## Quality Control and Improvement with MINITAB Prof. Indrajit Mukherjee Shailesh J. Mehta School of Management Indian Institute of Technology, Bombay

## Lecture - 25 Linear Regression (Continued) and Multiple Regression

Hello and welcome to session 25 in the course Quality Control and Improvement with MINITAB. I am Professor Indrajit Mukherjee from Shailesh J. Mehta School of Management IIT Bombay. So, previously we what we are doing is that last session, what we have done is that we are trying to understand regression simple regression and a model adequacy test like that.

So, there can be scenarios where model adequacy can fail and in that case what is to be done there also we want to see in regression. So, I will take one more examples to understanding simple regression, what are the complexities that can arise ok.

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So, this is one of the examples that we are taking over here, where we have two variables Demand and one is Energy Usage, one is Y and one is X over here and this is the scatterplot that you see over here. And this scatterplot says that there is a linear relationship that exists between X and Y over here; and this is the X variable and this is a Y variable over here.

And what we are seeing is that, normal probability plot also says that there may not be any problem and Anderson-Darling test also says there is no problem, but when the residual what we are doing is the residual with fit for what we are seeing is that, there is certainly increase in variability of the residuals as we move ahead with the fits fit values over here. So, it indicates that although we have fitted a regression model over here scatterplot is finely prominent over here.

And we have done model adequacy checks and one of the model adequacy checks is normality distribution normal distributions of the residual, and it is not violating that the Anderson-Darling test shows that Durbin-Watson test also shows that the p-value is quite not significant.

So, in that case there is no problem in autocorrelation of the residual, but Breusch-Pagan test when I am doing this in R what I am saying is that p-value is quite significant that means, 0.0007 and that means, heteroscedasticity is an issue over here. So that means, the model cannot be generalized and we need to correct we need to correct this model.



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And how do we do that? Then what can be done is that we already know that there is a transformation which can be used and we have used a Box-Cox transformation over here, which indicates a value of 0.05 approximately 0.5. So, lambda rounded value is 0.5 so, lambda equals to 0.5 and this indicates that there is a if there is y values, y to the power lambda we have to do and this will be 0.5 on this power over here.

So, this is nothing but square root of y and this will be a function of x we which we have to generate like that ok. So, we have done that correction and after doing the correction what happens regression equation is square root of y and this is the  $\beta_0$ , that was generated and this is the  $\beta_1$  or slope multiplied by x.

Analysis of variance also shows that the x variable is quite significant and the p-value is less than 0.05 and also when we plotted the residual versus fit over here, we do not see any abnormalities now over here.

And the Breusch-Pagan test was again reconducted with this data set of residuals that was saved after we have generated the equation with square root of y and the value of p is 0.89, which is showing that the heteroscedasticity problem is not there.

So, this equation that we are generated can be used for a any unknown observation of x to predict what will be the y like that. We will generate square root of y so, that can be converted into y basically ok. So, this is one of the example. So, let us try to see how we have done this in minute I have so just to for you to facilitate.

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And so, here is the C15 and C16 column is given over here and what we will do is that, we will apply first we will see the scatter plot. So, graphically we can do the scatter plot over here and we can take let us say this is demand information and it is already taken over energy research over here.

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So, if you click ok Y and X variables, the same graph that I have shown in the excel sheets in the PPT this is the same graph what we see. So, strong positive relationship is exist over here that is shown in the scatterplot.

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Then what we will do is that I will go to regression and then fit regression over here. So, fit regression model and then, we will do the demand and then we will take the energy usage over here and then in models what we do is that we include the constant term this is important. So,  $\beta_0$  will be included in the term.

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And in options at present no transformation is required. So, I have click to no transformation over here and other things we do not; we do not do anything over here, one more thing that can be done when whenever we are doing a regression over here. So, maybe validation so, this part can be done in many situation we do that in regression validating the models like that.

So, there are two methods over here, validating with proportional test sets and k fold cross-validations like that. So, people prefers to do K fold cross-validations so, and

generally number of folds that is taken is 10. So, you can see cross-validation, how people are doing 10 fold cross-validation.

The theory behind this is simple very simple, I divide into 10 datasets like that one of the data set will be used as a test data set on which the r square value will be generated and that is the way we do cross-validation. So, that is one option we can keep in mind, when we are generating. So, that we can generalize so, but model adequacy test is required and that will show whether everything is fine.

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So, normal probability plot in and also what we can do is that there is a Pareto plot which can be done and residual what we want is standardized residual; because, we are talking about using standardized residual for normal plots and also for residual versus fit plot, and residual versus order plots can also be seen which says whether there is any dependency between the errors like that.

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So, this can be seen and storage at finally, we can store the standardized residual and click ok and when you click ok over here what will happen is that you will generate equations also.

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	Sale Price(/1000)	Taxes (/1000	)		Temperature	Yeild		HOUSE SIZE	MARKET PRI	E.	Demand NL (Y)	Energy Usage(X)	SQRT(Y)	SRES				
1	25.9	4.917	5		55.0	73.3		72	1	56	0.79	679	0.88882	-0.56559				
2	29.5	5.020			56.0	74.6		98	1	53	0.44	292	0.66332	0.12101				
3	27.9	4.542	2		55.5	74.0		92	2	30	0.56	1012	0.74833	-1,48944				
	25.9	4.557.			59.0	78.5		90	1	52	0.79	493	0.88882	-0.12883				
4		5.059			56.0	74.6		44		42	2.70	582	1.64317	0.89193		100	0	
5	29.9					74.0		16		1.00	2.64	1156	1 00700	0.1.1333				
4	29.9	3,891			55.5	74.17		411		17	3.64		Laurna	0,14555				
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Then, you will generate these Pareto effects shows that anything beyond this red line indicates that that variable is significant that means, energy is said significant over here. So, it depends on the alpha value that we have taken. So, formula is there to find out this cut-off over here anything beyond the cut-off indicates that that variable is important. So, this is a standardized effect plot over here.

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Normal probability pot that you see indicates that not much deviation is there, we have also save the residual. So, residual is saved over here so, we can check whether the basic assumptions of normality for the residual is ok.

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So, we can take the residual and check the Anderson-Darling test we can do that and what we see is that Anderson-Darling test is not showing any adversities over here.

## (Refer Slide Time: 06:45)



And then, here in the previous diagram what we have not seen is this one is that funnel shape what we told heteroscedasticity is prominent that we can see from this graph of residual versus fit.

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And however, the autocorrelation aspects we do not see like there any trends we would would not see over here. So, in this case also we have done Durbin-Watson stat that I told that in this was done earlier, and that was not the problem that was not the issue that we have identified over.

### (Refer Slide Time: 07:08)



So, the Durbin-Watson autocorrelation is not an issue over here because, p-value is coming out to be, but Breusch-Pagan test showed that there is significant heteroscedasticity that is that we are getting. So, in that case model cannot be generalized.

So, we need to do something on this. So, what we can do is that? We can go for transformation, we can go for transformation over here and using the Box-Cox transformation this was done, and what we can do is that this is the then we have to convert the Y variable over here. So, that the residuals we will not have a model adequacy problem over here.

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So, what we have done is that? We have gone for the first option may be that Box-Cox transformation. So, how do you do Box-Cox transformation? Box-Cox transformation of which variable demand over here subgroup size is this.

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Where we want to save that one optimal or rounded value so, let us try to see first then we will save. So, in this case if we click ok what will happen is that Box-Cox will recommend you what is a transformation that is required. So, over here you see the estimated values 0.35, but you can round it off because lower and upper confidence level will include this.

So, 0.5 we can consider as rounded value, because lambda, Y to the power 0.5 is understood by many people that is square root transformation. So, the square root of Y is

required so, we can use that. So, what I have done is that I have taken square root of Y over here, that is in C17 and then I have regressed C17 with C16 like that.

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So, then what I have done is that regressed regression models over here fit regression model. So, everything remains same only instead of this I have taken square root of Y over here.

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	29.5	5.0208			56.0	74.6		98	153		0.44	292	0.66332	-0.44050				
	27.9	4.5429			55.5	74.0		92	230		0.56	1012	0.74833	-1.73409				
	25.9	4.5573			59.0	78.5		90	152		0.79	493	0.88882	-0.36072				
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Everything remains same and I click ok and then what is generated is that, now energy usage is going to be significant p-values over here, even after transformation and 10 fold cross-validations these values is around 61 that means, cross-validation values that we are getting around 61 percent ok.

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Sale P	rice(/1000)	axes (/1000)			Temperature	Yeild		HOUSE SIZE	MARKET PRICE		Demand NL (Y)	Energy Usage(X)	SQRT(Y)	SRES				
	25.9	4.9176			55.0	73.3		72	156		0.79	679	0.88882	-0.74462				
	29.5	5.0208			56.0	74.6		98	153		0.44	292	0.66332	-0.44050				
	27.9	4.5429			55.5	74.0		92	230		0.56	1012	0.74833	-1.73409				
	25.9	4.5573			59.0	78.5		90	152		0.79	493	0.88882	-0.36072				
	29.9	5.0597			56.0	74.6		44	42		2.70	582	1.64317	1.10842		P/	0	
D. M.	29,9	3,8910	realize manage		55.5	74.0		46	157		3.64	1156	1.90788	0,49190			1	
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So, that is on the lower side, but still we may be satisfied with this energy but, there is a significant relationship that exists between this data set and here also this effect plot also shows that this is significant over here. Energy usage is prominent and this variable needs to be considered and there is no problem with the normal probability plot also.

And we want to check whether the final one is heteroscedasticity is problem is eliminated here also we do not see much problem in the behavior of the residuals with respect to X or with respect to fitted values like that. So, and we have done the testing, we have done the Durbin-Watson test for autocorrelation.

We have also done with the transform data, with the transform data and the residual that we have generated and we have also seen that the Breusch-Pagan test also does not show significance, that we that observation we have done when I have converted the data so over here.

What you see is that? After square root transformation Breusch- Pagan test that this is 0.8985 and that is more than 0.05 and that indicates that the problem of heteroscedasticity is removed by using a box cox transformation over here, using a Box-Cox transformation over here. And MINITAB gives you an option that means so whenever I am doing regression over here. So, if I close this one and you can do the transformation.

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So, here regression what you can do is that regression fit regression model over here, and in options what you can do is that you can say transformation lambda equals to 0.5 transformation I want.

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	Coefficients fo ferm Constant inergy Usage(X) C5 Sale Price(/1000) 25.9	0.8396 + 0.000 r Transform Coef 0.8396 0.000364 C6 Taxes (/1000 4.9176	0364 Energ ned Resp SE Coef 0.0561 0.000042 C7	gy Usage(X) conse <u>T-Value</u> 14.98 8.58 <b>C8</b>	P-Value VIF 0.000 0.000 1.00 C9 Temperature 55.0	C10 Yeild 73.3	C11	C12 HOUSE SIZE 72	C13 g MARKET PRICE 156	C14	C15 Demand NL (V 0.7	ct6 ) Energy Usage(X) 3 679	C17 5 SQRT(Y) 0.88882	C18 SRES -0.74462	C19 SRES_1 -0.72844	C20	C21	
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And after doing that you click ok. So, MINITAB will automatically generate a Box-Cox transformation with lambda equals to 0.5 cross-validation 10-fold cross-validation we are doing.

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CS         C6         C7         C8         C9         C4         C13         C13         C4         C13         C13         C4         C13						1 S 10-fold R-si 34 55.179 nse P-Value 0.000	a(pred) 10-fok 56.12% 0.2055 ormed Respo j MS F-Value 5002 73.61	R-sq(adj) 58.27% Ince for Tran	S R-s 0.200195 59.07 Analysis of Vari Source Regression	
Sale Price/0000         Temperature         Yeld         HOUSE 32E         MAXEM PDCC         Demand Rk (1) (nergy UsageQ) S01170         SES         98.53           25.9         4.076         55.0         73.3         72         159         0.79         679         0.882         94.85.3           25.5         5.000         56.0         74.6         98         153         0.44         282         0.6132         0.4240         0.7244         0.7249           25.9         5.000         56.0         74.6         92         220         0.56         1012         0.4633         0.7349         1.7278           25.9         5.0507         55.0         74.0         62         200         0.56         1012         0.4603         0.7349         1.7278           25.9         5.0507         55.0         74.6         44         42         2.70         582         1.6407         0.8119         1.7778           25.9         5.0507         55.0         74.6         44         42         2.70         582         1.6407         1.1084         1.1779           25.9         5.0507         55.0         74.6         44         157         3.44         1.1064         1.17					6	10-fold R-si 34 55.179 nse <u>P-Value</u> 0.000	a(pred) 10-fok 56.12% 0.2055 prmed Respo j MS F-Value 5002 73.61	R-sq(adj)           6         58.27%           Ince for Tran           DF         Adj SS           1         2.950           1         2.950	S R-s 0.200195 59.07 Analysis of Vari Source Regression	
25.9         49.76         55.0         73.3         72         156         0.79         679         0.8882         0.74442         0.72944           28.5         50.008         56.0         74.6         94         153         0.44         262         0.6632         0.47462         0.72944           27.9         4.5429         55.5         74.0         92         220         0.56         1072         0.73249         -77294           25.9         4.557         55.0         73.5         99         152         0.79         430         0.8882         -0.4842         0.2744           25.9         4.5571         55.0         73.5         99         152         0.79         430         0.8882         -0.4847         0.72444         1.77249           25.9         5.0597         56.0         74.6         44         42         2.70         582         1.46317         1.1042         1.17192           26.9         5.0597         56.0         74.6         44         42         2.70         582         1.46310         1.11192         1.17192           29.9         5.0597         56.0         74.6         44         42         2.70         582 </td <td>2 C16 C17 2 C18 C19 C</td> <td>C15 g</td> <td>CI3 g CI4</td> <td>C12</td> <td>C10</td> <td>is 10-fold R-si 34 55.173 nse P-Value 0.000 0.000 C9</td> <td>a(pred) 10-folk 56.12% 0.2055 prmed Respo j MS F-Value 5002 73.61 7 C8</td> <td>R-sq(adj)           6         58.27%           Ince for Trans           DF         Adj SS           1         2.950           2         2.050           C6         C6</td> <td>Source Regression CS</td> <td></td>	2 C16 C17 2 C18 C19 C	C15 g	CI3 g CI4	C12	C10	is 10-fold R-si 34 55.173 nse P-Value 0.000 0.000 C9	a(pred) 10-folk 56.12% 0.2055 prmed Respo j MS F-Value 5002 73.61 7 C8	R-sq(adj)           6         58.27%           Ince for Trans           DF         Adj SS           1         2.950           2         2.050           C6         C6	Source Regression CS	
295         5.000         560         74.6         99         153         0.44         232         0.6012         0.4000         0.67799           293         4.5429         555         74.0         92         23.0         0.56         1072         0.4490         -0.7799           25.9         4.553         59.0         78.5         90         152         0.79         460         0.8082         -0.4000         -0.7799           29.9         5.0971         56.0         74.6         44         42         2.70         582         1.4417         1.1042         1.17192           29.6         5.0971         56.0         74.6         44         42         2.70         582         1.4417         1.1042         1.17192           29.6         3.6971         55.5         7.0         46         137         3.44         1.156         1.6470         0.6119           1         H         +         Simple Linear Represion.max         4 <t< td=""><td>12 C16 C77 12 C18 C09 C (Y) Energy Usay(X) S01(Y) S185 S18(5,1</td><td>C15 g Demand NL (V)</td><td>CI3 <sub>22</sub> CI4 MARKET PRICE</td><td>C12 HOUSE SIZE</td><td>C10 Yeild</td><td>d s 10-fold R-sr 34 55.173 nse P-Value 0.000 C9 Temperature</td><td>a(pred)         10-folk           56.12%         0.2055           prmed         Respo           j MS         F-Value           5002         73.61           7         C8</td><td>R-sq(adj)           6         58.27%           Ince for Tran           DF         Adj SS           1         2.950           C6         axes (/1000)</td><td>S R-5 0.200195 59.07 Analysis of Vari Source Regression Part Harmon CS Sale Price(/1000)</td><td></td></t<>	12 C16 C77 12 C18 C09 C (Y) Energy Usay(X) S01(Y) S185 S18(5,1	C15 g Demand NL (V)	CI3 <sub>22</sub> CI4 MARKET PRICE	C12 HOUSE SIZE	C10 Yeild	d s 10-fold R-sr 34 55.173 nse P-Value 0.000 C9 Temperature	a(pred)         10-folk           56.12%         0.2055           prmed         Respo           j MS         F-Value           5002         73.61           7         C8	R-sq(adj)           6         58.27%           Ince for Tran           DF         Adj SS           1         2.950           C6         axes (/1000)	S R-5 0.200195 59.07 Analysis of Vari Source Regression Part Harmon CS Sale Price(/1000)	
27.9         4.5429         35.5         74.0         52         236         0.056         1012         0.4181         -17.4269         -17.2784           25.9         4.5571         59.0         75.5         590         152         0.79         430         0.8882         -0.6287         -0.8397         -0.8267         -0.8370         -0.8370         -0.827         -0.8370         -0.827         -0.8270         -0.8370         -0.827         -0.8370         -0.827         -0.8270         -0.8370         -0.827         -0.8370         -0.827         -0.8370         -0.827         -0.8270         -0.8370         -0.827         -0.8370         -0.827         -0.8270         -0.8370         -0.827         -0.8370         -0.827         -0.8270         -0.8370         -0.8371         -1.1042         1.17192         -0.8421         -1.111         -1.111         -0.821         -0.8411         -1.111         -0.8111         -0.8111         -0.8111         -0.8111         -0.8111         -0.8111         -0.8111         -0.8111         -0.8111         -0.8111         -0.8111         -0.8111         -0.8111         -0.8111         -0.8111         -0.81111         -0.8111         -0.8111         -0.8111         -0.81111         -0.81111         -0.81111	g         C16         C17         g         C18         C19         C4           (Y) [nergy:Uage(X)         S00TM)         S845         S845,1           79         679         035892         -0,74462         -0,7264	C15 15 Demand NL (Y) 0.79	C13 g/ C14 MARKET PRICE 156	C12 HOUSE SIZE 72	C10 Yeild 73.3	15         10-fold R-signal           34         55.178           nse         -           P-Value         -           0.000         -           C9         -           Temperature         -           55.0         -	a(pred)         10-fold           55.12%         0.2055           prmed         Respo           j MS         F-Value           5002         73.61           7         C8	R-sq(adj)           6         58.27%           Ince for Tran           DF         Adj SS           1         2.950           6         axes (/1000)           4.9176	S         R-5           0.200195         59/07           Analysis of Vari           Source           Regression           C5           Sale Price(7000)           25.9	
229         42073         990         785         99         152         0.79         489         0x882         cd/007         0x870           229         5.0997         56.0         74.6         44         42         2.70         582         1.6497         1.1042         1.1792           249         5.0997         56.0         74.6         44         42         2.70         582         1.6497         1.1042         1.1792           249         6.0997         55.0         74.6         44         42         2.70         582         1.6497         1.1042         1.1792           10         +         ************************************	g         C16         C17         g         C18         C19         C           (1)         (1)         (2)	C15 20 Demand NL (Y) 0.79 0.44	C13 pj C14 MARKET PRICE 156 153	C12 HOUSE SIZE 72 98	C10 Yeild 73.3 74.6	15         10-fold R-signal           34         55.178           nse	a(pred)         10-fold           55.12%         0.2055           prmed Respo         j MS           F-Value         5002           5002         73.61           7         C8	R-sq(adj)         58.27%           Ince for Trans         DF         Adj SS           1         2.950         3.060           C6         axes (/1000)         4.9176           5.0208         5.0208         5.0208	S         R-5           0.200195         59/07           Analysis of Vari           Source           Regression           C5           Sale Price/1000)           25.9           29.5	
299 3.0997 560 746 44 42 2.70 582 1.64317 1.1042 1.17192 299 3.8101 555 72.0 46 157 3.644 1157 3.64 1156 6.2190 6.1191 1 H + Single Linear Represionances 4	C16         C17         g         C18         C09         C           Y1         Energy Usage(3)         SORT(1)         SR45         SR45,1         SR45         SR45,1           79         Or 90         SOR502         -0.4430         AC344         AC344         AC344         AC344         AC3443         AC3444         AC3444         AC3444         AC3444         AC3444         AC3444         AC3443         AC3444         AC34444         AC3444         AC34444         AC34444         AC34444         AC34444         AC34444         AC34444         AC344444         AC344444444         AC3444444444444444444444444444444444444	C15 pp Demand NL (Y) 0.79 0.44 0.56	C13 10 C14 MARKET PROCE 155 153 230	C12 HOUSE SIZE 72 98 92	C10 Yeild 73.3 74.6 74.0	15 10-fold R-si 34 55.178 nse P-Value 0.0000 0.000000	q(pred)         10-fok           56.12%         0.2055           prmed Respo           j MS         F-Value           5002         73.61           7         C8	R-sq(adj)         58.27%           ince for Tran         DF           Adj SS         1           2.950         2.950           C6         axes (/1000)           4.9176         5.0208           4.502         2.920	S         R-s           0.200195         59.07           Analysis of Vari         Source           Regression	
749 3/8410 55.5 74.0 46 1577 3.64 1156 1.60728 0.64191 6.61191 4 1 + + Single Linear Regression.mnz 4	C16         C17         C18         C49         C4           (1) Energy Usapp(0)         SORT(1)         SRES         SRES.1           (2) 0         79         O18         SRES.2         -0.7464         -0.7364           22         20.6512         -0.4603         -0.7374         -0.7374           26         50.7012         -0.7384         -0.72798         -0.72798           79         400         SR802         -0.36072         -0.35752         -0.3575	C15 20 Demand NL (V) 0.79 0.44 0.56 0.79	C13 70 C14 MARKET PRICE 156 153 230 152	C12 HOUSE SIZE 72 98 92 90	C10 Yeild 73.3 74.6 74.0 78.5	ID-fold R-set           34         55,178           nse         P-Value           0,000         0,000           C9         Temperature           55,0         55,0           59,0         59,0	Appred         10-fold           56.12%         0.2055           primed         Respo           pimed         Respo           j MS         F-Value           0002         73.61           7         C8	R-sq(adj)           6         58.27%           Ince for Tran           DF         Adj SS           1         2.950           C6         axes (/1000)           4.9176         5.0208           4.5429         4.5573	S         R-s           0.200195         59/07           Analysis of Varies         Source           Regression         CS           Sale Price/1000)         25.9           29.5         27.9           25.9         25.9	
	C16         C17         C18         C19         C           (M) Derey Usapp(X)         500T(M)         5885         5885.1           79         6.79         0.5802         -0.7446.4         -0.7244           4220         0.64532         -0.4453         -0.7349         -0.7234           56         D102         0.7483         -0.7349         -0.7379           79         490         0.8622         -0.8072         -0.8072           70         552         1.64117         1.0342         1.7172	C15 pp Demand NL (Y) 0.79 0.44 0.56 0.79 2.70	C13 12 C14 MARKET PRICE 155 153 230 152 42	C12 HOUSE SIZE 98 92 90 90 44	C10 Yeild 73.3 74.6 74.0 78.5 74.6	Is         10-fold R-signal           34         55.178           nsc         9           P-Value         0.000           0.000<	g(pred)         10-fold           56.124         0.2055           prmed         Respo           j MS         F-Value           5002         73.61           77         C8	R-sq(adj)           6         58.27%           Ince for Tran           DF         Adj SS           1         2.950           *         0.66           axes (/1000)         4.9176           5.0208         4.5429           4.5573         5.0597	S         R-s           0.200195         59/07           Analysis of Vari         Source           Regression	
	0         Cfo         Cf7         g         Cf8         Cf9         Cf9           (1)         Energy Usage(X)         SORT(Y)         SR45         SR451            70         Or9         D8882         -04426         A7244          A724         A7246         S7445          A7456          A7476          A74776          A7476          A74776          A74776          A74776          A747776          A7477776          A7477777777777777777777777777777777777	C15 p Demand NL (Y) 0.79 0.44 0.56 0.79 2.70 3.64	C13 p C14 MARKET PRICE 155 153 230 152 42 157	Ct2 HOUSE SIZE 98 92 90 90 90 90 90 90 90 90 90 90 90 90 90	C10 Yeild 73.3 74.6 74.0 78.5 74.6 74.0	Ib-fold R-ss           934         55.178           nse         0.000           0.000         0.0000           0.000         0.0	g(pred)         10-fok           56.124         0.2055           prmed         Respo           j MS         F-Value           5002         73.61           6002         73.61           7         C8	R-sq(adj)           b         58.27%           DF         Adj SS           1         2.950           *         * <td>S         R-s           0.200195         59/07           Analysis of Varie         Source           Regression         CS           Sale Price(n000)         25.9           29.5         27.9           25.9         25.9     <!--</td--><td></td></td>	S         R-s           0.200195         59/07           Analysis of Varie         Source           Regression         CS           Sale Price(n000)         25.9           29.5         27.9           25.9         25.9 </td <td></td>	
Single Linear Regression.max 🗰 🗒 🗆 –	C16         C17         C18         C19         C19           (1) fuergy Usaqu(0)         SORT/m         SNRS         SNRS         SNRS           79         670         SORT/m         SNRS         -0.7424         -0.7244           220         6.64312         -0.4445         -0.7243         -1.72796           56         1071         0.74833         -1.7340         -1.72796           70         420         SORT/m         SNRS         -0.8372           70         522         1.64317         1.0842         1.1712           64         1156         1.67780         0.4110         0.4110	C15 p Demand NL (Y) 0.79 0.44 0.56 0.79 2.70 3.64	C13 p C14 MARKET PRICE 156 153 230 152 42 157 4	Ct2 HOUSE SIZE 98 92 90 44 46	C10 Yeild 73.3 74.6 74.0 78.5 74.6 74.0	ID-fold R-si           34         55.178           nse         P-Value           0.000         0.000           C9         Temperature           55.0         56.0           55.5         59.0           56.0         55.5	repred) 10-fold 56.12% 0.2055 0000 73.61 0000 73.61 7 C8 7 C8	R-sq(adj)           b         58.27%           ance for Trar           DF         Adj SS           1         2.950           *         7.66           axes (7000)         4.9176           4.5273         5.0597           3.8910         Ie Linear Regree	S         Res           0.200195         59:07           Analysis of Varia         Source           Regression         Regression           Sale Protections         25:9           22:9         25:9           22:9         25:9           22:9         25:9           22:9         25:9           22:9         25:9           20:9         25:9           20:9         25:9           20:9         25:9           20:9         20:9           20:9         20:9	
📲 🖓 Dune here to search 🛛 🗧 🧮 🚔 🖼 🦓 🗰 🚱 🚯 🗰 🖓 🕅 🕅 🕅	C16         C17         C18         C19         C10           (7)         Gengy Usaget0         SORT/M         Stats         S455.1           279         G79         G5822         -0.74442         6.759.4           44         282         G6532         -0.4445         6.759.4           56         1020         G7433         -1.7149         -1.727.9           79         449         G8642         -0.4645         0.11742           70         521         1.44317         1.1084         1.1712           64         1154         1.42171         1.0444         1.1712	CI5 2 Demand NL (Y) 0.44 0.56 0.79 2.70 3.64	C13 10 C14 MARKET PRICE 156 153 230 152 42 157 4 4	C12 HOUSE SIZE 98 92 90 44 46	C10 Yeild 73.3 74.6 74.0 78.5 74.6 74.0	3 10-fold R-ss 34 55.177 nse P-Value 0.000 0.000 7emperature 55.0 56.0 55.5 59.0 56.0	g(pred)         10-fold           56.12%         0.2055           prmed         Respo           j MS         F-Value           5002         73.61           7         C8	R-sq(adj)         58.27%           b         58.27%           DF         Adj SS           1         2.950           2         3.660           axes (/1000)         4.9176           5.0208         4.5573           3.5057         3.8910           telenar Regree         response	S R+3 0.200195 5907 Analysis of Varie Regression CS Sale Price(7000) 25.9 25.9 25.9 25.9 25.9 25.9 25.9 25.9	

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And in that case, what is a corresponding p-values, what is the final equation also it will show. So, this is the final equation it is showing. So, copy as picture we can just paste this one over here and you can see what is the equation final equation that is generated over here.

And the residual that will be generated that is a actual versus minus predicted values for a given value of X and all the residuals when we plot that one and we do the model adequacy check of heteroscedasticity and other things what we observe is that it will it is satisfying basic all conditions, all conditions it is satisfying. So, this regression equation can be used for generalization.

So, within the range of X so, we will not extra pull it, but within the domain of X where the equation is generated within that, any value of X you give I can predict what will be Y over here. So, in this case how do you do that? So, in this case let us assume that this I want to predict something that energy level 676, what will be around 700. Let us say 700 what will be the value of demand. So, what will be the value of demand?

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	Coefficients for Tr Term Constant Energy Usage(X) 0.0 C5 Sale Price(/1000) Tax 25.9	Coef 5 0.8396 000364 0. C6 es (/1000) 4.9176	ed Respo E Coef T 0.0561 000042 C7	000500 14.98 8.58 C8	P-Value VIF 0.000 0.000 1.00 C9 Temperature 55.0	C10 Yeild 73.3	C11	C12 HOUSE SIZE	C13 Z MARKET PRICE	C14	C15 2 Demand NL (Y) 0.79	C16 Energy Usage(X) 679	C17 g SQRT(Y) 0.88882	C18 SRES -0.74462	C19 SRES_1 -0.72844	C20	C21
	Coefficients for Tr Term Constant Energy Usage(X) 0.4 C5 Sale Price(/1000) Tax 25.9 29.5	Coef 5 0.8396 000364 0.7 C6 es (/1000) 4.9176 5.0208	ed Respo E Coef T 0.0561 000042 C7	000500 14.98 8.58 C8	P-Value VIF 0.000 0.000 1.00 C9 Temperature 55.0 56.0	C10 Yeild 73.3 74.6	C11	C12 HOUSE SIZE 72 98	C13 2 MARKET PRICE 156 153	C14	C15 20 Demand NL (Y) 0.79 0.44	C16 Energy Usage(X) 679 292	C17 g SQRT(V) 0.88882 0.66332	C18 SRES -0.74462 -0.44050	C19 SRES_1 -0.72844 -0.67369	C20	C21
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So, in this case what we will do is that regression and regression what you have is predict. So, you can do prediction over here. So, energy uses let us say 700 what will be the predictor square root of Y over here ok. So, we can also see this square root of Y over here.

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So, in this case options confidence interval that can be generated.

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| 29.5  | 5.0208  |  |   | 56.0  | 74.6  | 98  
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  | 0.44  | 292  | 0.66332   | -0.44050  | -0.67369  |   
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| 27.9  | 4.5429  |  |   | 55.5  | 74.0  | 92  
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  | 0.56  | 1012   | 0.74833   | -1.73409  | -1.72798  |   
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| 25.9  | 4.5573  |  |   | 59.0  | 78.5  | 90  
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  | 0.79  | 493  | 0.88882   | -0.36072  | -0.38750  |   
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1	25.9	4.9176			55.0	75.3		12		30		0.79	6/9	0.88882	-0.74462	-0.72844			
2	29.5	5.0208			56.0	74.0		98	1	33		0.44	292	0.665552	-0.44050	-0.67569			
3	21.9	4.5429			33.3	74.0		92	2	30		0.50	1012	0.000003	-1./5409	-1./2/98			
4	25.9	4.5575			59.0	78.5		90	1	20		0.79	493	0.88882	-0.36072	-0.38750			
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So, results over here, regression and predicted tables over here. So, in this case storage if you want to store that one that is also possible, new model is not required. So, in this case what will happen is that this predicted value will be given over here. So, if I copy this one and I paste it over here and I can paste it over here and to show you the values what is being generated over here from the regression equation.

So, fit value is around 1.97. So, this is approximately. So, this generate a square root of Y, this is square root if you make square of this you will get the actual value of Y over

here. So, it will give you a confidence interval, it will give you also a prediction interval. So, this can be we can generate the confidence interval based on certain formulations over here.

So, this is the expected value, but it will have a range it will not be exactly values that you that will come out, but the range of this confidence interval of the values that is predicted is approximately 1.05 to 1.34 and prediction interval is around 0.04 to 2.25 0.04 to 2.25. So, this is this can be also done in MINITAB software.

So, what is the prediction interval, what is the confidence interval for a given value of X? So, given value of X is given as 700 for this I want to predict like that.

So, 700 should be within the operating zone of that control variables that we want to predict, after generating the regression equation and we can do all the checks and finally, we will adopt the equations like that. In real life also we develop the models between Y as a function of X and then, try to use that to reach to the optimal solutions like that where should be the x so that I get the best Y like that ok.

So, this is a simple linear regression where we have many things to understand model adequacy cross-validation then R square values then, beta is significant or not slope is significant or not ANOVA analysis all these things needs to be considered when we are talking about regression ok. So, we can extend this concept of regression to multiple regression, simple regression to multiple regression over here.

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So, multiple regression is nothing but when we have more than one X over here, this is the natural scenario over to we will encounter most of the time. So, this is the matrix of X and there will be one single Y over here. So, this is known as multiple regression, this is known as multiple linear regression.

So, simple is one Y and one X like that simple is one Y and one X, but in case of multiple linear regression what will happen is that there will be multiple variables that will influence that means, in a process when we are talking about this is the CTQ, which is y that can be influenced by many X over here.

So, X p up to X p variables. So, X 1 up to X p variables can influence the process CTQ and all may be potential X all maybe potential X over here, then we want to generate the functional relationship between y and function of all X 1 to X p and I want to generate that function.

So, how do we do that? We do the that by regression, we do that by regression when I have more than one X variable we call it as multiple linear equation and this is the expression that is generalized expression that you see. This is the model empirical model functions that is given over here, and there will be some error whenever I am generating a function and it will not be realistic.

And so, there will be some difference between actual and predicted that will be error or residual and that will be saved over here. So, that we can see and this is the matrix notation that you see in case when multiple X and multiple we have multiple X for predicting a single Y like that. And this is the beta coefficients that is  $\beta_0$  plus  $\beta_1$  like this up to beta p. So, this is estimated over here. So, this is a matrix that you see over here and this beta can be estimated from these values of Y and X.

So, I will have y and I will have multiple observations  $X_1$  up to X p observation. So, this we will have some values let us say for a given value of this can be some values 2 over here, and this can have 1 minus 1 4 or something like that. So, there will be different value. So, 1 row of X will give me certain y over here. So, this is the setting condition that will give me the process condition output condition over here that is the given over here.

So, if you have multiple y observation and multiple X observation and for any row of X we will have y conditions like that then, that will if that is there in that case by matrix we can matrix formulation, we what we can do is that matrix algebra what we can do is that, we can generate what is the value beta over here.

And this is based on some least squares functions over here that is error minimization. Basically, it will minimize error defined partial derivative should be taken over here and that will give me the values of  $\beta_0$  up to  $\beta_p$  ok.

Q	uality Contr	ol and Im	proveme	nt using M	INITAB	
Example		~	V			
Table contains data	Pull strength	Wire length	Die height	Pull strength	Wire length	Die height
on three variables	(Y)	(X1)	(X <sub>2</sub> )	(Y)	(X <sub>1</sub> )	(X <sub>2</sub> )
(whore strongth is	9.95	2	50	11.66	2	360
(where strength is	24.45	8	110	21.65	4	205
considered as Y)	31.75	11	120	17.89	4	400
that were collected	35	10	550	69	20	600
in an observational	25.02	8	295	10.3	1	585
study in a	16.86	4	200	34.93	10	540
semiconductor	14.38	2	375	46.59	15	250
manufacturing plant.	9.6	2	52	44.88	15	290
In this plant, the	24.35	9	100	54.12	16	510
finished	27.5	8	300	56.63	17	590
semiconductor is	17.08	4	412	22.13	6	100
wire-bonded to a	37	11	400	21.15	5	400
frame. Obtain a least	41.95	12	500			
square regression model.		Da	ta Source: <b>N</b> bability for	lontgomery, D. engineers. John	<b>C.</b> (2005). Appli Wiley & Sons	ed statistic
<b>D</b>	Prof. Indra	jit Mukher	jee, SJMS	OM, IIT Bom	bay	

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And MINITAB does it automatically for you. So, in this case one of the example that I am taking over here is known as pull strength and I want to see whether there is any relationship between wire length and die height over here. These are the two X variables and I have multiple observations over here, and this is one set of observation that you are seeing and this is another set of observation that you are seeing over here.

Same variables and same Y over here so, we have placed it side by side. So, that you can see the complete data set like that there are two variables or predictors and one predicted values or CTQ's over here, and I want to see whether the both the variables are important to be included or one is sufficient to model is one and which way I should develop the model.

So, this is a scenario, where multiple regression is required to so, that we can model Y as a function of multiple X; X1, X2 over here.

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So, what we do over here is basically we again do the regression analysis here we instead of one variable two variable information you will get wire length and die heights over here, and this is P-value is showing to be significant again the same interpretation. If P is significant in that case, it will indicate that these variables are important and this should be included in the models like that ok. And R square what you can see the interpretation that we have seen R square that is how much of the variability SS regression by SS total how much of the variability is explained and this is coming out to be 98 which is quite significant and, but what we do is in multiple regression we see R square adjusted ok.

So, R square adjusted gives you a precise estimation over here which is formulation is given over here and we go by mean square, we go by mean square calculation because this prevents overfitting of the model. This is preventing overfitting of the model because, if you keep on adding X R square will increase, but it will not increase R square adjusted until and unless it has significant influence to reduce the mean square error like that ok.

So, another is predicted value that means one observation will be dropped and what is the value prediction, how close is that prediction over here. So, that can be done by R square predicted value over here and MINITAB gives you all options to see how they are calculating R square predicted and you can see some resource on out books resource how R square predicted is.

So, each of the observation will be removed, it will generate a equation and then predict the single observation that is the way we do for R square prediction over here.

Analysis of variance then analysis of variance shows that when I have two variables over here overall it is significant on that regression equation yes it is significant out of these two variable, which is important both are important because the p-value is less than 0.05. So, our interpretation is that we should include both of them in the model ok.

And the overall equation that you will see is that expected value of strength is equal to this is  $\beta_0$  over here, and equation is generated by MINITAB  $\beta_1 X_1$  this is the equation and this is plus  $\beta_2 x_2$  over here, both are significant this coefficient are significant and this is plus sign this plus sign indicates that both are linearly positively related over here. X1 increases, y increases, X2 increases, y also increases like that.

So, these things can be interpreted out of the analysis and how we do that we want to see and this is the surface plot what you see over here, and this is showing you that pull strength that is y how it is related with X1 and the MINITAB also gives you an option to make a 3D plots like that. If you have only two X variables and one Y variables then plotting is also possible like that.

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Session 24	Nonlinearity Transformation	31-01-2021 22:54	Microsoft Excel W	69 KB			
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Weekwise Final Slide	Sales vs Tax Heteroscadastic	31-01-2021 13:25	Microsoft Excel W	9 KB			
-	Simple Linear Regression	25-12-2020 22:20	Minitab Worksheet	7 KB			
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So, we will show that one also. So, in this case how this data is generated later let us go to the analysis part of this. And so, what we will do is that, we will go to the data set and we will try to see multiple regression and when we open the data set this is the data set that is C1 to C3 columns what you observe over here pull strength, wire length, and die height.

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So, what we will do is that, stat we can see graphically first how these two variables are and each of them are related to the Y variable. So, what we will do is that we will say pull strength and wire length I want to see and again pull strength with die height I want to see, how the relationship is and it will plot two diagrams like that.

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So, one of the diagrams is with wire length what you see is that, this is very strong relationship that we observe wire length with the strength and positive relationship exists. So, we expect the coefficient of beta should be positive and here it is somewhat not so prominent, but increasing trend we can see over here.

So, not so strong, but there is a positive relationship that we can understand and it exist and so, we should include that also in the model and after doing the scatter plot we understand, which is to be then we can go for regression. (Refer Slide Time: 21:17)



And fit regression and fit regression model what we will do is that, we will take pull strength as the response variable and continuous predictor it is continuous variable die height and wire length is placed over here.

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And in models what we will do is that we will include constant term that means, beta it has to be included that we have considered other things we are not changing over here. So, terms so we can add, but we you are not adding terms over here. So, we want linear equation at this present moment not polynomial at this time point.

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There if transformation is required we will see, if it is not required we do not need transformation. So, no transformation option is given ok. And coding we can avoid this time because; sometimes x variables are coded like that so, that helps in there is a theoretical advantage if we are doing coding over here ok, in design of experiment coding is done. So, that is an important aspect and step-wise regression we will try to understand afterward.

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And model cross-validation is possible here also. I can go for K fold cross-validation, 10 is the K that we can assume over here, and then graphically we can see is normal plot residual versus fit residual versus order standardized residual and pareto effects whether, all the significant or not I will click ok and then, I can store the residual standardized residual over here and I click ok and then click ok over here and let us see what we are observing.

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So, first is equation that is generated over here, MINITAB displays the equation and so, the equation will be given and we can just paste this over here and we can see that this equation is coming over here. So, this is the equation that we are having and then, next observation our observation is this is a coefficient information that we are getting.

So, this is the equation, second is model adequacy we want to see whether both the variables are important what we observe is that wire length is having a P-value, which is significant and also die height is having a P-value which is significant both the variables

are important then, what we can do is that we can go to the ANOVA analysis and try to see.

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And so, this is the ANOVA analysis which we can copy and try to see this as an image and enlarge that and here also it will be if the coefficients are significant ANOVA will also show that one. So, wire length is coming out to be high value also F over here, die height is also high. So, the P-value is significant that we are observing over here and both the variables are important. So, overall regression there is significant so, over all regression indicates that any one of the variable is significant and that that shows over here in the regression and individually if you have to see each of this P-value we can observe and we can see both are significant over here.

And degrees of freedom regressions what you see over here is that, there are 2 variables so, we have 2 degrees of freedom for these two x variables so, 2 degrees of freedom and each is consuming 1 degree of freedom over here, total number of observations is total degree of freedom 25th or 25 observations we have so, (25-1). And error is the remaining degree of freedom that we can calculate ok.

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And then, it indicates that both are important for us and there are some unusual observation that you there you can see and K fold cross-validation, if you want to see this one copy as image and you can paste this one.

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And you can see that, after cross-validation also model giving good results. So, overall R square adjusted is around 97 that is very good, we will see R square adjusted value over here I told. R square predicted should be closed close to R square adjusted, if the model is correct and can be generalized and 10-fold cross-validation and R square values of that.

Cross-validation means, we are taking one 10, we have divided the data in 10-folds 10 different data sets randomly and one of the dataset is used as testing and the other data set will generate the training data set which is the training data set and based on that we will generate the equation and then, test what is the R square values for the test data set like that.

So, that will be calculated for this and then what is reported is 10-fold R square values that is 97 that is quite good that is quite good over here, what we are observing.

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And then what we see is that, we have the plots also and plots if you see the effect plots what you see is that this at level of alpha 0.05 and this is the cut off over here that you see; and this calculations you can just check formula to do this calculation 2.07 how it and this is given in MINITAB.

So in this case, and also any general books on how they are how they are calculating these values of cut off over here. So, A is significant which is beyond this cut-off, B is also significant which is beyond is both are important and can be included in the regression equation.

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Also normal probability plot you see not much deviation, which most of the observations are middle part.

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So, there is not much deviation, but we have save the residual and we can just check whether the basic residuals follow normality assumptions at the end you will find the residual and this is saved already and you go to Anderson-Darling test and Anderson-Darling test on this dataset indicates that the P-value is not significant.

So, in this case the error residuals is more or less, we can assume that that is ok. And what we can do is that we have not generated the heteroscedastic plots. So, in graph what we can do is that residual versus order residual versus order.

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So, we have not done it. So, we can just check that on graphically. So, this is the graph that we are generating based on this data set, not much unusual observation. So, Breusch Pagan test can be done over here and try to confirm whether there is any heteroscedasticity behavior of the residuals that can be observed, but I do not think it is there and also there is no as such strength that we observe in the standardized residual with observed order over here.

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So, in this case also not so prominent, but we can do that individual testing like that. So, in this case and also we can do the surface plot that I have not shown.

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So, surface plot can also be done, graph over here 3D scatterplot 3D surface plot is option is there. So, I can do a wire diagram or I can do surface plot over here, if you click ok it will tell which is the Z direction which is a variable. So, this is x 1 and x2 variables like that, and you can change the shapes you can change the plots types of plots like this.

So, this is the plot that will be generated surface plot and you can just rotate this one also. So, you can rotate the axis like that. So, that is also possible over here.

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So, I can rotate that is possible over here. So, this is if you want to rotate and see what is happening over here. So, this is also possible in MINITAB and that gives you an idea, how the surface is over here ok.

So, this is also possible in MINITAB this is also possible in MINITAB. So, that we can see all aspects of the regressions all aspects of the regression over here. Similarly there is another data set like this heat and with some variable x 1 to x 4 and we want to see the relationship between this.

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So, we can close this one and we can see another examples of heat and this. So, if you want to generate this one regression equation regression fit regression. So, in this case variables will only change so, heat is the outcome that is measured over here and these are the x1 to x4 variables that you want to include in the model select that one. And then in model include the constant terms that is there and we do not want to increase any other terms over here.

So, this is ok and in options no transformation because everything is let us assume that everything is ok. So, then validation and everything store residuals over here. So, you can store the residuals and you click ok finally, when you click ok.

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	Pull strength	Wire length	Die height		y	x1	X2	X3	X4		Heat	x1_1	X2_1	X3_1	x4_1		Time	Velocity	Temperature	Yeld
1	24.45	2	110		240	23	24	91	100		76.5	1	20	16	60		1300	0.0120	7.5	
2	31.75	11	120		230	45	24	88	110		104.3	11	56	8	20		1300	0.0115	11.0	
4	35.00	10	550		274	60	25	87	88		87.6	11	31	8	47		1300	0.0130	13.5	
5	25.02	8	295		301	65	25	91	94		95.9	7	52	6	33		1300	0.0125	17.0	
6	16.86	4	200		316	72	26	94	99		109.2	11	55	9	22		1300	0.0		
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So, then what happens? The equation is given at the first stage coefficient, which is significant which is not over here. So, you see x1 is significant over x1 is also not significant none of the variable is coming out to be significant over here. So in this case, what is happening is that all the P-values, but in this case ok.

So, but there is a clear relationship R square adjusted value is 97.36 and K fold cross-validation is also high ok. So, in this scenario what we are getting is that x1 is quite prominent, x1 is values is quite prominent over here.

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And the variables what we are seeing is that, there is some issues over here in this case and there is no issues other than that. So, if we have included only one variable over here x1 what happens, that we can see x1 over here only x1, if we consider only x1 over here, what is the scenario?

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	Pull strength	Wire length	Die height		у	x1	x2	x3	x4		Heat	x1_1	x2_1	x3_1	x4_1		Time	Velocity	Temperature	Yeld
1	9.95	2	50		240	25	24	91	100		78.5	7	26	6	60		1300	0.0120	7.5	
2	24.45	8	110		236	31	21	90	95		74.3	1	29	15	52		1300	0.0120	9.0	
3	31.75	11	120		270	45	24	88	110		104.3	11	56	8	20		1300	0.0115	11.0	
4	35.00	10	550		274	60	25	87	88		87.6	11	31	8	47		1300	0.0130	13.5	
5	25.02	8	295		301	65	25	91	94		95.9	7	52	6	33		1300	0.0125	17.0	
6	16.86	4	200		316	72	26	94	99		109.2	11	55	9	22		1300	0.0		
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+	Regression x1_1 Error C1 g	1 1450.1 1 1450.1 1 1450.1 11 1365 7 C2 Wire length	Adj MS F- 1450.1 1450.1 115 1 C3 Die height	Value P- 12.60 12.60 C4	Value 0.005 0.005 CS V	C6 x1	C7 x2	C8 x3	C9 x4	C10	C11 E	C12	C13 x2.1	C14 x3.1	C15 x4.1	C16	C17 Time	C18 Velocity	C19 Temperature	v C2 <sup>4</sup> Yeild
4	Regression x1_1 Error C1 pull strength 9.95	1 1450.1 1 1450.1 1 1450.1 11 1265 7 C2 Wire length 2	Adj MS F- 1450.1 1450.1 115.1 C3 Die height 50	Value P-1 12.60 12.60 C4	Value 0.005 0.005 CS y 240	C6 x1 25	C7 x2 24	C8 x3 91	C9 x4 100	C10	C11 E2 Heat	C12 x1_1 7	C13 x2_1 26	C14 x3_1 6	C15 x4_1 60	C16	C17 Time 1300	C18 Velocity 0.0120	C19 Temperature 7.5	v C2 <sup>4</sup> Yeld
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4 1 2 3 4	Regression x1_1 Free Pull strength 9.95 24.45 31.75 35.00	07 A0133 1 1450.1 1 1450.1 1 1450.1 1 1450.7 C2 Wire length 2 8 11 10 10 10 10 10 10 10 10 10	Adj MS F- 1450.1 1450.1 115 1 C3 Die height 50 110 120 550	Value P. <sup>4</sup> 12.60 12.60 C4	Value 0.005 0.005 y 240 236 270 274	C6 x1 25 31 45 60	C7 x2 24 21 24 25	C8 x3 91 90 88 87	C9 x4 100 95 110 88	C10	C11 12 Heat 78.5 74.3 104.3 87.6	C12 x1_1 7 1 11 11	C13 x2_1 26 29 56 31	C14 x3_1 6 15 8 8	C15 x4_1 60 52 20 47	C16	C17 Time 1300 1300 1300	C18 Velocity 0.0120 0.0120 0.0115 0.0130	C19 Temperature 7.5 9.0 11.0 13.5	v C2 <sup>4</sup> Yeld
4 1 2 3 4 5	Regression x1_1 From Pull strength 9.95 24.45 31.75 35.00 25.02	01 Adj 53 1 1450.1 1 1450.1 1 1450.1 1 1450.7 C2 Wire length 2 8 11 10 8	Adj MS F- 1450.1 1450.1 115.1 C3 Die height 50 110 120 550 295	Value P-' 12.60 12.60 C4	Value 0.005 0.005 V 240 236 270 274 301	C6 x1 25 31 45 60 65	C7 x2 24 21 24 25 25	C8 x3 91 90 88 87 91	C9 x4 100 95 110 88 94	C10	C11 18 Heat 78.5 74.3 104.3 87.6 95.9	C12 x1_1 7 1 11 11 7	C13 x2_1 26 29 56 31 52	C14 x3_1 6 15 8 8 8 6	C15 x4_1 60 52 20 47 33	C16	C17 Time 1300 1300 1300 1300 1300	C18 Velocity 0.0120 0.0115 0.0130 0.0125	C19 Temperature 7.5 9.0 11.0 13.5 17.0	v C2 <sup>4</sup> Yeild
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Fit regression in case of all variables, we can only consider x1 variables over here. And I click ok, and what I will observe is that not much variable it is explain R square adjusted is low. So, we keep on adding the variables and there is no lack of fit also in this, but overall explanation of the total variability. So, we keep on adding the variables x1 is added, that explains some part of the variability when I add x2 that add some part variability x3 and x4 like that.

So, this kind of analysis simple analysis can be done let us also assume these C5 to C9 variables over here, and in this case also we can see the regression equation how we which what is the equation that is generates over here.

th M íæl≞y⊵∎sk∗i⊻ y≥∎sk∗ Regression Analysis: Heat ... Y X I MULTIPLE LINEAR REG Pull stren; Wre lengt Die height Regression Analysis: Heat versus x1\_1 y x1 x2 x3 x4 Heat x1\_1 x2\_1 x3\_1 x4\_1 Time velocity Temperatur Yeld (Y) Drive in tim Dose (X2) Y1\_STD x2\_STD x2\_STD Y (Transisto RBM Heat = 81.48 + 1.869 x1\_1 Continuous predi Coefficients 
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	todel Su s 11.7866 nalysis o course C1 rull streng 9. 24. 31. 35. 25. 16. н + Хироб	mmary <u>R-sq</u> <u>85</u> .20% of Varia <u>95</u> <u>75</u> <u>75</u> <u>75</u> 000 002 <u>86</u> <u>Mult</u> <u>1027</u> <u>86</u>	x R-sq(ad 76.75 ance ani cc C2 e length 2 8 11 10 8 4 tiple Linear	<ul> <li>R-sq(prime)</li> <li>52.4</li> <li>52.4</li> <li>646 MAC E.</li> <li>C3</li> <li>Die height</li> <li>500</li> <li>110</li> <li>120</li> <li>550</li> <li>295</li> <li>205</li> <li>205</li> <li>205</li> <li>205</li> </ul>	ed) 10-fo 8% 16.2 1/shua D- C4	Add S 10-fol 0035 Value	d R-sq 48.45% x1 25 31 45 60 65 72	C7 X2 24 25 25 26	C8 x3 91 90 88 87 91 94	C9 x4 100 95 110 88 94 99	C10	C11 22 Heat 78.5 74.3 104.3 87.6 95.9 109.2	C12 x1_1 7 11 11 11 7 11	C13 x2_1 26 29 56 31 52 55	C14 x3_1 6 15 8 8 8 6 9	C15 x4_1 60 52 20 47 33 22	C16	C17 Time 1300 1300 1300 1300 1300	C18 Velocity 0.0120 0.0120 0.0115 0.0130 0.0125 0.0	C19 Temperature 7.5 9.0 11.0 13.5 17.0	v Yeid
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So, this what we can do is that, we can just go for this Y variable that is over here and these are the x1 to x4 over here and this is selected sorry this is selected over here in the continuous predictor x1 to x4. So, this is selected over here and if I go for this what happens is that, here only one variable comes out x1 to be prominent over here P-value is not significant over here, but we are retaining those variables because that gives me R square adjusted value.

And we can do it automatically also. So, let us try to also discuss this one, how do we select which is the variable to be included which is excluded. So, regression analysis also gives you a fit regression model.

## (Refer Slide Time: 31:14)

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There is a option of step-wise regression over here. So, if I go for step-wise regression over here, it will automatically suggest which variables to keep and which variables not to keep like that.

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So, if I change these variables over here let us say heat is the first variable and we are going for x1 to x4 over here, and I click ok and in this case if I click ok it will suggest which of the variables to be taken and you see that it has only considered one variable that is first variable x sorry second variable it is considered to be placed over here.

So, there is certainly some other problems that is existing and x1 and x2. So, x1 and xs2 is prominent. So, these two variables are included over here. So, these are the two variables to be included, we do not want to include all variables.

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So, we will discuss more about this stepwise regression and you see whenever there is a like previously what we were facing is that which variable we should take because they are not prominent. So, which one will go in which one will go out like that we are not certain like that.

So, what we do is that, we have a method which is known as stepwise regression and best subset regression, which will allow us to identify which variables to include in the model, which variables to in exclude in the model. Because, I was not sure that it is not significant all are not significant.

So, in this case which one will go in and which will give me the best fit like that. So, MINITAB this technique which is known as stepwise automatically identifies, which two variable basically maximizes the R square predicted and R square adjusted value over here. So, this is around 97 percent.

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And this is the best model that you can get out of this dataset that you have generated. So, include x1 this one column C12 and C13 and that gives me an option that, which variables should go in and which variable which should not be included. So, we will continue with this discussion of best subset regression in scenarios when we are in dilemma which will go in and which will go out.

And then, extend that one and discuss about one topic which is known as multi co linearity in regression and that is a one I wanted to discuss. Because, that is that would significantly affects the model generalization basically. So, we will discuss about that in your next class ok.

So, we will start from here where we left we will take some example and how to include x variables like there should not be any dilemma this will go in this will go out, and no confusion in selecting of the variables. So, I have a easy way by going through the stepwise regression and using best subset regression like that, best subset methods to select the variables that will lead to the final generalized model like that.

So, we will stop here and we will continue in our next session.

Thank you.