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REGRESSION ANALYSIS OF AUTHORIZED SERVICE COMPLAINTS IN TERMS OF EQUIPMENT COMPLAINTS

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ABSTRACT
Authorized service providers play an important role in our lives. If we are not happy with their service, it is possible that we report our complaints to the call centers. In this study, we analyze the authorized service and equipment complaints reported to the call center of a boiler manufacturer in Turkey. Our aim is understand whether an empirical model can be constructed relating authorized service complaints to various categories of equipment complaints so that the company can improve its services accordingly. Results indicate that there exists a significant multiple linear regression model expressing authorized service complaints using some categories of the equipment complaints.
Keywords: regression analysis, customer complaints, call center

1. INTRODUCTION
As technology evolves, technological products are used almost everywhere since they make our lives easier. When these products break down or have problems, we want them to be fixed quickly, accurately and at the same time with low cost. At this point authorized service providers play an important role to resolve the equipment complaints and meet customer expectations [1,2,3]. If we are not happy with their service, it is possible that we report our complaints to the call centers [4].
One of the most important technological products that we have as one of our basic household appliances are boilers. We use them for heating and supplying hot water. Due to their tremendous workloads, boilers sometimes develop failures or problems and we need technical support to fix them. We contact the related call center to report the detailed boiler problem. The complaints can be either due to the equipment (boiler) or due to the authorized service. Equipment complaints are obviously easier to analyze the reason of the problem than the authorized service complaints since the latter may depend also on the types of the equipment complaints as well as on the manner or technical background of service employees [5].
There are many engineering problems where empirical models [6,7,8] are used for analysis. Regression is a powerful empirical model to study the relation between two or more variables. We formulate the number of authorized service complaints with a multiple linear regression model [9] to determine the types of equipment complaints having significant effect. This model can be used to reduce the number of authorized service complaints.

2. PROBLEM DEFINITION
A call center collects the complaints of customers. The complaints can be either due to the boiler which we call them equipment complaints or due to the authorized service. Equipment complaints are rather obvious and can be reduced by improving the quality of the boilers and training the authorized service employees. On the other hand, authorized service complaints are more complex since they may depend also on the types of the equipment complaints as well as on the impoliteness or insufficiency of authorized service employees. Hence they are not so obvious and should be analyzed carefully to determine the types of equipment complaints which have significant effect on the number of authorized service complaints in order to reduce the respective number of complaints.

Call center employees welcome customers on the phone to gather their complaints. There are four stages to fix the customer complaints:

- Stage 1: Complaints are received. Customer name, surname, address, phone number and complaint details are asked. Information is entered into the CRM program.
- Stage 2: Customer information and complaints are evaluated by call center employees. Complaints are directed to convenient technical services by call center employees via CRM program.
- Stage 3: Technical services receive the complaint via CRM program.
- Stage 4: Technical service employees go to customers to fix the problems.

It is obvious that the first three stages last shortly whereas the fourth stage is the bottleneck activity since its duration depends on the problem type and the experience of the employee.

3. REGRESSION MODEL

Multiple linear regression analyzes the linear relationship between one dependent and two or more independent variables. We use the multiple linear regression model given in Equation 1 to express the authorized service complaints in terms of equipment complaints where *j* is the index of independent variables and *i* is the index of observations.

$$y_i = \beta_0 + \sum_{j=1}^{k} \beta_j x_{ij} + \varepsilon_i \qquad i = 1, 2, ..., n \tag{1}$$

Let y_i denote the dependent variable which is the number of authorized service complaints in month *i*, x_{ij} be the independent variable which is the number of detailed equipment complaints for the category *j* in month *i*. Complaints of 23 months are taken from the boiler manufacturer. The following eight categories of equipment complaints regarding the boiler are considered as predictors in the model.

Firing problem (FP): The boiler cannot make the firing and hence the water is not heated.
Breakdown (BD): The boiler doesn't work when it is turned on.
Water leakage (WL): The boiler leaks water.
Constantly working (CW): The boiler should stop working after it operates 15-20 minutes. However it works constantly even if hot water is not on.
Error code (EC): There exists an error code on the boiler screen.
Noisy working (NW): The boiler operates loudly when it is on.
Hot water problem (HW): The boiler cannot heat the water.
Low pressure (LP): When the pressure inside the boiler drops, the performance of the boiler reduces.

4. REGRESSION ANALYSIS

Regression analysis is performed in Minitab. Table 1 lists the best two fitting linear regression models with different numbers of predictors evaluated according to the criteria given in columns two to six.

Table 1. Best fitting linear regression models.

Number Vars	R-Sq	R-Sq (adj)	R-Sq (pred)	PRESS	S	PREDICTORS FP	BD	WL	CW	EC	NW	HW	LP
1	94.6	94.4	92.3	21816.1	27.00		X						
1	78.5	77.5	75.5	69683.4	53.97					X			
2	97.7	97.5	97.0	8592.1	18.15	X	X						
2	97.2	96.9	95.8	11802.0	19.93		X	X					
3	98.0	97.7	97.2	7931.8	17.39	X	X		X				
3	97.7	97.4	96.6	9625.8	18.39	X	X						X
4	98.0	97.6	96.2	10749.9	17.60	X	X		X			X	
4	98.0	97.6	96.9	8767.0	17.78	X	X		X		X		
5	98.1	97.5	96.7	9277.2	17.91	X	X		X		X		X
5	98.1	97.5	95.9	11562.8	17.97	X	X		X		X	X	
6	98.1	97.4	94.4	15884.1	18.22	X	X		X	X	X	X	
6	98.1	97.4	95.4	12990.4	18.23	X	X		X		X	X	X
7	98.2	97.3	93.7	17908.7	18.69	X	X		X	X	X	X	X
7	98.2	97.3	93.1	19753.8	18.71	X	X	X	X	X	X	X	
8	98.2	97.1	92.2	22247.2	19.27	X	X	X	X	X	X	X	X

Adjusted R^2, predicted R^2, prediction sum of squares (PRESS) and standard error of regression (S) are used as statistics to compare the models. The larger the adjusted R^2 and predicted R^2, the more explanatory and predictive power has the model respectively. Similarly smaller PRESS and S values enable a better fit in regression models. The first three-predictor model listed in Table 1 seems to be the best one according to these criteria. However, one should check the significance and multicollinearity of the coefficients and do residual analysis to propose the best model.
Table 2 gives part of the Minitab stepwise regression model output. This is the best three-predictor model and also the best model listed in Table 1. Variance inflation factors (VIF) of coefficients of the predictors indicate no problem about multicollinearity. However p-value of 'Constantly Working' is greater than 0.05 which means that this predictor is not significant in the model.

Table 2. Stepwise regression output.

Stepwise Selection of Terms: α to enter = 0.15, α to remove = 0.15

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
17.3875	97.98%	97.66%	97.21%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-3.80	7.02	-0.54	0.594	
Firing Problem	0.706	0.234	3.02	0.007	4.18
Breakdown	0.4995	0.0343	14.54	0.000	2.83
Constantly Working	1.108	0.664	1.67	0.112	1.86

We apply forward and backward elimination procedures to the data via Minitab and obtain the same regression model which is presented in Table 3. This is the best two-predictor model and also the second best model listed in Table 1. VIF values of the predictors indicate no problem about multicollinearity. Furthermore, p-values of the coefficients of the two predictors are less than 0.05 (in fact 0.000) which mean that both predictors are significant in the model. The constant term in the model has a high p-value of 0.434 indicating that this term is not significant in the model.

Table 3. Forward/Backward elimination output.

Forward Selection of Terms: α to enter = 0.1

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
18.1470	97.68%	97.45%	96.98%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	4.25	5.32	0.80	0.434	
Firing Problem	0.959	0.186	5.15	0.000	2.43
Breakdown	0.4780	0.0332	14.38	0.000	2.43

Model adequacy checking is done on the residuals of the model presented in Table 3 to check whether the model assumptions on the random error term are satisfied or not. Figure 1 gives the related residual analysis plots. According to the normal probability plot of the standardized residuals, we can conclude that normality assumption is almost satisfied. Furthermore, constant variance and zero mean assumptions of the random error term are also valid according to the residual vs fitted value plot. Residual vs observation order plot enables us to conclude that independence assumption seems to be also satisfied. Based on the collected data and the performed analyses, the following regression model is significant and adequate in explaining and and also predicting authorized service complaints:

'Authorized Service Complaints' = 4.25 +0.959'Firing Problem' +0.4780'Breakdown'

As a conclusion, number of complaints of firing problem and breakdown are significant in explaining the number of authorized service complaints. So, one can give more importance in the avoidance and service of these two types of complaints since they further reduce the authorized service complaints. Furthermore, firing problems are twice as important as breakdown problems according to the model.

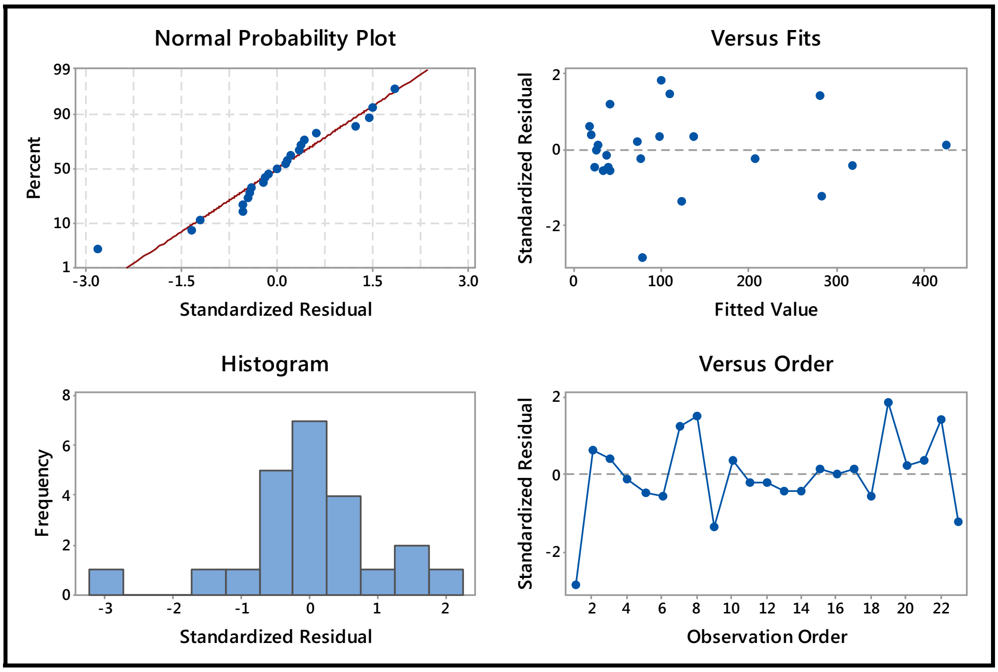

Figure 1. Model adequacy checking results.

5. CONCLUSION

We perform regression analysis on the authorized service complaints of a boiler company in Turkey and obtain a significant and adequate linear regression model in terms of two categories of equipment complaints according to the collected data. This model suggests that avoidance and technical service of firing problems and breakdowns of boilers are important in reducing the number of authorized service complaints. In this context, firing system of boilers can be improved in quality during manufacturing. Special trainings, both technical and behavioral, can be given to the authorized service employees about the two complaint categories of the boiler to resolve these types of problems satisfactorily. As a further study, one can collect more data to justify the model.

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