column would give you some understanding that how the concept of sigma and its specifications gives us the overall number of defects based on the sampling which you are doing. Also based on the fact what is the level of confidence of number of defects I want to have in a particular number of such drawings which I am making I am picking up those things. So, in that case parts per million defective for the case when it is plus minus sigma it is 317300, so out of million; so this would be basically the defects, and if I go to plus minus six sigma which is the last value to come out to be about 0.002, which is almost 0.

So, based on the level, so it has nothing to do with how you will going to achieve that; obviously, it will mean that you want to basically tighten up the vendors supply quality,

you want basically want to tighten up the type of machining concepts we are going to use. You are going to basically give training to your workmanship, you are basically going to use a better coolant when you are doing the processing and the grinding machine, you will basically have a good jigs and fixtures you will basically have a good environment, give a good training to the workman and so on and so forth. So, there would be thousand of a one thing based on which you can increase the overall quality, but when you basically bring into the actual implementation stage then you will find out the number of defects based on what is the overall specifications would be based on the fact which I have just stated.

(Refer Slide Time: 18:15)

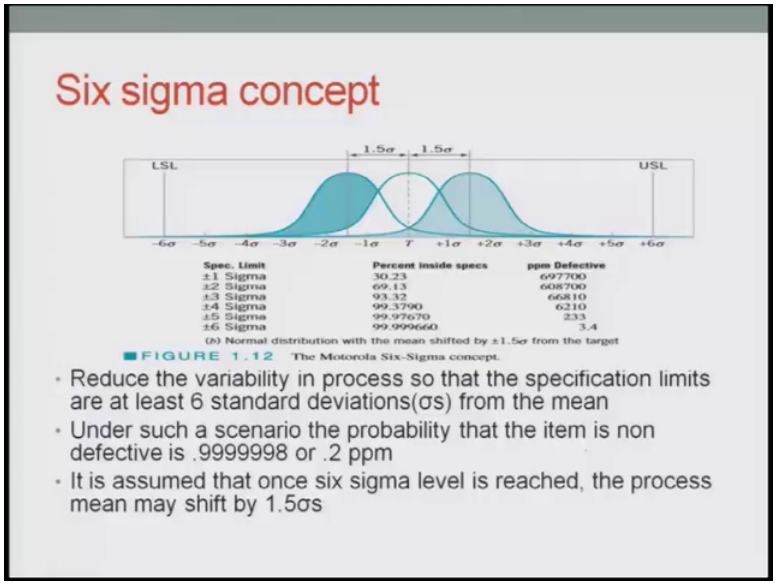


So, continuing the sigma discussion six sigma discussion the probability of producing a product within this specification is about 0.9973 which transforms to about 2700 defects parts per million, this is the concept of 3 sigma quality performance as I mentioned. Consider which means that consider if we consider product which has thousand components of above type, and so for it to work correctly all hundred must function correctly. So, the probability that if there are 100 such products and if all of them are working based on the fact that the level of confidence of defects being there or not being there is being guided by plus minus 3 sigma that means, I am saying that plus minus 3 sigma deviation would basically have good products. Anything outside the range is a bad product defective product.

So, the probability that is the particular product is non defective from that baskets if they are such 100 such components would be the case that the level of confidence which I can say or that the chances that the product would be particularly good is about 99.73 percentage. So, each being good would be 99.73 multiplied 100 number of time. So, it basically comes out be 0.7361. So, the probability that the product will be defective if I find out from that overall group which is 100 products would be 1 minus 76.31. So, it is basically comes out about 23 percent or 24 percent take about.

So, I am not considering the decimal basis I am just saying that if it there are such 100 products level of confidence for each being 99.73, so the overall probability that the defects would not be there in those 100 process individually would comes out be about 76 percent which is 76.31. And hence the probability that there is some defective product would come out to be about 24 percent.

(Refer Slide Time: 20:39)



So, now consider the fact that for a curve which is about 100,000 which is 1 lakh components or an airline which is about 1 to 2 million components hence the corresponding probability would be calculated accordingly. So, again coming back to this the graph which is the standard normal deviate, and if you see it I basically have or I utilize the figure 1.12 again from Montgomery book and if you remember I did motioned time and again and I am going to mention in time. And again we are following this book

as the basis for which we have basically design the course and the lectures are being developed.

So, in this case if I consider the deviation of the mean value corresponding to the fact that it can go either onto the right or the left based on the fact that that sigma value would be considered as an input or corresponding to the deviation. So, it would mean that the corresponding specifications are giving along the first column, the percentage inside this specification based on the fact that the mean value can be either shifted on to the left or the right is given starting from 30.23 till to about 99.999660, and the parts per million defective also can be calculated. And the values I am basically reading the first value and the last value are given by 697700 till the value of about 3.4.

So, which means that reduce the variability in the process so that the specification limits are at least six standard deviations or total 3 plus 3 and minus 3 fluctuation on to the right on the left from the mean. Under such a scenario the probability that the item is non-defective would be given to about 0.2 in ppm which is parts per million. It is assumed that once six sigma levels is reached the process may shift by minus 1, five sigma on to the left on the right.

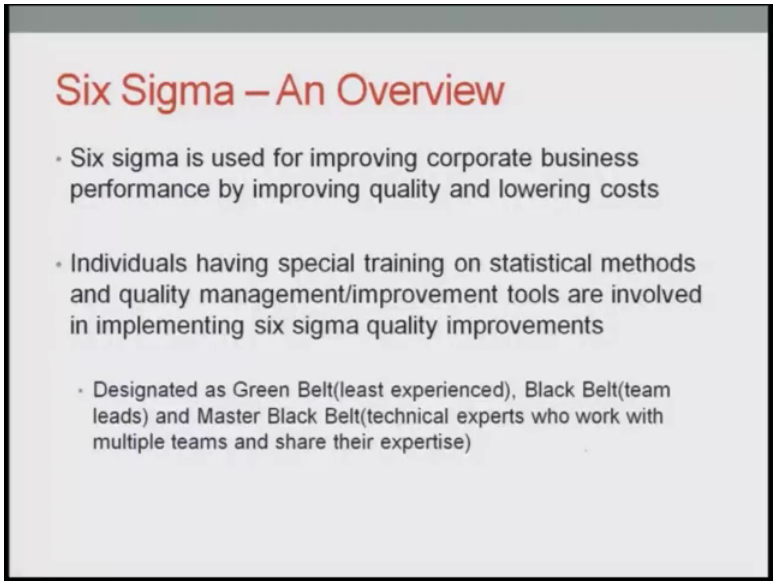
So, based on which we can basically do your calculations and then try to bring the process in that bounds that you are able to calculate, what is the number of defects parts per million or per thousand or per lakhs, based on which you can do your calculation and find out that increasing and decreasing level of confidence of good items. Basically what is the overall percentage of good or bad items which you have within that the level of confidence which you want to have. But one should basically remember that if you are being more and more stringent which is good they would be a cost, cost means on the negative side; that means, if you have to basically try to give a training, which you are trying to increase the vendor quality, if you are trying to get good raw materials for which cost would be higher. If you want to basically have a process using utilizing very good machineries, so all this basically would have a huge amount of cost.

But you should ask a question that whether if this cost is there, and when if you try to implement then from the concept of quality whether that is compensated by the overall good quality which you are getting. So, if it is obviously, you will take a very judicious decision. But if you consider the overall philosophy based on which I started the course

it means that quality is basically and continuous improvement. And your main emphasis is basically to improve the quality in such a way that it becomes part and parcel of your thinking process of philosophy how you do your work on a daily basis.

So, the first point which I mentioned that how you balance the cost is basically from a very practical point of view whether those amount of efforts is actually needed from your end. Considering the overall improvement which you can have on the type of vendors type of raw materials type of trimmings and so on and so forth cannot be increased after a certain value. So, if that is the case whether it is really worth. So, you have to make a decision, but having said that I will again comeback to my first initial philosophy when we started the course is that quality has to be in built in whatever work you try to do.

(Refer Slide Time: 24:48)



So, six sigma is used for improving continuing the concept of six sigma: six sigma use for improving corporate businesses performance by improving quality and lowering the cost. Individual using special training on statistical methods and quality management improvement tools are to be involved and should be utilized in order to implement the six sigma quality improvements.

So, basically we see nowadays they are designated as green belt, black belt, master black belt basically these are people who have the training such that they incorporate the concept of statistical process control how it can be brought into the picture and implemented on the shop floor for services, for manufacturing goods whatever it is.

(Refer Slide Time: 25:33)

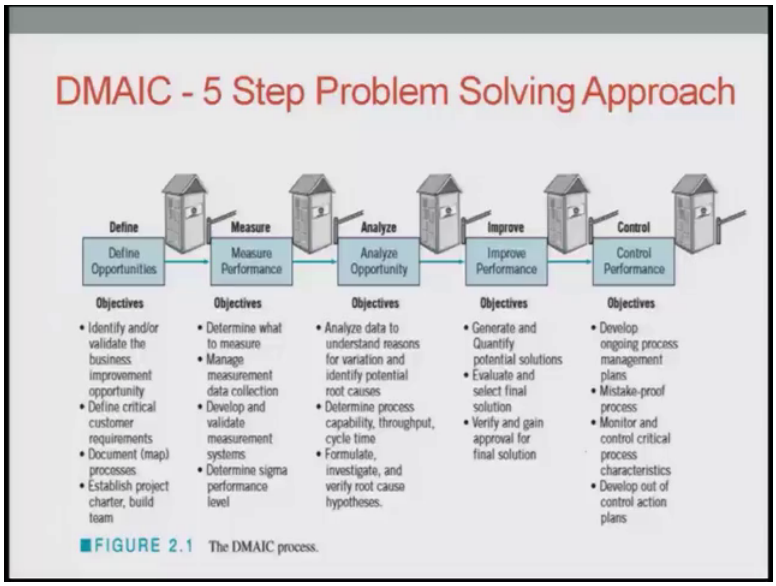


FIGURE 2.1 The DMAIC process.

So, now we will basically go into more of a understanding in the qualitative sense about concept of quality. So, we will basically define the five. So, called concept which is defined, measure, and analyze, improve and control in a overall sense about the concept of quality which is known as the DMAIC step which is the five step problem used in problem solving approach. So, first is define the opportunities, I will just read and explain the first few bullet points, and then basically try to explain that in further details as for the discussion what is needed for this course.

The second would be measure the performance, third is analyze the opportunities based on which you are trying to do your business, then you will try to basically improve the performance of your production of your services. Whatever you are trying to deliver to your customer, then you have acontrolled performance concept, where you try to basically analyze that what the control things which you want to implement in order to implement that concept of quality for the overall production and the service concepts.

So, the objectives are basically the bullet points, identify and or validate their business improvement opportunities which are there for you; so if you think that costs are decreasing for the raw materials, so rather than basically trying to pass on overall profit to yourself by not decreasing the overall selling price of that product. You should basically aim even though it definitely may not have any immediate implication for your quality, you will basically try to share the overall the profit between the customers in

yourself, but having said that obviously, this concept of lowering of raw material cost on lowering of overall cost which you are having would also be implementable for the other competitors who are selling the same type of product. So, in order to basically have an understanding that how you will basically improve the overall process you will try to implement in a very finer points the concept of quality and how can quality can be improved next.

Say for example, you will try to increase the overall a level of confidence of the workers by trying to basically take the overall profit breaking in between the customer and yourself, you will try to basically pass onto the customer utilizing a training concept for your workmanship. Or say for example, you will try to basically improve the overall level of training which is the vendor should have or say for example, if you think that you have the money you will try to basically procure a good machine to do the work. Or say for example, you basically and a pay more attention in trying to basic improve the overall supply chain management system which is there with your end.

So, with this I will basically stop here for the 7th lecture and continue with this slides which are basically the five step problem solving approach and then discuss about the concept of quality more detail in the 8th and 9th lecture. And build up the concepts such that it can be implementable and we can use the concept of quantitative techniques to understand how quality can be implementable.

Thank you very much and have a nice day.