hatQuality Control and Improvement with MINITAB
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Lecture - 05
Data Visualization for Quality Control and Improvement

Hello everyone, welcome to session-5 of Quality Control and Improvement using MINITAB. So, I am Prof. Indrajit Mukherjee from Shailesh J Mehta School of Management IIT, Bombay. So, we are discussing on tools that are used for visualization, ok. So, in this context, we are just discussing about histogram where it can be used and what scenarios. Histograms are generally used whenever I have a continuous data. So, for that generally histograms are preferred.

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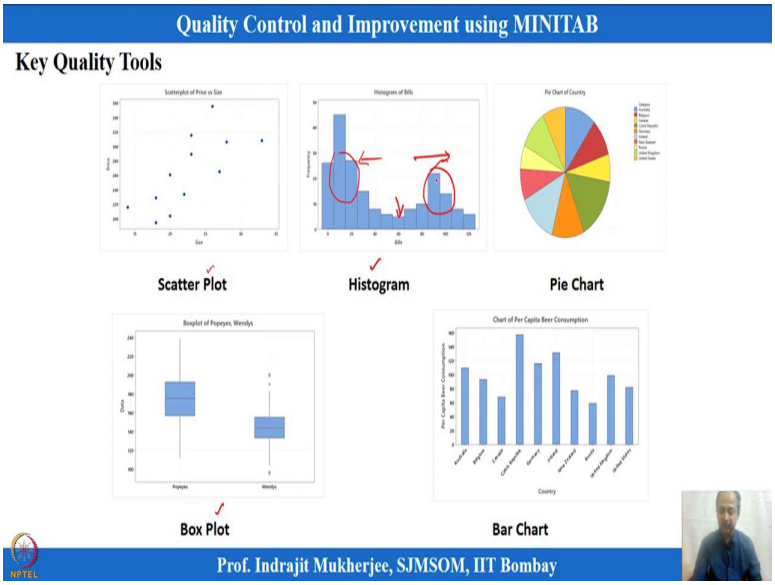

So, there are many key quality tools which we will highlight over here. So, one of the tool is histogram, another one is box plot that is the two important tools that is used in quality so visualization of the data, so and that can be used for some interpretation out of the data. So, that we will see how it is possible.

So, here you see I will talk about box plot over here, I will talk about histogram, and then we may go to scatter plot over here. So, histogram is just representation of the data. So, how the data is spread over here. So, what is the spread of the data that can be seen? So, there can be a spread from this range to this range.

And where is the peak of the data concentration of the data, cg of the data basically? CG of the data may be somewhere over here. So, but the spread of the data is showing that there are two clusters over here. So, one is this cluster over here, and one cluster is over here. So, that means, a mix of data is basically plotted over here ok. So, it will give you some sense about the data distribution. And what is the spread of the data.

Then we can see the descriptive statistics in MINITAB which can be used to see what is the mean value, what is the other measures or statistic that can be that we can also figure out, that means, what is the mean, what is the standard deviation, and the what is the range, what is the maximum-minimum, interquartile range, all things are possible over here.

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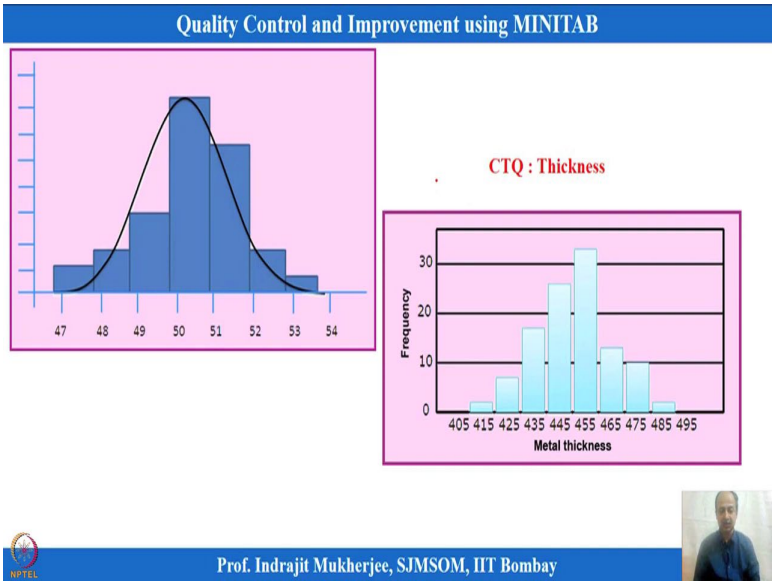

So, let us take an example of CTQ, and let us try to demonstrate that one. Let us try to see that assume that CTQ is thickness. So, we will illustrate in MINITAB how these plots are possible. So, last time also we are discussing on this. So, I will open some data sets which is available with us, and that will help us to illustrate in MINITAB.

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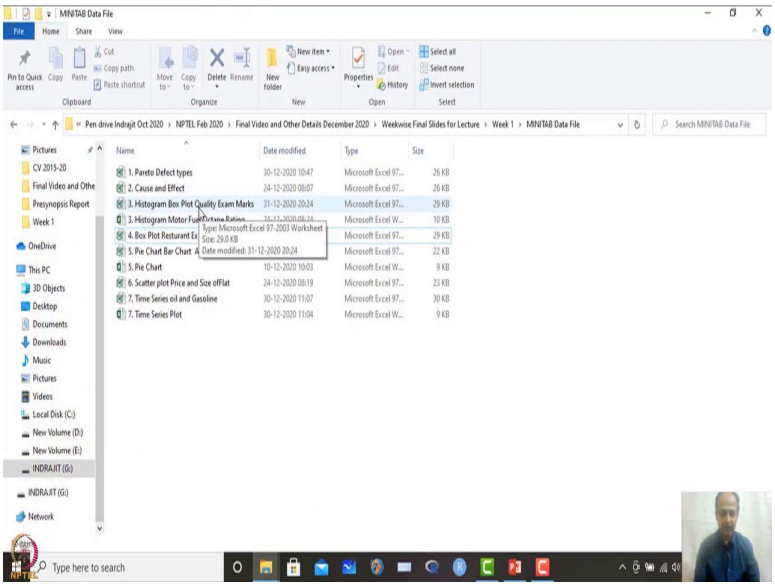

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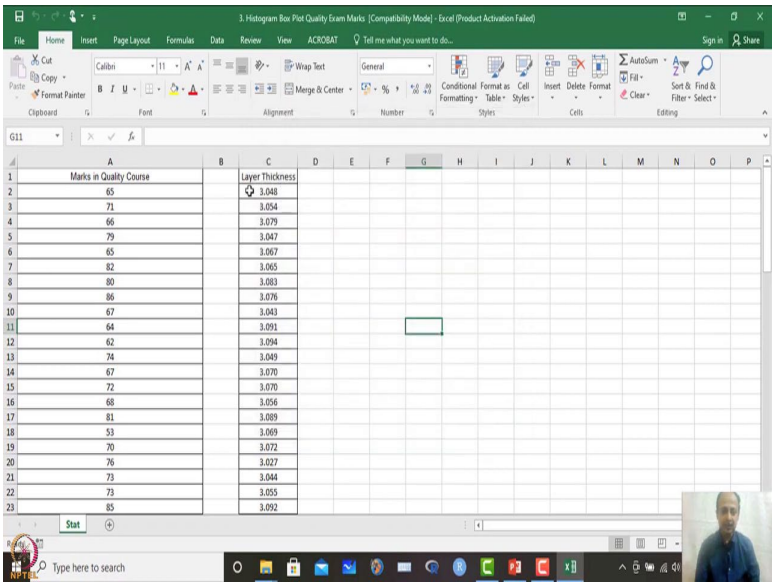

So, I am opening in excel. So, some other data sets, and then we will place it in MINITAB and see. So, there is a layer thickness which is an important characteristic which we want to plot over here which is a CTQ basically. There are marks in quality also we can illustrate. First let us try to see that in a manufacturing process some we are producing some thicknesses or coating over a given surface.

So, in that case, layer thickness is important. And target value we can assume as 3. So, let us try to see by plotting this one, whether some more information we can get out of

histogram. So, I have come copied this data set over here. So, I told you that when you install MINITAB, what will happen is that an icon will be coming to your desktop.

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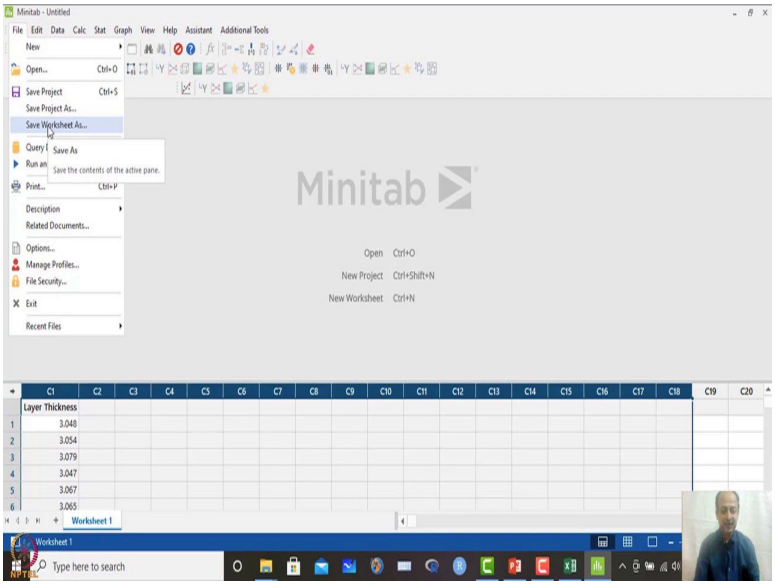

And then when you click that icon, what will happen is that we will get some interface like this. And we can just see the interface over here and C1. So, these are the columns where you have to cut paste the data set. So, first row over here where you can write the data, name of the data variables like this.

And then you can type in the data also, or you can copy paste the data from excel sheets. So, I will copy paste the data from over here. And I have already copied this one and then what I will do is that in MINITAB this worksheet, what I will do is that I will highlight on the first row, and then I will control V, I will paste this one ok.

Whenever I have pasted this one, so there are there are windows over here. So, what you see over here, this is the session window where the results will come when you do some analysis over here. And if you have to save this worksheet which is coming over here, so this worksheet this is known as worksheet over here like excel what you see worksheets.

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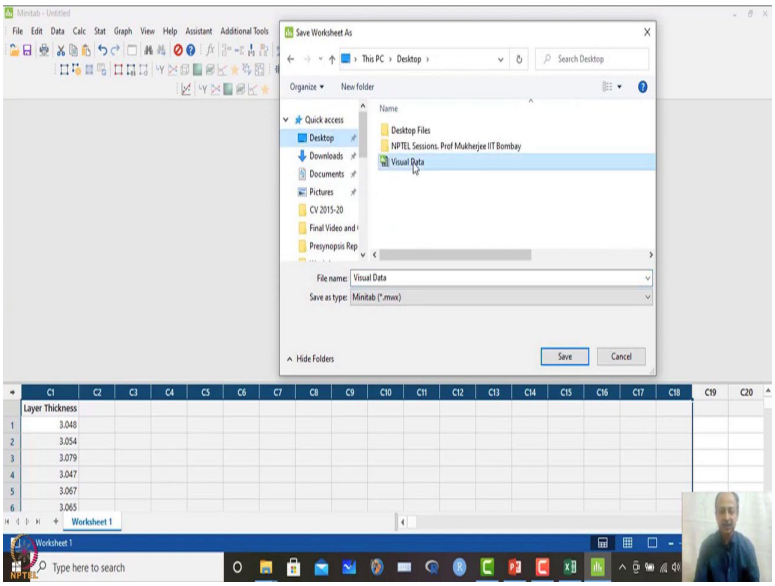

So, this can be saved over here save worksheet as. So, what you can do is that save worksheet as, and then on the desktop maybe we can save this one. Let us say visualization of data I am going to replace this file which is existing. So, I am just replacing with a new file.

So, you can also name a new file because you know I had already created earlier so for some illustration. So, again I am redoing that when I have replaced that file. So, now, this file consists of only C1 columns with layer thickness ok.

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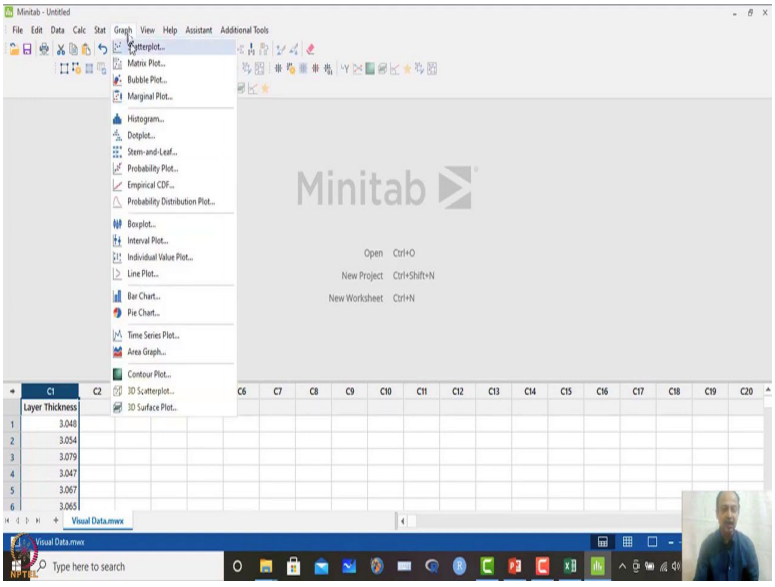

Then I told that where from I will draw the graph. So, there is graph option over here, there are many options that you can see over here. So, out of the all the options you have histogram over here as one of the options. So, there can be other options. So, I am concentrating on histogram over here.

So, for visualization of the data, this is a continuous data, continuous scale data, so that you can understand. Thickness is measured over here. And it is a least count is up to three decimal place which was measured over here ok.

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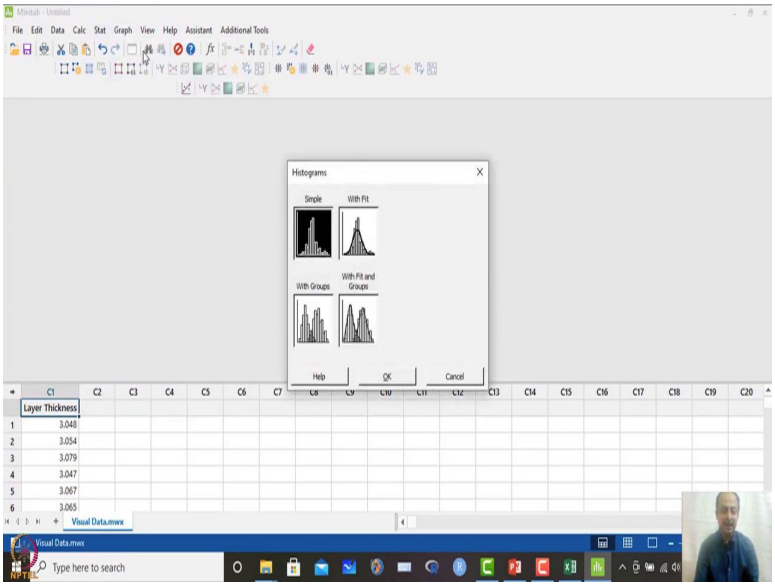

So, what I will do is that, I will plot this histogram over here. So, I clicked histogram, so then it will have simple histogram ok. I will mention it ok, I will draw a simple histogram.

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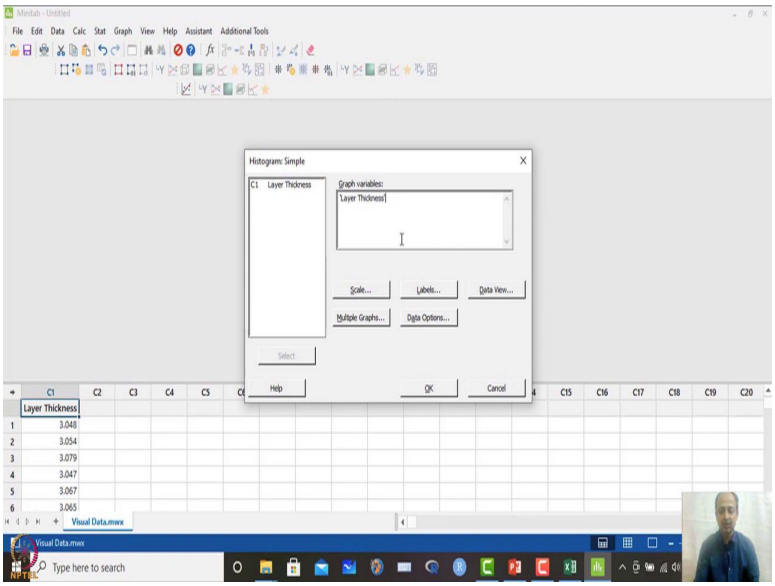

Then what is the graph variable, your cursor should be over here, and double click this C1 column over here. And otherwise what you can do is that I can just delete this one, I can just highlight this one and select from here. So, that is also possible.

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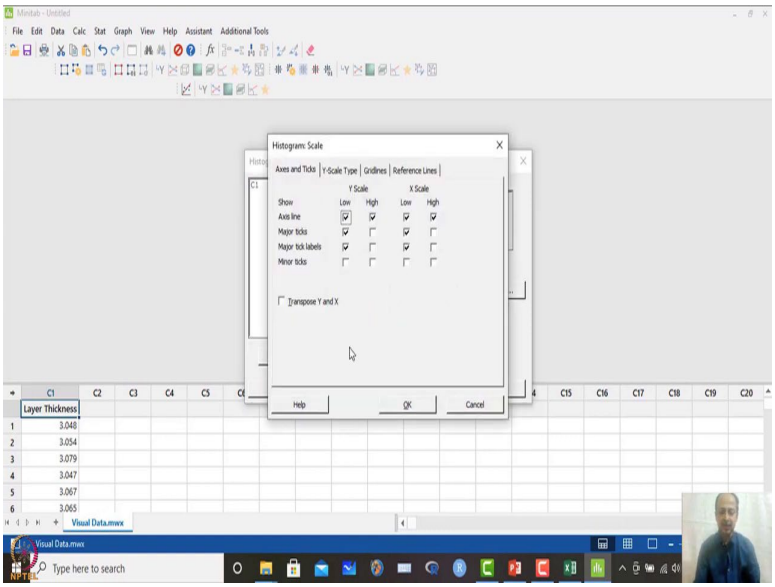

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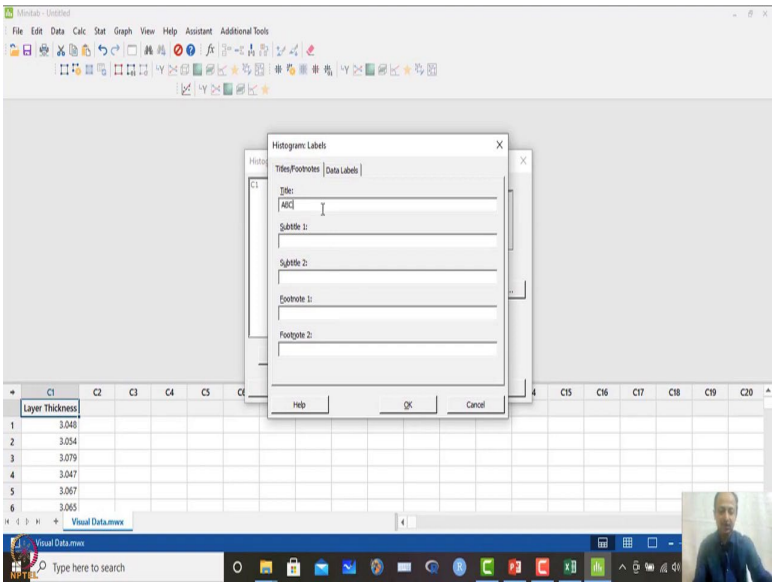

Then you have some scales over here keep it as default, do not want to change this one. Labels, I do not want to; if you want to name or give some titles that you can give ABC or something this is always possible. So, I am not doing this. This you can explore by yourself ok. So, data views and all these things do not do anything over here. We do not want multiple graphs to be plotted. So, data options are over here.

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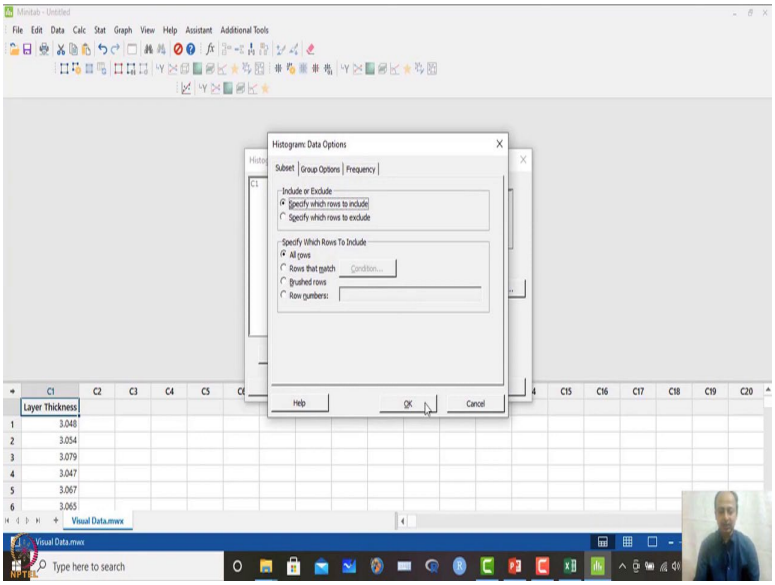

So, these are also not required because I have already given the options that layer thickness has to be plotted ok.

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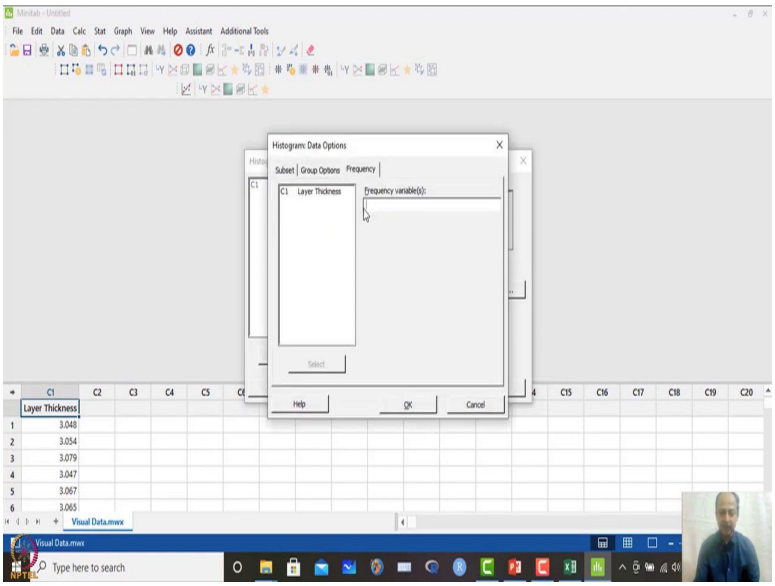

So, maybe the frequency over here which you want to; which you want to highlight over here. So, maybe that if that information is available. So, in this case, that can be provided over here that is not required over here. So, label what we can do is that maybe data labels what we can do is that use Y values to data label over here. So, in this case what will happen. When I click OK over here, I will get the frequency information also.

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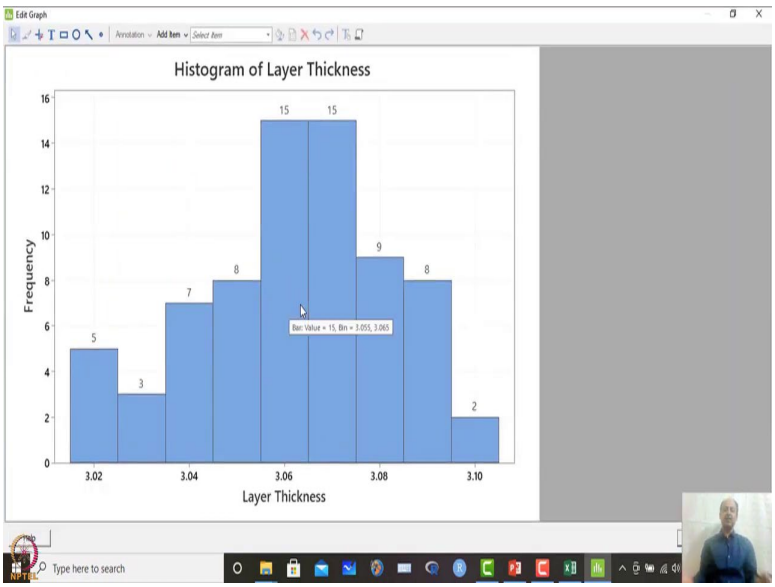

So, this session window will give you this window will give you all the results over here and graphs. So, when you double click this graph, you can just see that MINITAB has

already done the basic analysis, and it has plotted the histogram based on the its default options that is there.

So, a number of classes what do you see over here 1, 2, 3, 4, 5, 6, 7, 8, 9 classes, it has divided the total data set and the width of the class is the interval which MINITAB automatically determines. And there are formulas to do that also. So, in that case, MINITAB does it automatically for you and gives you the frequency.

So, this over here what you can see this is the bin size over here. So, this is varying from 3.015 to 3.025. And within this bin, there are five observations. Similarly, next bin you can see how many or in that class how many observations.

So, maximum observations are within this range over here what you see 3.07. So, it is varying from this range over here. So, this is 3.055 and this will be around 3.075. So, we can assume 3.07 more or less is the average or center of gravity or accuracy or what you can see the CG of the data set right over here ok.

So, and the spread of the data varies from this range to this range. So, what you can see that peak of the data set. So, we can also plot this one by we can also what we can do is that when I draw histogram, it will ask with fits.

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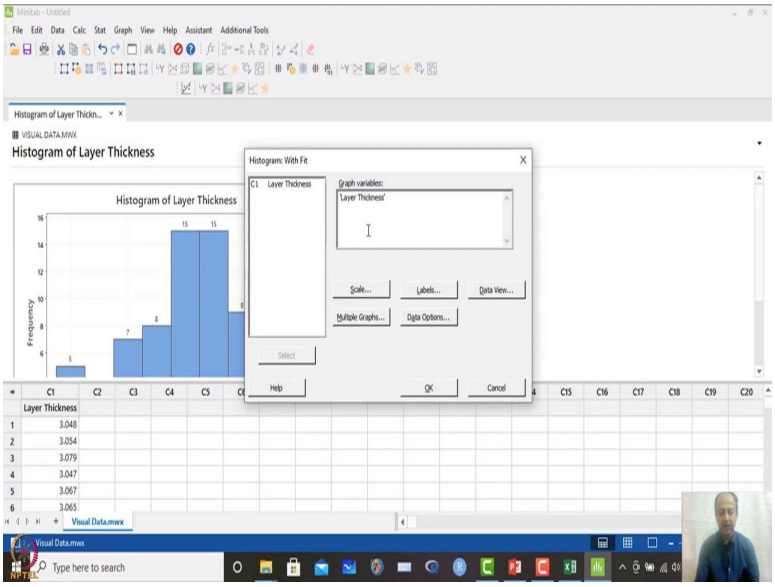

So, some normal distribution overlayer graphs can be placed, overlayer distribution graph can also be placed over here.

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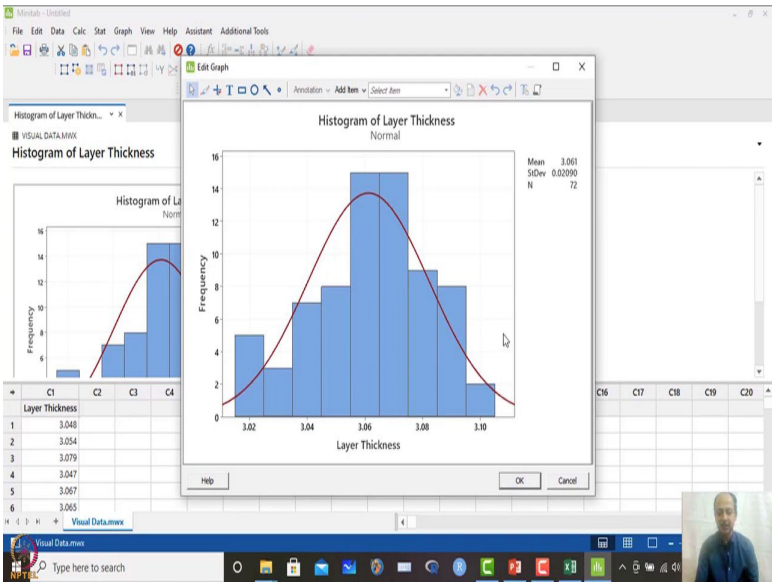

So, if you click OK, so it shows you some normal distribution plot over here. So, mean is given, standard deviation is given. Number of observation is 72 that will be given over here. So, these observations and also you can copy this graph like this. So, if you want to copy the graph and paste it in reports or in excel file.

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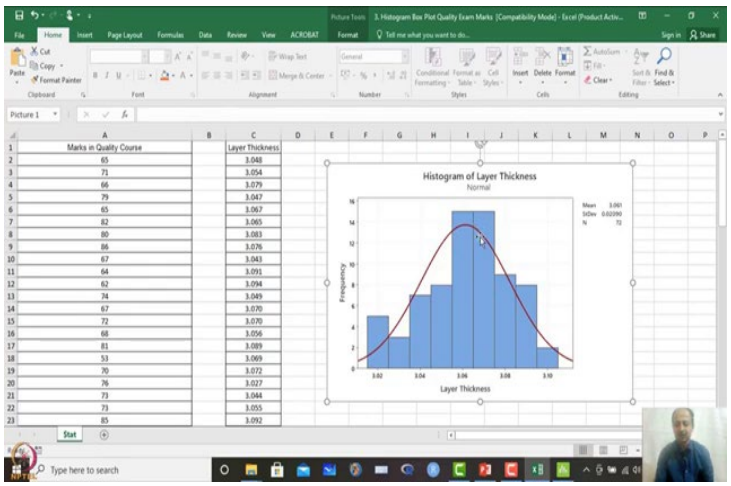

You paste it over here and just move wherever you located. So, this is possible in board. And this is also possible in excel. So, you can save these graphs also ok. So, that is also possible. So, this gives you some basic information. Now, mean standard deviation, I may need more information over here, so that will not come in histogram over here. So, maybe maximum values, minimum values.

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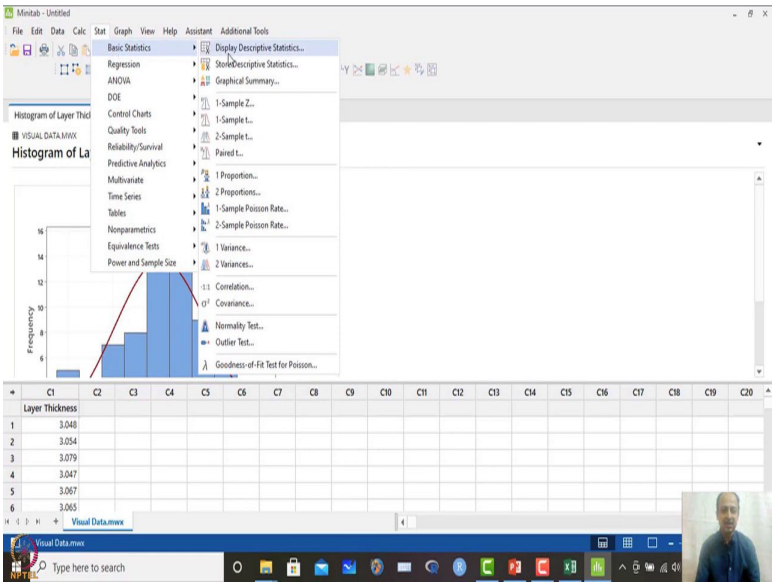

So, then what I have to do is that I have to go to stat, and they could go to basic statistics and maybe display descriptive statistics. So, one go you can draw histograms also using this option. So, MINITAB has this stat option where we will use basic stat, regression, ANOVA, in this course design of experiment, control chart, quality tools.

Some more with respect to time we can plot also which is known as time series we will not cover, but we will show you some illustration of graphical illustration how it is done. So, a MINITAB has options of non-parametric test. Those are the tests we will also illustrate in certain scenarios where it is required ok. So, what we will do is that now in this case, so, I want to see the basic statistics.

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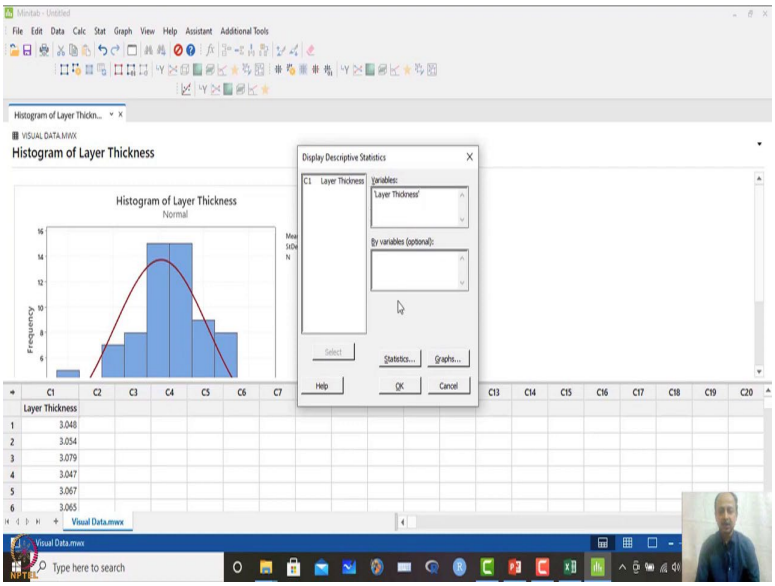

So, in this case display descriptive statistics I will mention which is the so cursor will be here and double click C1.

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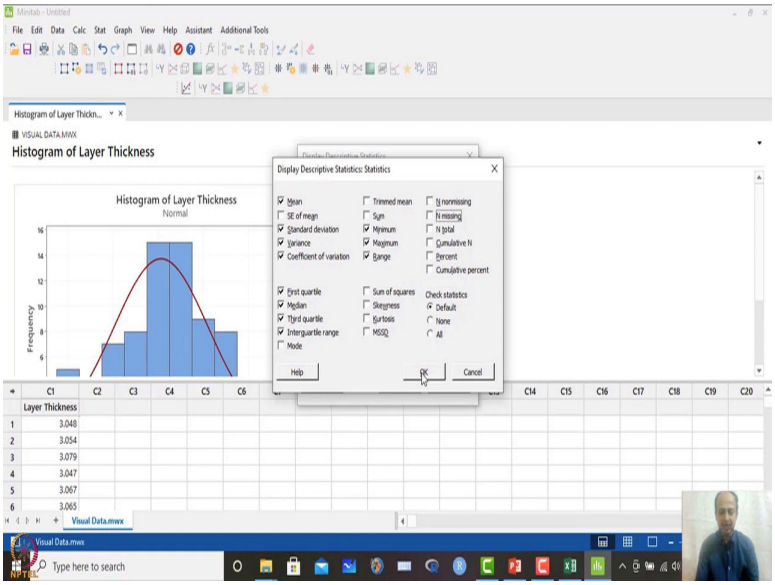

So, what are the statistics that will be required? So, I have gone to statistics and I have clicked that one. I want mean information, I want standard deviation information, variance information, coefficient of variance information, first quartile median, these are all information what I want to see; maximum, minimum, range, these are not required. So, maybe these are the basic things one wants to see in the data set.

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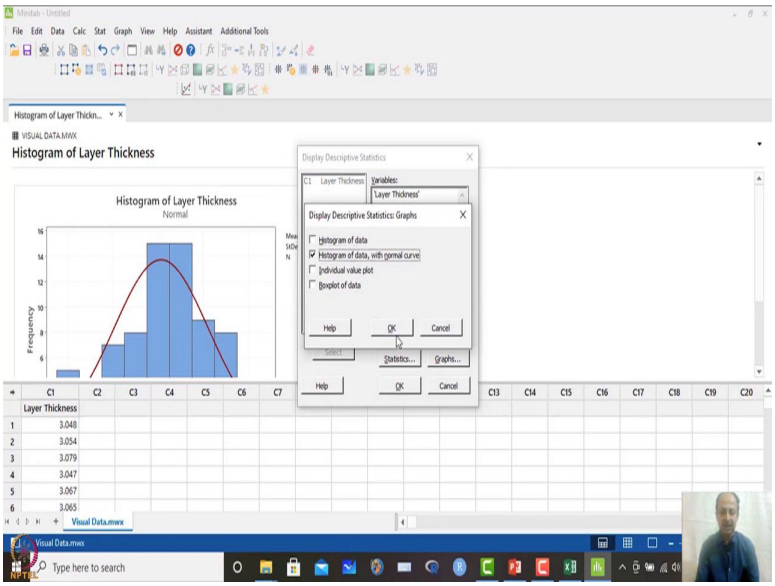

So, in this case, I will click OK. And if you want to see histogram over here also with normal fits is also possible.

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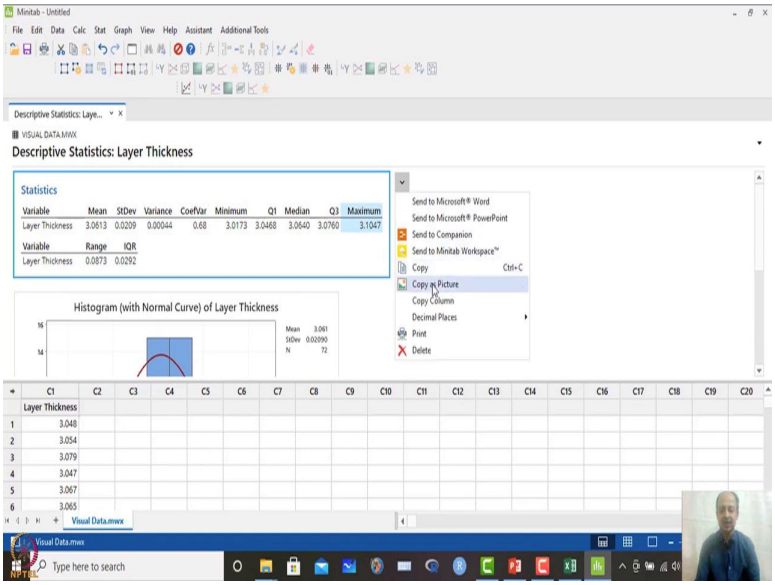

So, this when you click this one, so this comes automatically in MINITAB. So, now, these things can also be, the results can also be copied as a picture, and you can just paste it wherever it is required. So, if you want to paste it over here, you just paste it over here, and then save that one or in reports anywhere ok.

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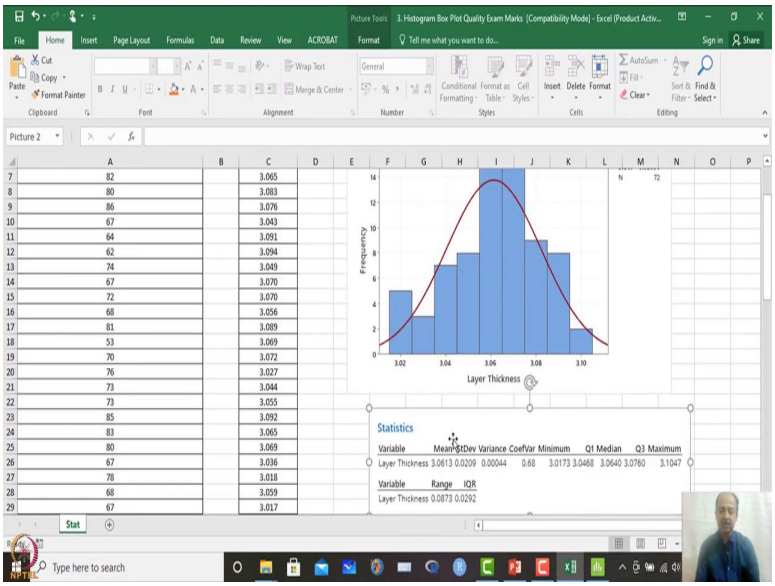

So, what information we get over here mean value is 3.0613. So, up to fourth place of decimal data sets, we are getting standard deviation. Coefficient of variation, that means, what is the magnitude of variance with respect to mean. So, variance information is also given over here minimum, maximum, inter quartile, quartile 1, quartile 3, median value that 50 percent observation are less than this 50 above this one.

So, range information is also given inter quartile range is also given. So, all information we can get out of the MINITAB software which is necessary over here. So, mean is 3.06, but I told you initially that our target is 3, that means, CTQ that is generated thickness layer that is generated over here should lie between 2.9 to 3.1 let us say, and the target value is 3.

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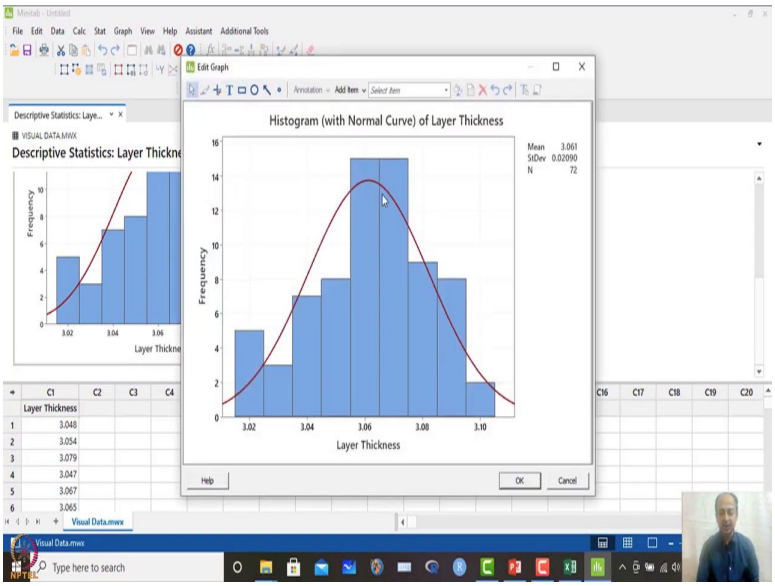

So, what we can see from this graph is we are basically off-centered you see. So, 3 is around on this axis on the left-hand side. And our average what is coming out of the process is around 3.07. So, we are accuracy part we are missing over here. And also, we are getting some information which is beyond 3.1 that is out of spec also data we are generating over here ok.

So, that is also an alarming situation in quality, that means, our process is off-centered, variability is high, and also, we are producing which is creating rejections also. So, this gives you an immediate impression of the data set without much statistics I can make this kind of interpretation out of the data ok.

So, another important thing what can be done when whenever I have the spread of the data, we can also see another important graphical illustration over here which is known as box plot.

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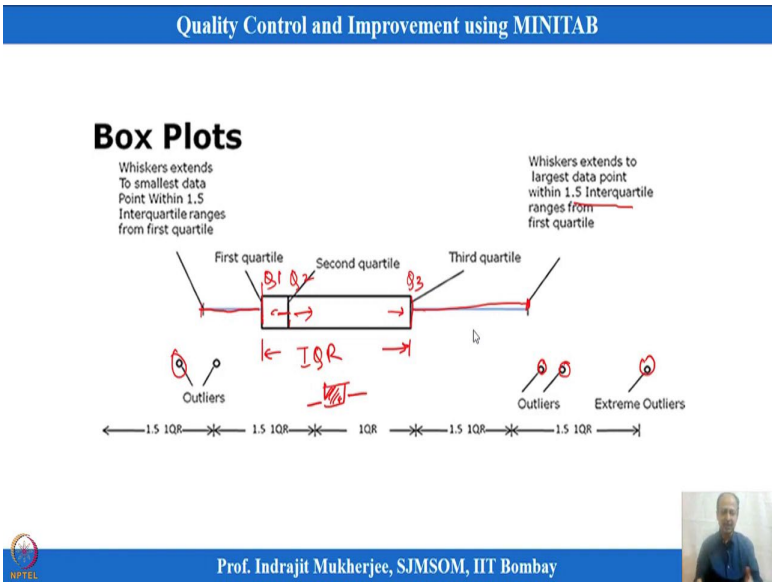

So, here also box plot is sometimes used to define some of the. So, this what it will show is that what is the width means within which we have the complete data set. So, this is the range which is known as interquartile range within which most of the data sets are concentrated over here.

So, if it is more spread, that means, we have a much variability in the data. If this spread is very less or we have a small spread of this. So, in that case, data is squeezed more or less over here. And in that case, density of the data is high. So, variability is less we can also interpret way. So, it is like spring more it is spread more, more less, that means, more data spread of the data is quite high.

And if this is less squeezed, that means, we have a much less variability in the data. So, we can think about that. And these are the stretchable extension what you see over here. So, these are known as whisker over here. So, this line what you see over here extended up to 1.5 into interquartile range what you see over here definition. And anything lying outside this is basically outlier over here that is indicative measures that it takes.

Anything beyond this is an outlier there are other tests for in identifying outliers, but this is in box plot also we can see that which data is very unusual. So, that we can also see from the box plot. So, this on this the first start of the box over here this is known as first quartile Q1, and this is the second quartile which is known as Q2 or the median value of the data set where 50 percent of the observation will be on the right hand side of this

value and 50 percent on the left hand side; left hand side of this value and right hand side of this.

And this is known as third quartile values over here. And difference between this first quartile and third quartile, this area is known as interquartile range ok. Here also Whisker is extended to the smallest value 1.5 of that. And anything beyond that is a outlier basically ok. So, this is also possible in MINITAB. So, we will use the same data sets to illustrate box plot where we have drawn histogram.

Here we want to see the interquartile and where the data is most concentrated. So, what we will do is that is also possible over here. So, that is also possible over here. So, this same data set we are using. So, I will go to MINITAB over here.

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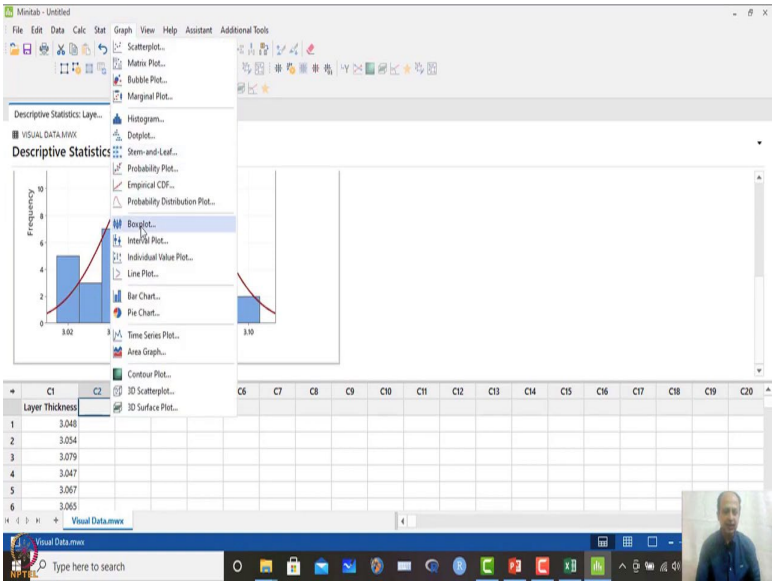

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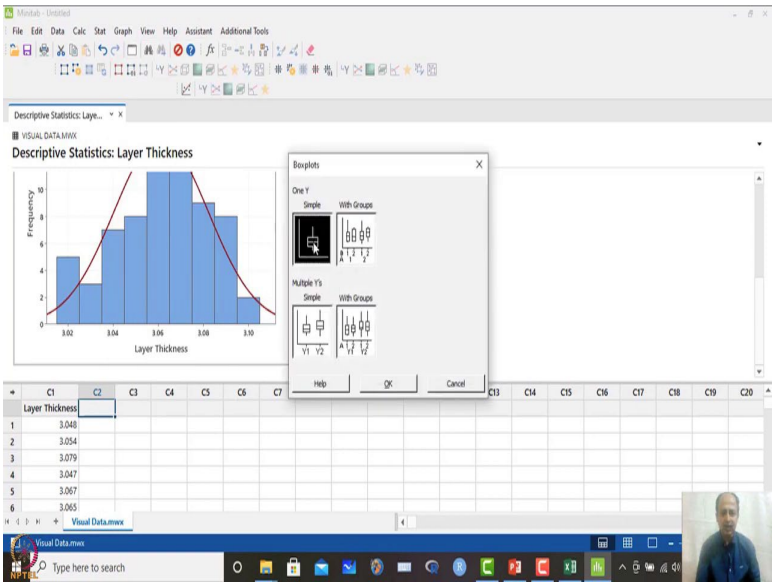

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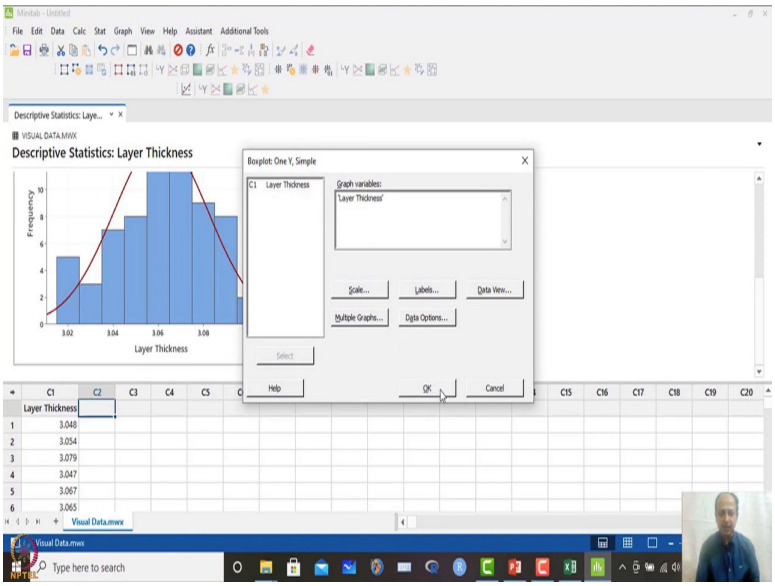

And then what we can do is that we can just see the box plot, and then we go to graph, and there is a box plot option over here. Then there is simple box plot over here. I click OK. And I give the variable a C1, double click that one. And do not go, I do not need to see much options over here.

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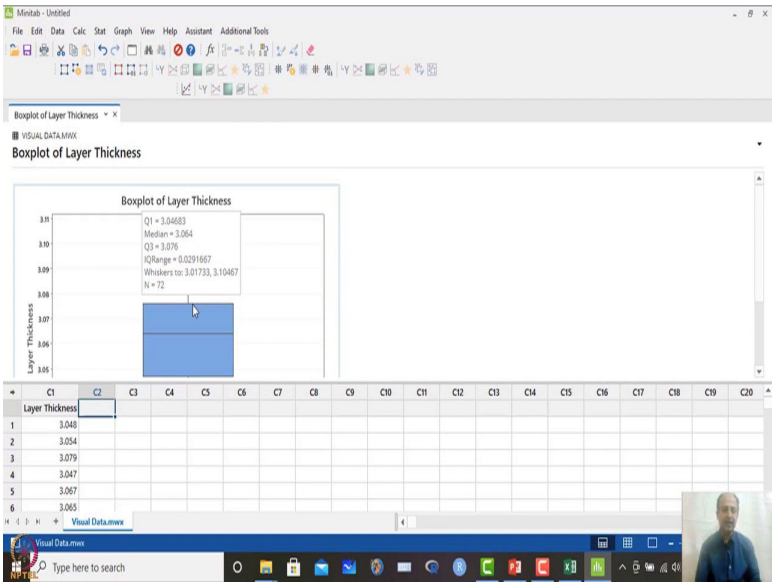

So, we can place the values over here also. So, just click on this, and you will get all information quartile 1 is 3.04 that is a 25 percent of the observation is less than this; 3.06 is the median value. So, 50 percent of the observations are below this, and 50 above this one. So, this is the interquartile range.

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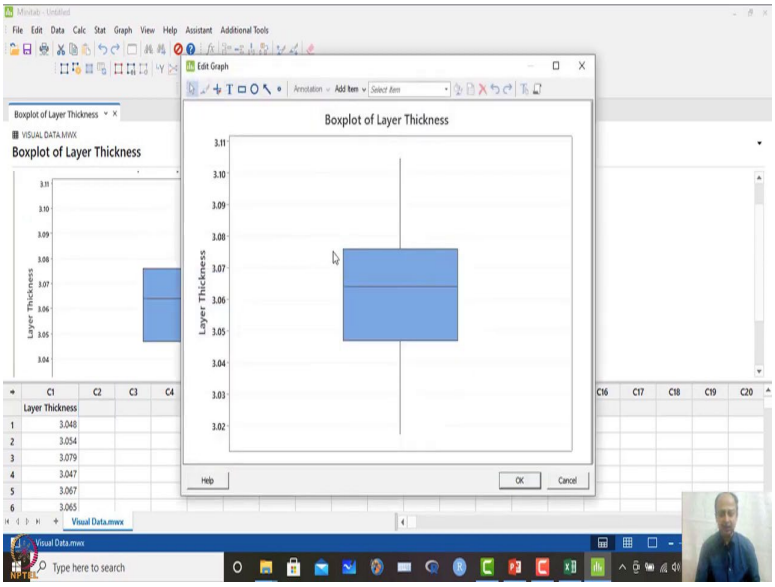

So, this is the spread of the data set what we can see. So, most of the data set are concentrated in this zone. So, data set concentration can be seen over here, so ok. So, this is the width of the box. So, most of the data are concentrated within this, ok. So, this is

the interquartile range. So, this information we can get and how this is useful I will use an example to illustrate that one.

So, let me also take some examples, like let us say the quality marks and which I have not discussed or what we have started. So, I am taking these marks in quality. I have to make a decision let us say whether to attend the course this is the last year marks whatever what was given.

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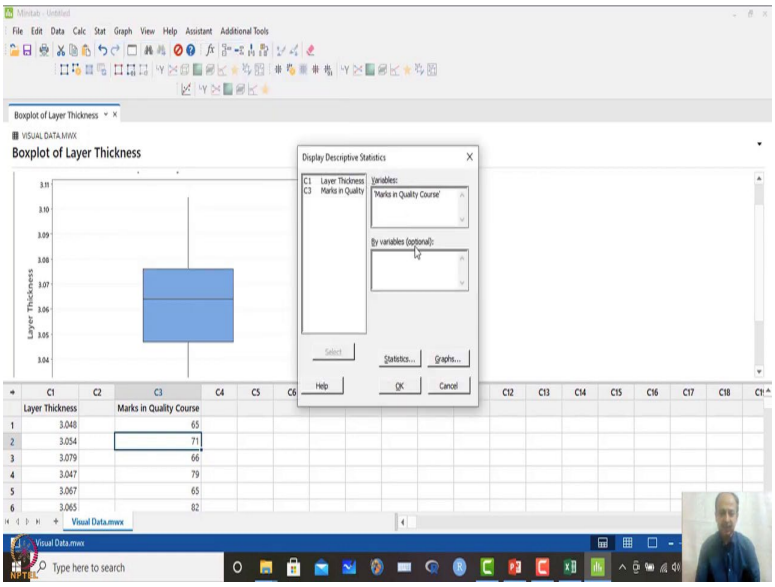

So, I want to select whether to go for this course or not.

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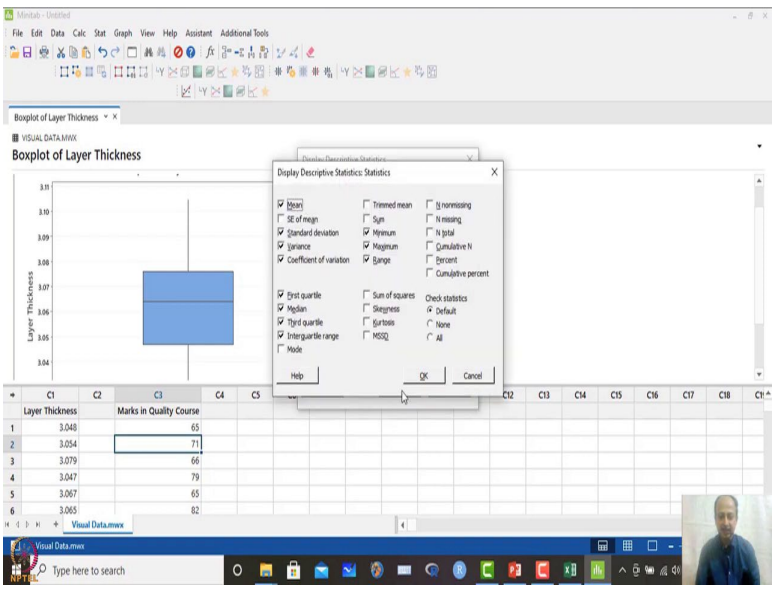

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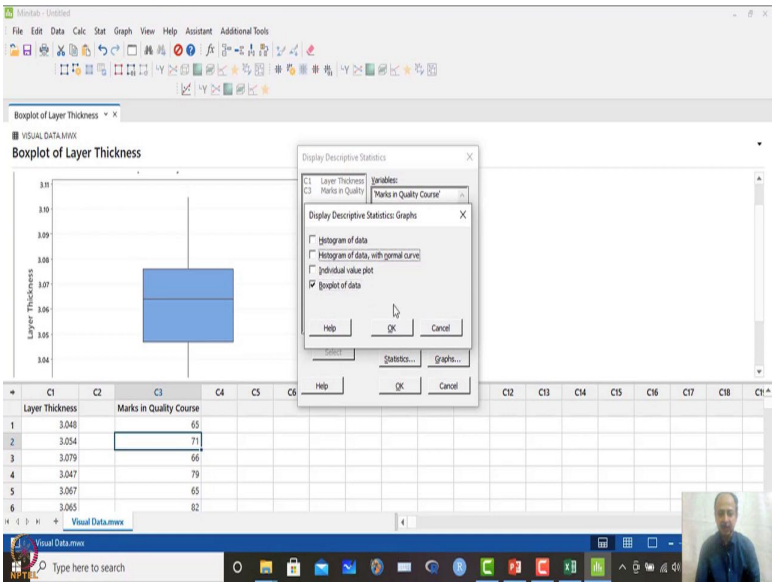

So, what we can do is that just we can see the basic statistics of this. So, display descriptive statistics. I will display the marks. And statistics what we have mentioned is already given over here. So, and graphical illustration I want to see the box plot of this rather than histogram. And, so I will click that one OK and I will click OK over here and then I will get the box plot over here.

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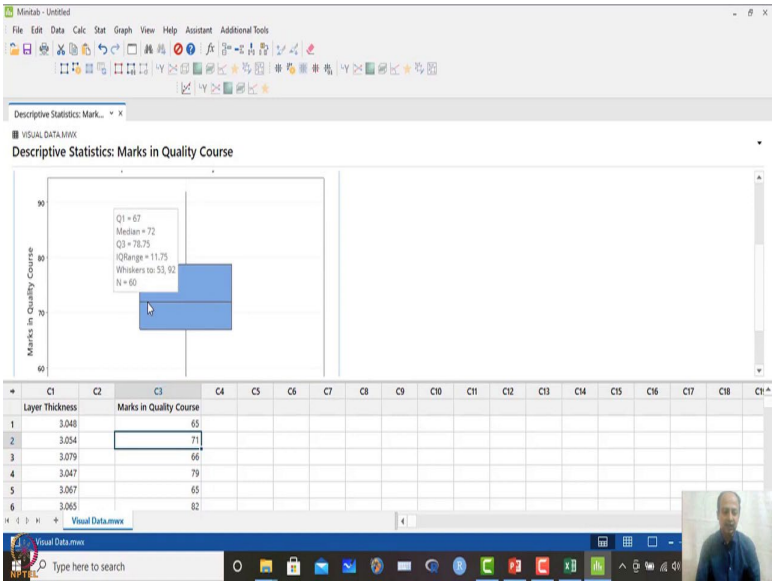

So, on an average the 50 percent median value is approximately equals to 72, so that means, on an average people are getting work. What we can say is that the middle value

50 percent of the people are below this, but 50 percent are above 72. So, this is a favourable situation what we can see over here.

And also, we can see that 72 is the average value from here. This can also be copied, results can also be copied from here, copy as a picture. And you can paste the results what I have shown earlier also over here. So, statistics can be pasted. So, that is also possible. So, in this case, what we are seeing is that on an average 72 marks are there.

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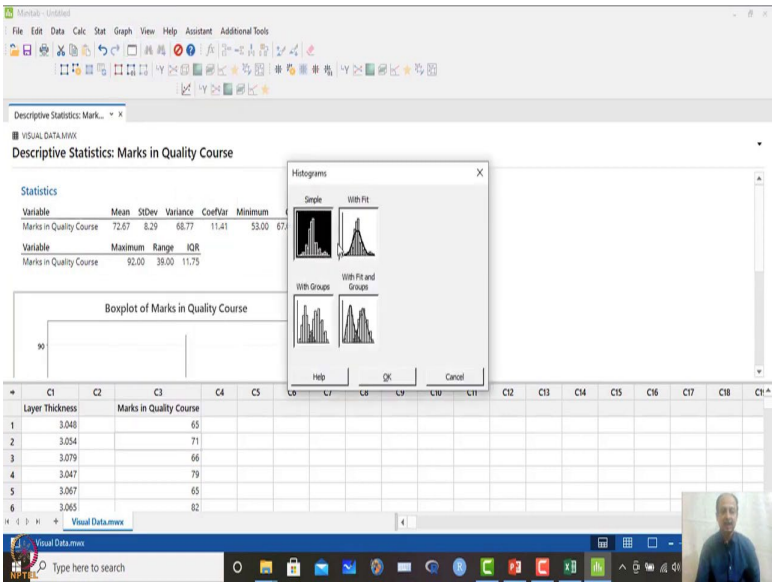

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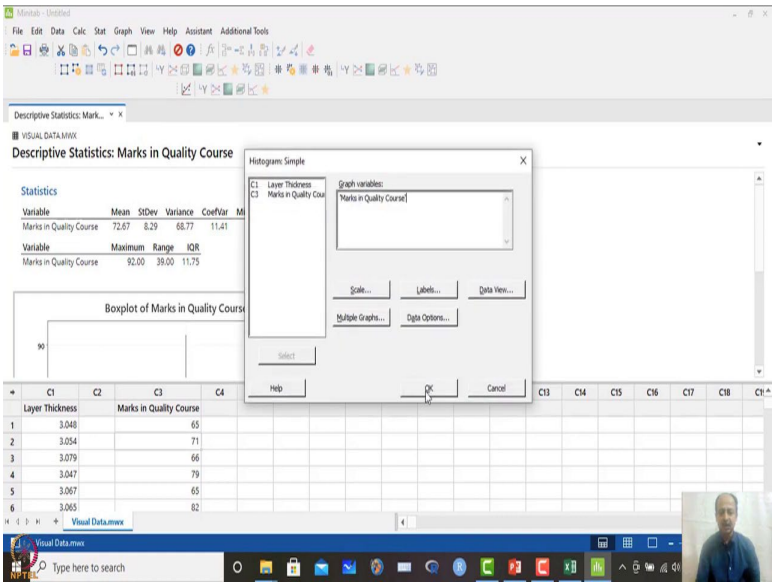

So, I can also see the histogram of the data set. And if you want to see the histogram of the data set, then some more information we can get. Just click, double click that variable graph variable, and click OK over here.

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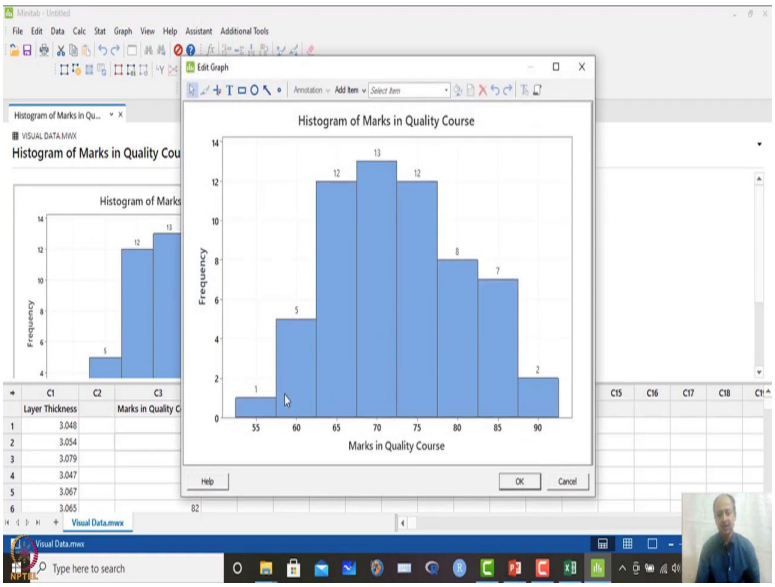

And then what you see is that you will get the histogram of the data. So, what you can see is that on the left-hand side much less observations are there. And on an average, 70 is the we can say center of gravity of the data. So, most of the people are more than 70 what we can see over here.

So, this is a favourable situation just by drawing what I am seeing is that number of people getting more than 70 is much higher as compared to the number of people getting less than 70. So, that is also reflected over here. So, it is more skewed on the right-hand side as compared to the left-hand side.

So, on the higher side of marks basically. So, in this case, I can make an immediate judgment ok, this course in that case I can take a chance because people are getting more than 70, most of the people are getting more than 70. It is skewed on the right, so that is why this is a favorable situation. So, that also is possible.

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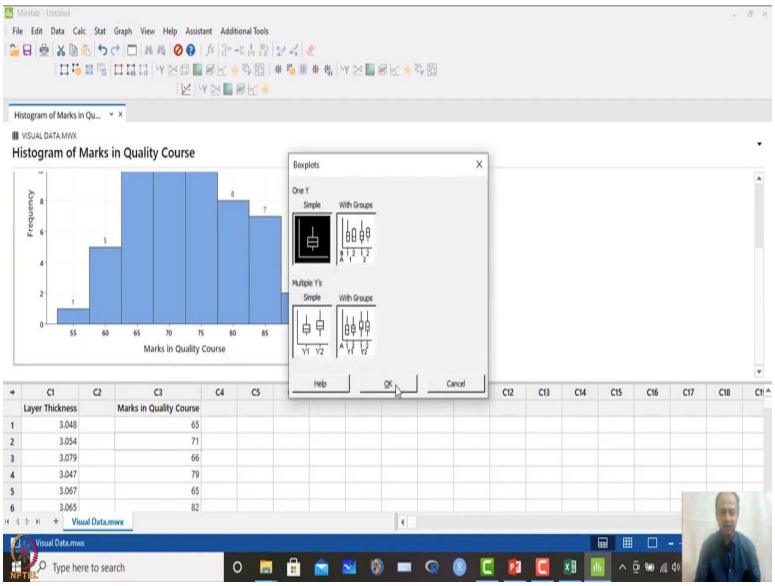

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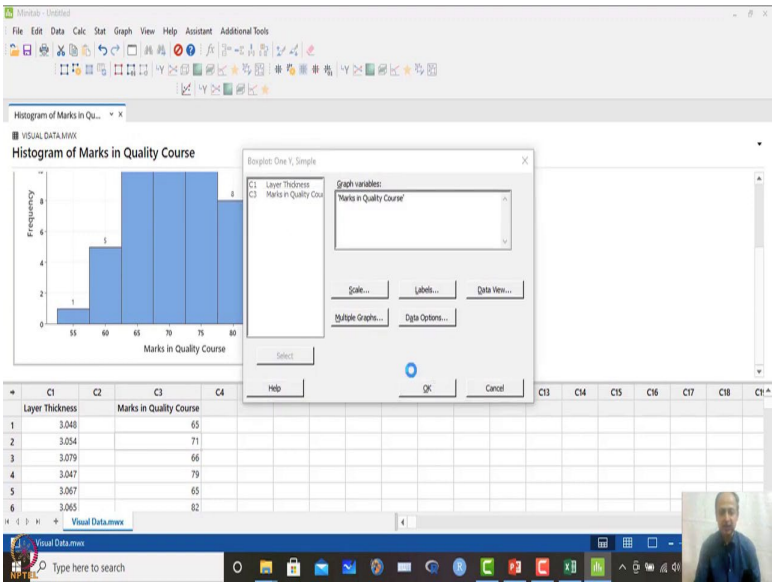

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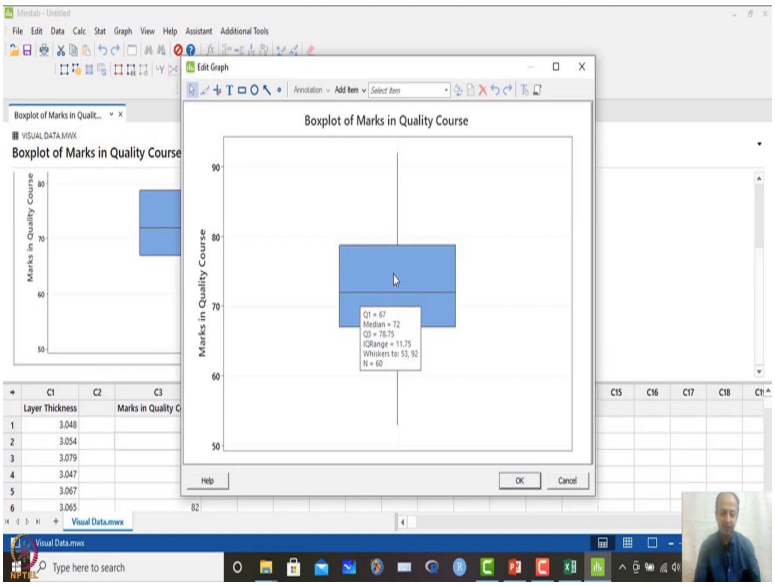

But if I want to make a box plot and interpretation also, I can see that one, and I can also see the marks information, and I can draw the box plot. And when I see that one also, I see the same information, but there is some variability over here, and but favourable is more than 70, many observations are more than 70.

So, you do not see symmetry over here. So, more observations on the other side, so density of that is more. So, colour blue is on the, so it is not symmetrically what do you see. So, there is this more values on the other side. So, skewness will be represented also in box plot.

You can directly see which side it is more skewed. Data is concentration, data concentration is more on one side as compared to the other side. So, that gives you an immediate impression that what we can do out of this data that we are. So, some inference we can draw, some decision we can make out of this ok. So, box plot can also be used we can draw multiple plots over here.

So, let us take another example like I have some data set where restaurant information is given. And I want to see which restaurants to go which has minimum service time. So, some data is provided over here. So, like a Burger King, Pizza Hut, McDonalds, Subways, Domino's Pizza and all are providing burgers let us say, and I want to take wherever there is a least time. So, some random sample information is given over here.

So, this information was collected by some researchers. And based on that, I have to make a decision which restaurants I should go. So, what I can do is that I can just copy this information. I do not know much about statistics, but I want to place that one. And I want to compare these data values.

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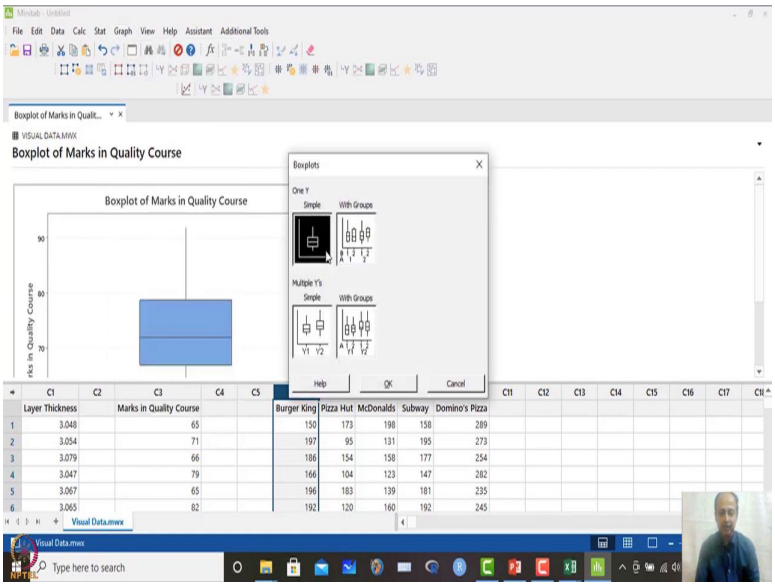

So, in this case, in one go, I want to analyze this one. So, Burger King this data I have pasted from there copy pasted from excel, and then I want to see that how its box plot, can I see multiple graphs in one. So, what I will do is that, I will go to box plot over here, then I will go to multiple Y options over here, I click OK over here.

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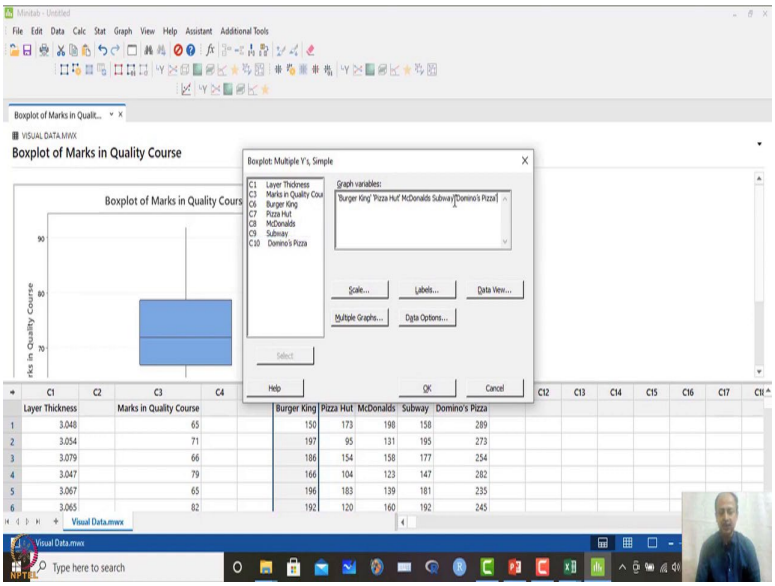

Then I, what I do is that Burger King from here, and I press shift and I select up to C10. So, then I select this one and it will automatically; or otherwise, what you can do is that just double click one, then second one, third one, fourth one and fifth one. And keep it as default and whatever conditions.

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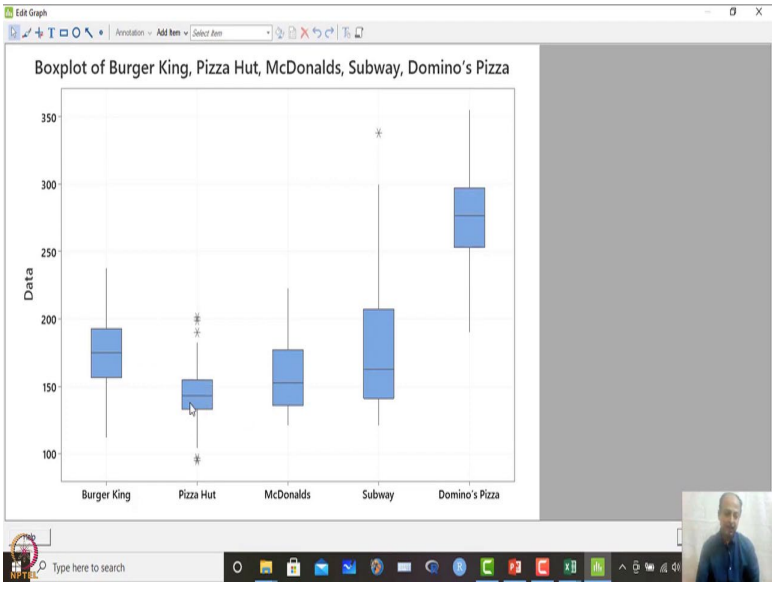

So, you will get this graph in the session window. So, if you enlarge this graph, what happens is that you can see in one scale in one graph you can see the variability of the dataset. So, the Pizza Hut condition what you see is that it is this is the median value

over here. And the median value is coming out of 143 which is very less as compared to any of the median that you see that central line that you see any of the median.

So, this is the lowest, it is giving you the lowest median, that means, you can also see that this information helps you that what is the median value of the observations which can be taken as the location of the data central tendency of the data set also we can consider. Sometimes medians can be useful for that interference also, but mean also can be calculated and we can see the values of means ok.

But what it says is that the median value is very low is lower than any of these options. So, immediately I can discard Domino's Pizza because this is very high. And then subway it is also high and variability is also high. This bandwidth of the box that you see over here the bandwidth is quite high. So, this is also not favourable for me, and this is also quite high, Burger King is also quite high.

So, I have options between Pizza Hut and McDonald. But if you see Pizza Hut and McDonald, what comes into my mind is bandwidth of the Pizza Hut that interquartile range is quite low as compared to McDonalds over here. So, I will select Pizza Hut because that is the service time of Pizza Hut is less as compared to McDonald over here. Although you can see some outliers over here, there is some service disruption may have happened in one or two cases, but I may be willing to take the risk.

But if it is on the lower side, you see that one star is over here on the lower side of this. This is also an outlier, but this is a favourable situation. If you see delivery time less means it is a favourable situation. So, in this case, I am not worried about this. And these two I can take it because I can see that most of the observations are having less variability in service time.

So, variation in service time is also less and the median value is also quite less. So, I will take a decision to go to Pizza Hut, and take the deliveries. So, if I have to choose between any of these restaurants based on the data, I will choose that one. So, a multiple box plot can be shown in single graph, that is also possible in MINITAB.

So, that is a quick understanding of the data I will have visualization of the data that is possible in many situations we will have such kind of plots which will be helpful in quality also. So, this is box plot what we have illustrated. So, you can just practice that

one, and see some of the data sets of CTQ. And plot in single one or plot in multiple plots in single graph, so that is also possible ok.

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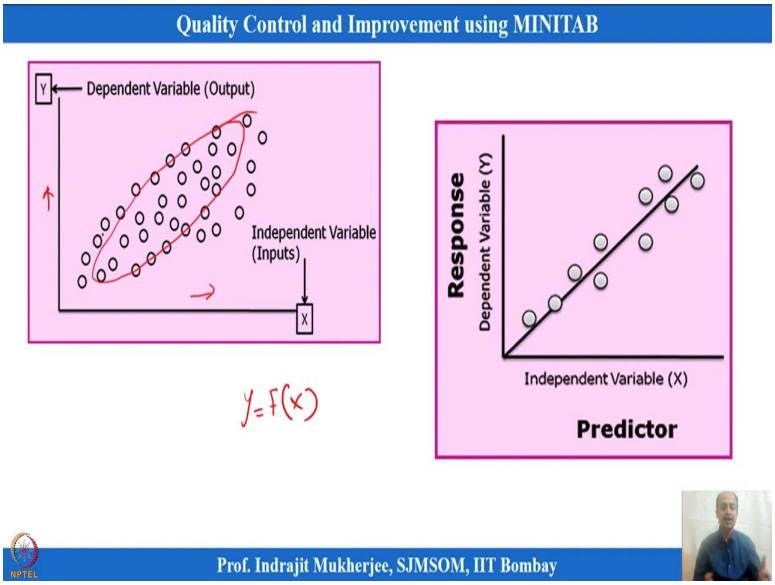

So, then we can do is that, we can also understand and plot like dependency between variables which is known as scatter plot. Sometimes what happens is that this is extensively used in regression. So, this can be used in regression, and we have regression analysis.

So, I will so this is one variable. So, this is one X variable on this axis over here. So, and the other axis is Y over here. So, this is another axis what we can see ok. So, here what is important is that, whether there is any relationship between the data set or not, so that I want to check.

So, whether there is any relationship that exists between the two data set X and Y. So, there I will see this is extensively used in when I am trying to develop a function between Y and X. So, that is where we will use. So, if I am interested to illustrate that this is a X variable, Y is a function of X, I want to see that one.

And whether linear function, non-linear function, so this scatter plot will help me to understand that whether one increases, other also increases or not, so what is the correlation that exists between the data set, strong relationship or weak relationship; linear, non-linear, many things are possible over here ok.

So, this will help in regression analysis. And regression is an important tool in quality. So, that is used in design of experiments also, ok. And that is also used in prediction. Many of the times predictive models are used to control the process to get the best CTQs, so that is also an important aspect what we cover in quality.

So, that is, but you can see any regression analysis in many other courses like statistical course. So, we will give a brief idea of regression also in this course ok. So, what I wanted to illustrate that this gives you a demonstration between relationship between two variables. So, this is known as scatter plot.

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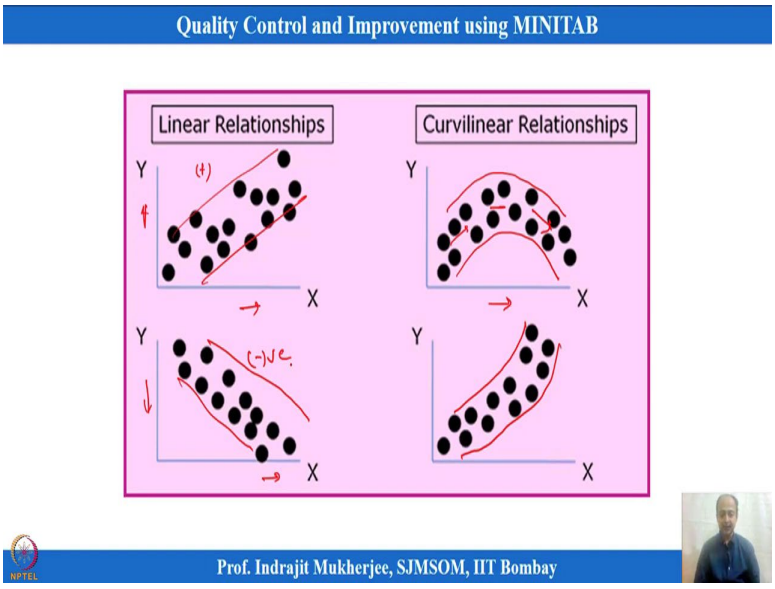

And the relationship can be like this. So, you can see that X and Y is on this axis. So, in this case, the relationship between these two variables name you can change it. So, one axis may be X_1, other axis maybe X_2, but X and Y is that I am trying to say that one is the CTQ, and one is the control variable. So, in this case, control level variable. So, that I want to illustrate over here. And for that what I am doing is that I am showing. So, this is a linear relationship.

So, what we can see is that, one increases, X increases on this side, Y also increases like this. So, here you can see some curvilinear relationship exists. So, this is X increases, initially it increases, and then it becomes steady, and then it becomes this down. So, it is a non-linear kind of scenario. This can also be thought of as non-linear relationship

means this is a polynomial equation basically. So, maybe X square is prominent over here. So, in this case some square equation will be prominent over here.

And here it can be negative relationship that means one increases other goes down. So, one is decreasing. So, one is increasing this can be positive, and this can be negative relationship what you see over here ok. So, these are the types of relationship when you plot that one, you will immediately you can visualize that one and immediately you can make an interpretation out of that ok.

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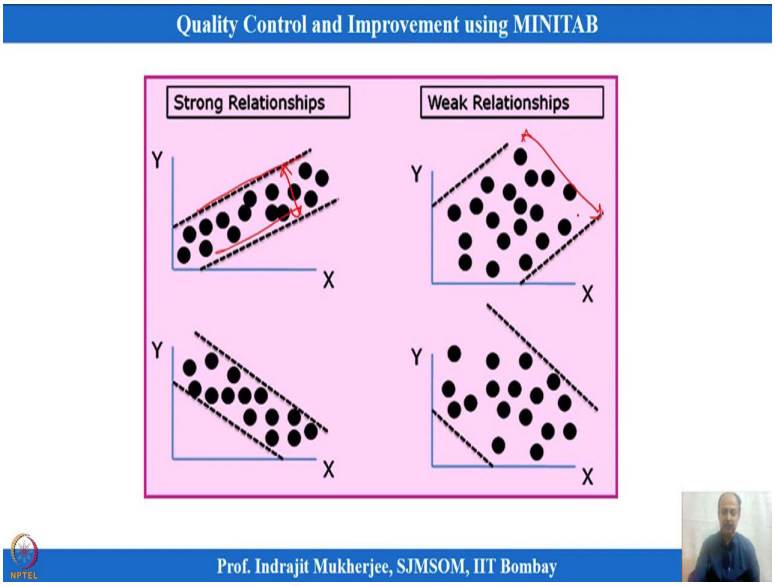

So, visualization of the data set. So, then here you can see that if the density of the data are more concentrated towards this, then that means, strong relationship. So, bandwidth of this is very less and all the data points are within this. So, this is a strong relationship positive one.

And when positive means, one increases, other also increases, and linear relationship that we have to take into mind to consider. So, but the width is very high over here. So, in this case, not very strong relationship. So, how do we say strong weak?

So, we have a correlation coefficient to understand the relationship between variables ok. Pearson correlation coefficient can be seen to see linear relationship between Y and X if X increases, Y increase. What is the strength of the relationship that can be seen linear relationship I am saying. So, in this case, there are options ok.

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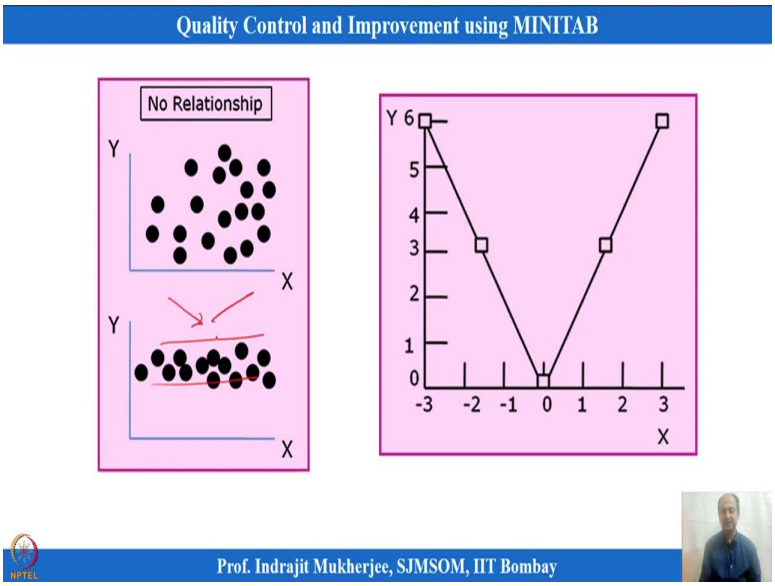

So, this can be seen. So, this is now there is no relationship. You see random ups and downs no trend as we can see increasing, decreasing, nothing is possible over here ok.

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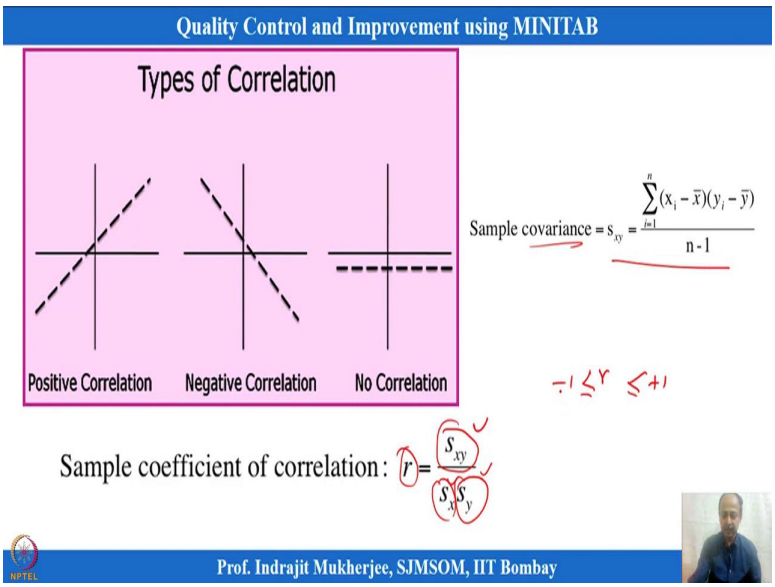

So, and this relationship what we see over here can be expressed in mathematical terminologies which is known as correlation coefficient over here which is given by covariance a measure that association between two variables divided by standard deviation of x variable, standard deviation of y variables. This is the covariance formulation over here what you see.

And covariance divided by these two will give you information about the strength of relationship. So, r lies between minus 1 and plus 1. So, this will be the minus 1 or plus 1 relationship that you will see ok.

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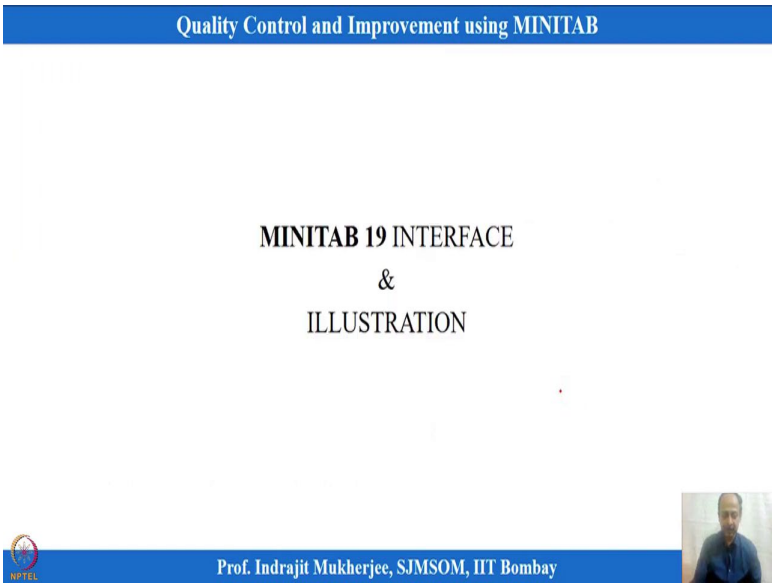

We will take an example to illustrate that one. So, let us take one examples to illustrate this one relationship between both variables, how it can be done in MINITAB. So, I will take one examples over here. And let us take a simple example scatter plot example.

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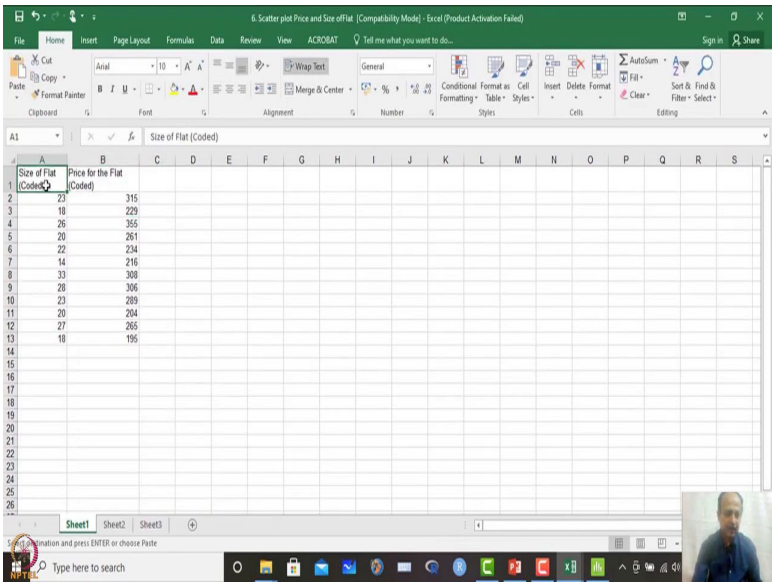

And where we have size of the flat and price of the flat, and I want to see whether relationship exist or not. So, these are coded variables. So, I am just copy pasting the information. So, and I am pasting it over here. So, in this case, I will paste the information over here. And then what I will do is that I want to see the relationship. And first I will draw the scatter plot, and then figure out what is the correlation between these two data points.

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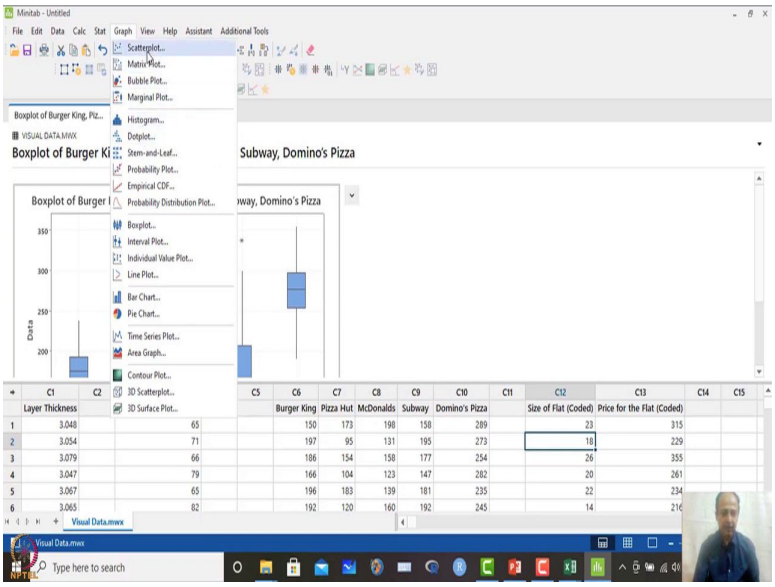

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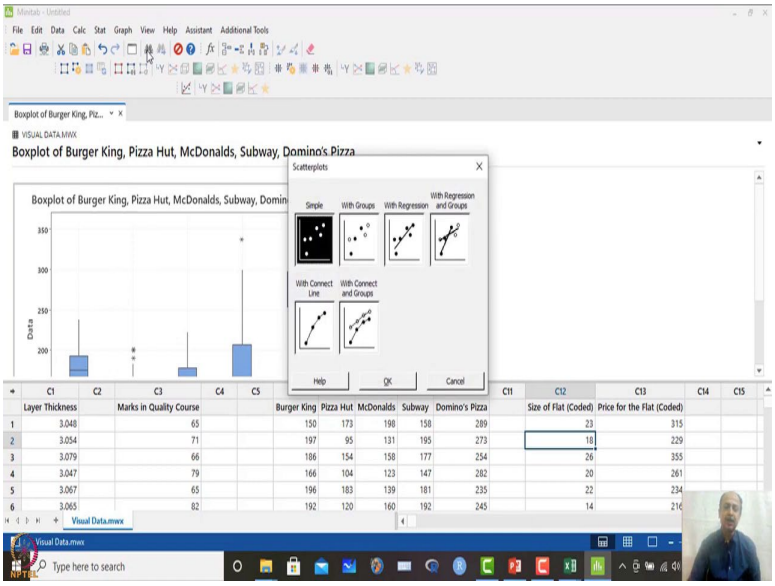

So, what I will do is that I will first option is scatter plot over here. So, when you click this one, what will happen is that it will show do you want a simple scatter plot? Yes, I want a simple scatter plot. There are many options with regression and all these things, I am not interested. I want to see.

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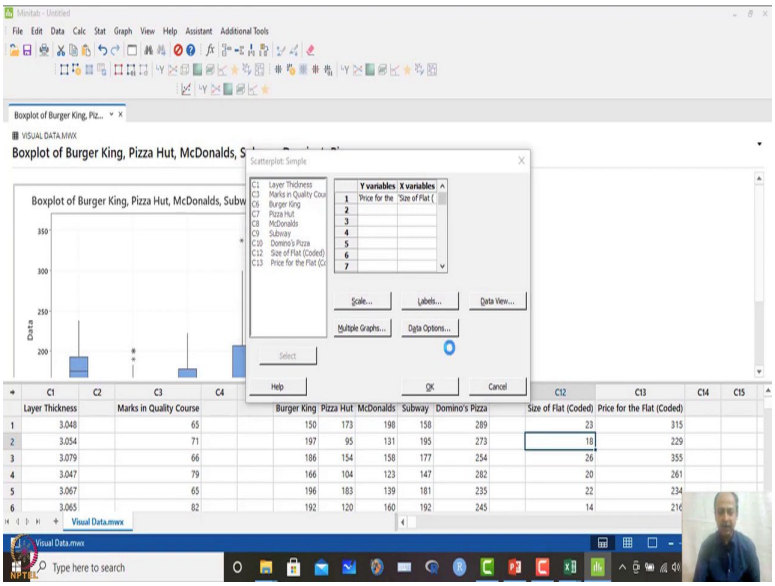

So, which is a Y variable, I am taking arbitrarily price as a Y variable and size of the flat as X variable over here. There are other options that is available over here. I am not going to the options. You can always explore that one. I will click OK over here and it will give me a visual impact over here.

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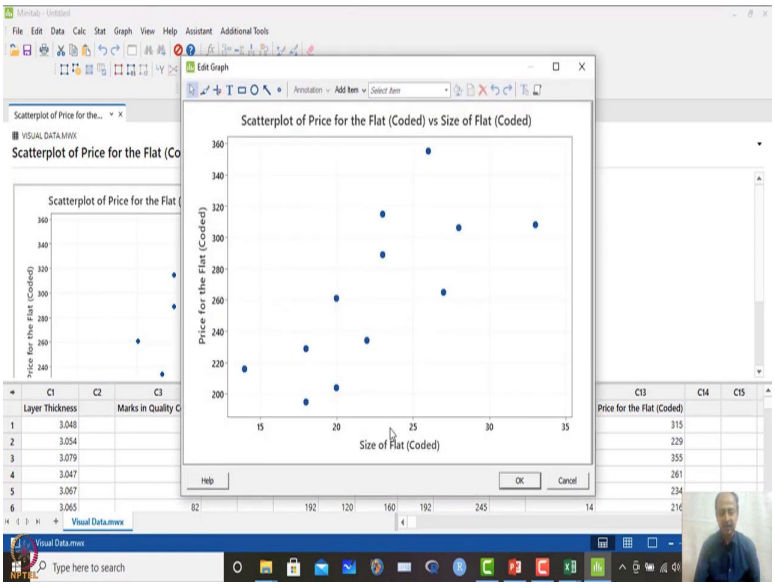

So, if you see the graphical illustration that indicates that size of the flat increases, price also increases. So, this gives you an impression that maybe they are related; maybe they are related over here ok. So, and positively related over here, linear relationship may exist but the strength of the relationship I need to check.

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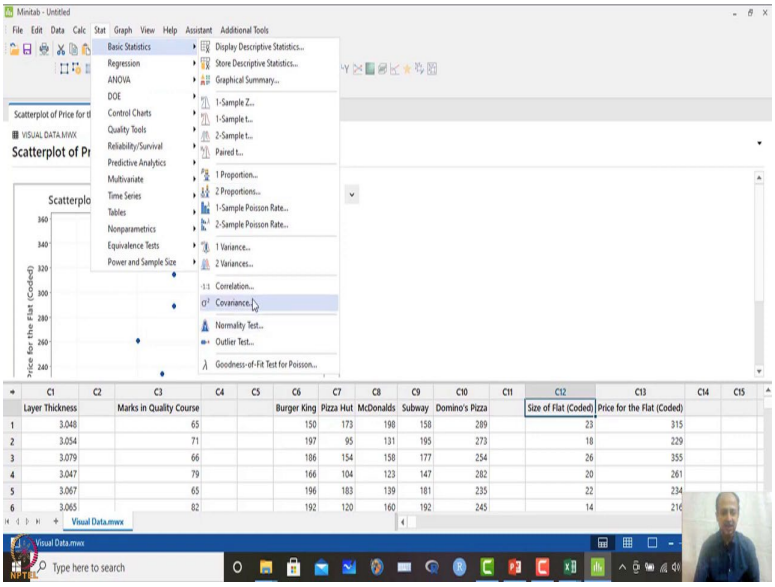

So, in this case, strength of the relationship, how do we see the strength of the relationship over here? Then I have an option to see that one. So, basic statistics then I have a correlation matrix, where the formula that I have shown covariance divided by

standard deviation of X and standard deviation of Y, that formulation what we have shown over here. This formulation will be used.

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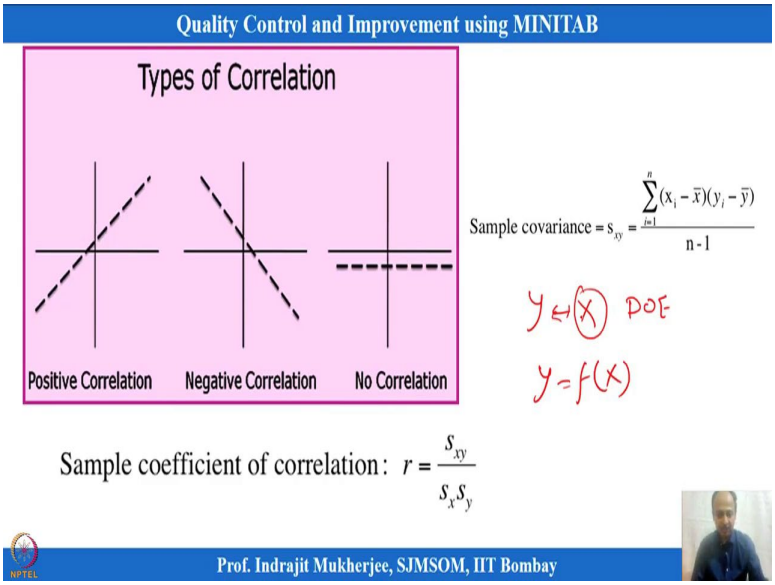

So, this is $\frac{S_{xy}}{S_x S_y}$. So, this is the relationship it will indicate what is the value of r. So, r is on the positive side, plus 1 side, so that is positive strong positive relationship; on the negative side towards minus 1, and close to minus 1 strong negative relationship linear relationship basically ok. So, then what I can do is that I want to see this one. So, in this case MINITAB, I will use this one stat, basic stat, calculation will be done based on the data set X and Y over here which I have defined.

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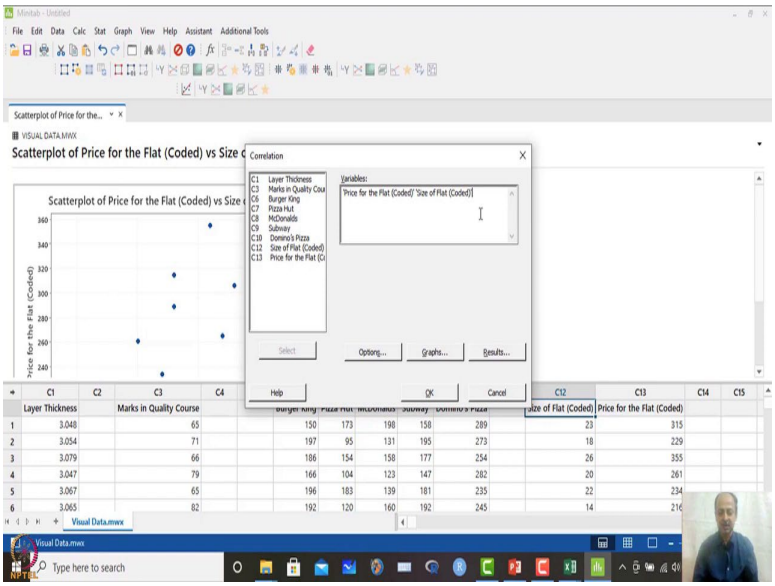

So, correlation between two variables, so I want to see price and size, let us say. So, you can just. So, sequence of this is not important whether price is placed first, size is placed second, it does not matter.

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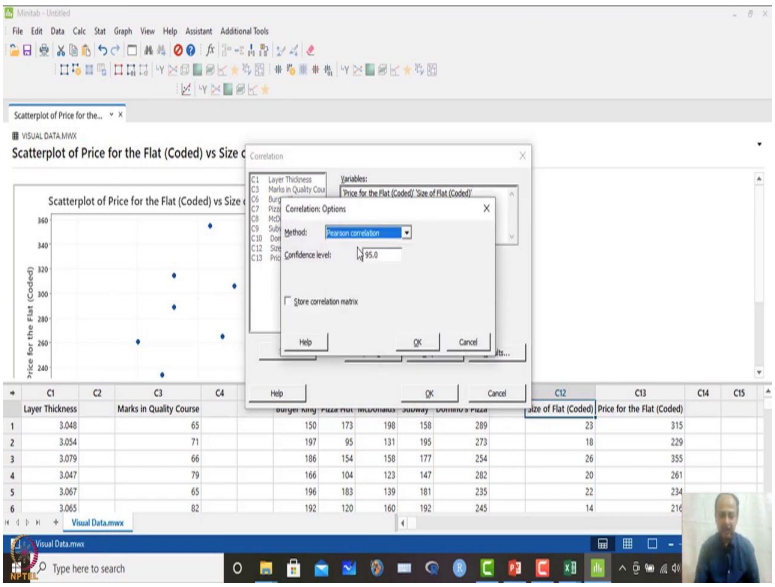

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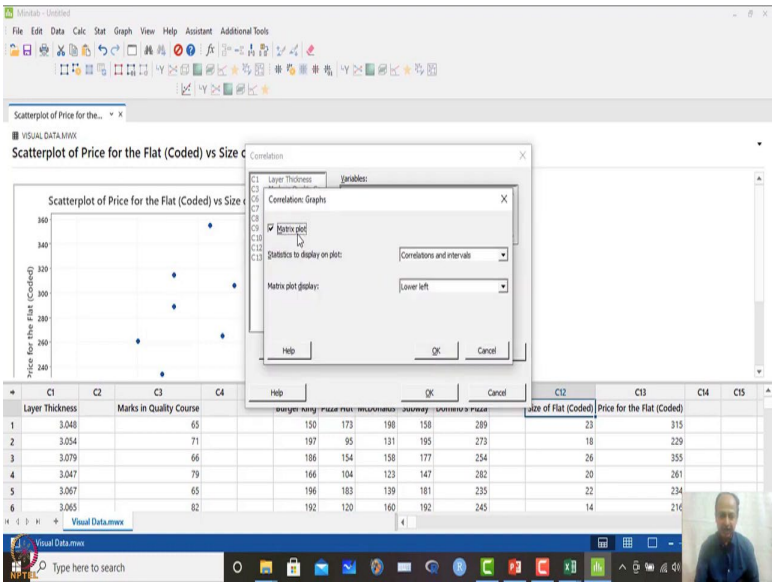

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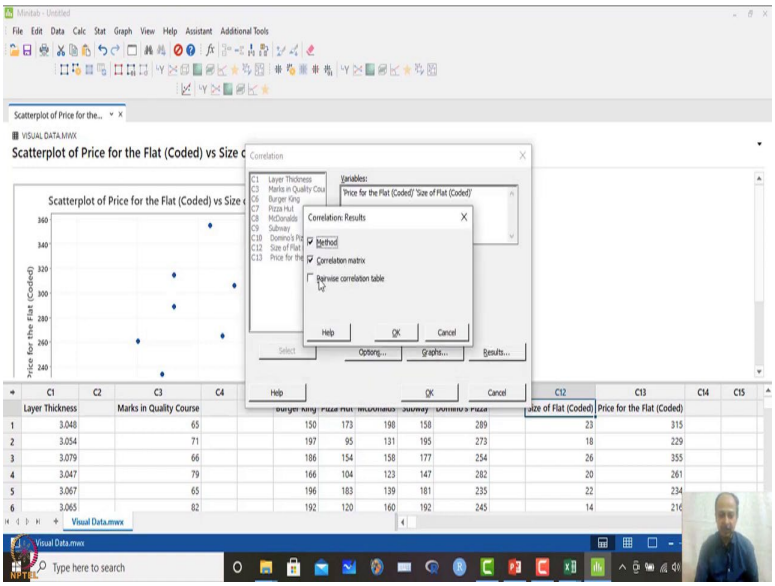

So, option is that I want to see Pearson correlation over here. So, in this case, and graphical matrix plot over here. So, what you want to see over here, I want to see correlations between the variables. So, only there are many options, so statistical interpretation. So, I will use the simplest one over here.

So, I will click OK over here. Then what you want to do you want to see the tables. So, whatever default also you can keep ok. So, correlation coefficient is coming out to be r , 0.727.

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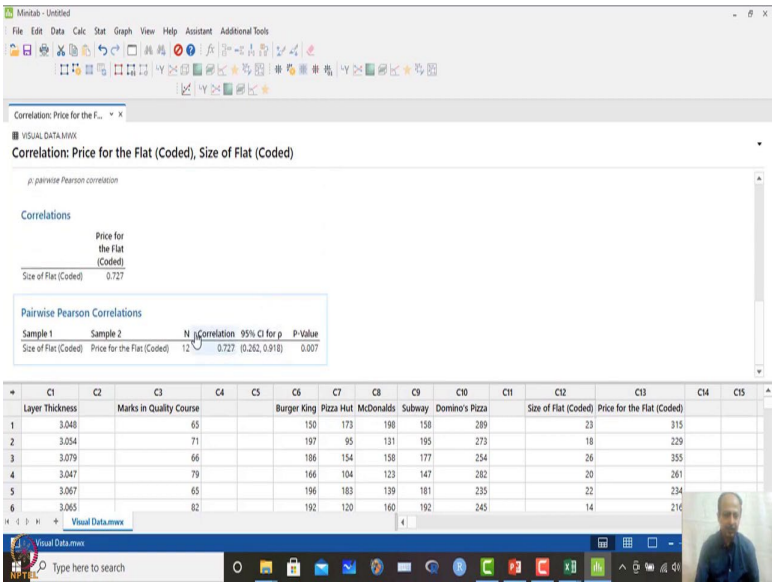

And so, this is the correlation coefficient that you see over here. So, this is the Pearson correlation coefficient that you see over here ok.

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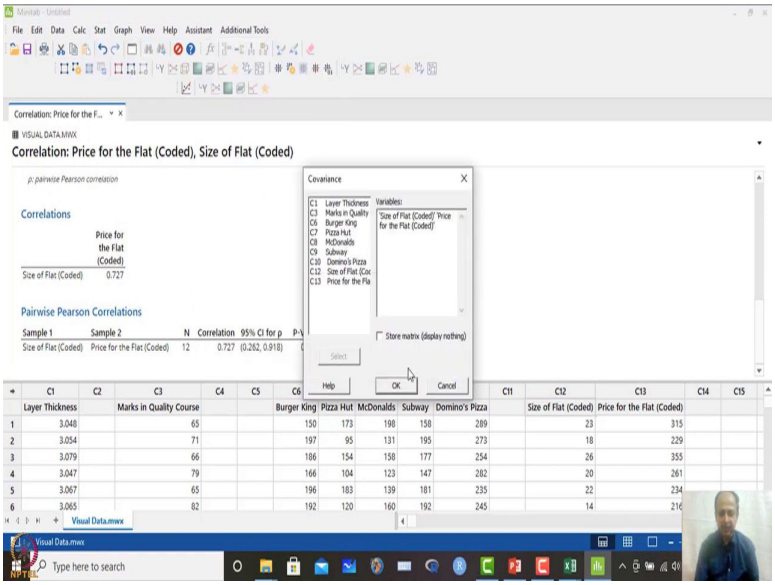

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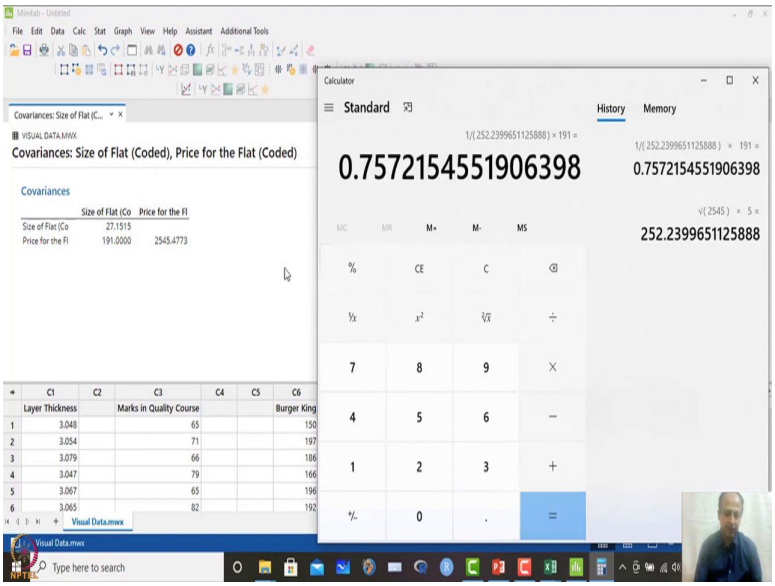

So, variance also what we can see is that basic stat we can also see the covariance of this we can calculate. So, in this case, covariance of this will be given like when you do that one. So, this is the covariance matrix what you see over here. So, in this case, so covariance what you can do is that price and size covariance is 191 basically. So, what I can do is that, I can open a calculator also.

And I can just see the calculations whether it is rightly calculating whether MINITAB is doing it correctly. So, 191 has to be divided by standard deviation. So, size and size this is 27 approximately. This is 2545. So, square root of these two values when you multiply, and then make an inverse, and then multiply with 191 you should get the correlation coefficient.

So, I am making a square root of 27 let us say, and when you do that one around 5, I can assume 2545, I will take a square root of that and it is about 50. So, 50 multiplied by 5, 250; 50 multiplied by I am doing 5 let us say and 250. And make a inverse of this and then multiply it with 191 that is the information that we have. And what we get is 0.75 approximation over here. So, in this case, and what we got earlier was a 0.75. So, earlier what we have got correlation coefficient.

So, in this case, what we have gone is that approximately 0.72. So, some calculation error is coming because of square root and all, but it is perfect. So, 727, if we go by exact

calculation method, so it will be same, value will be 0.7527. So, that is possible, so that is possible. So, we will ignore the last part of this. So, we will consider that one.

So, what is important over here strength of the relationship. So, this is 0.72, what we have seen over here what we have seen. So, graphically what we have seen and positive, so 0.727 that is positive. And generally more than 0.7 can be considered as a strong relationship. And this is on the positive side because this is plus r equals to plus 0.727, so that means, I have a somewhat strength of the relationship is quite high, linear relationship is quite high over here ok.

So, that can be also seen over here. So, this type of analysis how it will help is that it will try to identify. So, when I am defining a variable between relationship between two variables over here. So, y and x over here, and in that case whether they are related or not that will help me to select the x which will be used in design of experiments. And experiment on those things to develop the functional relationship y and x.

So, this can be one of the x that I am trying to see the scatter plot because there is a 2D plot and if you have more variables, we can add more variables over here 3D up to 3D plots are possible ok that can be visualized basically more than 3 dimensions cannot be visualized so in that case.

And it gives you some common sense that this is a potential variable which can be considered when I am modelling that one y with x or which variable can be considered in experimentation to understand when I change the x, it will have impact on y. So, we do not select arbitrarily we select those x, and try to enumerate those x at different levels and try to experiment on using statistical means ok. So, to understand the relationship between y and x.

So, selection can be initial selection can be based on correlation information. So, with this illustration, so we have we will stop over here for this session. So, what we have done is that we have shown you histogram where the data can be plotted and CTQ and we can see the variance of the data and we can also see the central tendency of the data. Then with MINITAB and that is quite convenient.

Then we have a box plot whether straight other data like spring, I can see that concentration of the data is more between these values and this one is first quartile and

third quartile. Interquartile range can also be we can think about the spread of the data ok. Box plot helps you, it can be used for multiple scenario comparison so which is the best option like restaurants what we have taken. So, that is one important plot.

So, in quality I am demonstrating three important plots in this session. So, one is histogram, one is box plot, and the last one what we have demonstrated is relationship between variables because this will help me to select the X variables or control variables which impacts Y basically. So, whether there is any relationship between X and Y, and I am showing linear relationship.

So, non-linear relationship also can exist. And in that case those variables can be selected for experimentation, and finding out the mapping relationship between Y and X which can be used for optimization also. So, this is the overall idea. And we will stop over here. And see you in session 6, and where we will discuss more about quality visualization of data and which are preferably used in quality control and improvement.

Thank you.