

Analysis of the influencing Factors in the Production of Parts with Nonconformities

FLAVIA FECHETE
Department of Engineering Manufacturing
Transilvania University of Brasov, Romania
Bvd. Eroilor nr.29, Brasov
ROMANIA
flavia.fechete@unitbv.ro

Abstract: Obtaining performance is one of the major goals of any company. This involves important decisions to optimize the allocation of cash resources, i.e. labor, raw materials, energy, capital equipment, etc.. The objectives of the organization can be measured as effectiveness (the extent to which objectives have been met) or as efficiency (the extent to which objectives have been achieved in the available resources).

Achieving performance is achieved by satisfying customer requirements. This can be done by delivering the requested products, at the established terms and prices. Delivery of non-compliant products will increase the number of complaints from customers and will affect the performance of the organization.

The aim of the paper is to analyze the factors involved in manufacturing non-compliant products and their degree of correlation using multiple regression.

Keywords: non-conformities, performance, complaints, multiple regression, correlation.

1 Introduction

Indicators that can measure performance in terms of customer satisfaction will address issues related to product quality, price and delivery times. Among these indicators, one decisive one is customer satisfaction. Customer satisfaction is vital to the success of a business, as it has been shown to be closely linked to redemption, loyalty and profitability. Consumers who are satisfied with their purchase are more likely to buy that product again; consumers dissatisfied with the products purchased express dissatisfaction with the organization, file complaints, demand recovery of money paid for the product and even negatively influences other buyers.

Satisfaction is the state of a customer that appears as a result of comparing the quality of a product / service with its expectations [1].

Satisfaction depends on the gap between reality and desire and is assessed by the quality level of the products or services offered. The following situations may result from such comparisons [2]:

- dissatisfied performance (dissatisfaction);
- performance is indifferent;
- performance in line with expectations (satisfaction);

- performance is above expectations (enthusiasm - the customer becomes loyal).

In the process of developing customer relations and evaluating their satisfaction, two aspects are important:

- communication with customers;
- customer loyalty.

In defining the communication system with the client, the contacts established with the client must be taken into account, in particular the visits made to the client, whether it is the formalization of a contract or for the resolution of complaints. All customer communication activities are essential in determining the level of customer satisfaction.

Customer loyalty, on the other hand, requires activities to analyze the customer's perception of the concept of value and value-creating processes. Developing customer relationships must be based on trust and mutual respect, and the organization's management must know how to communicate its customer value creation strategy.

Assessing customer satisfaction consists of two main steps [3]:

- Collection of relevant data and information regarding customer satisfaction and its perception

regarding the concept of value and evaluation of the organization's performance;

- Using customer feedback to develop improvement programs aimed at increasing customer satisfaction and customer loyalty.

Customer satisfaction can be assessed by questionnaires, by the number of complaints received or by the number of orders received.

In quality management, a nonconformity or defect is a deviation from the requirements set by a technical specification (including legislation), a standard, or from customer expectations. Nonconformities can be found when the product / service control is performed or during internal or external audits. The nonconformities found are usually classified according to two criteria: cause and severity. Depending on the cause, the nonconformities can be determined by:

- Procedures / Specifications: the procedure / specification is either inadequate or missing (does not exist or is not available in the workplace), or a deviation from the procedure / specification has been committed;

- Defective or uncalibrated equipment;
- Poor staff competence;
- Improper materials;
- Wrong execution, etc.

Performance indicator - Nonconformities is considered to be influenced in turn by other indicators, such as [4]:

- OEE (Total Equipment Efficiency) - Quality / Performance / Availability

The Total Efficiency of the Equipment is a composite indicator that measures the efficiency of the use of the equipment, being composed of three factors: availability, performance and quality. The general level of efficiency of the machines is calculated as a product of the three coefficients.

The OEE gives a correct perspective on the performance of the equipment. At the same time, it is a tool for continuous improvement, one of the purposes of the method is to reduce or eliminate losses.

- Unplanned interruptions (minutes)
- Personal qualification

The personal qualification indicator is calculated as the ratio between the defective parts made and the total number of parts.

2Multivariate analysis using multiple regression – case study

In this subchapter of the paper we used as an explanatory method of multivariate analysis multiple regression to analyze the correlations between the three variables: OEE variables, unplanned interruptions and personal qualification and establishing the validity of the multiple regression model.

Using statistical analysis - a component part of statistics, it is desired to identify permanent elements in the variation of stochastic processes and factors that influence the variation in time, space, or qualitative. For this purpose are used mainly regression analysis, correlation analysis, ANOVA, time series analysis.

In a research based on the correlation and regression analysis, the following problems must be solved: the identification of the existence of the connection consisting in the logical analysis of the possibility of the existence of a connection between the considered variables; determining the degree of connection intensity, a problem solved with the help of parametric or non-parametric indicators of correlation intensity, used in correlation analysis; establishing the meaning and form of the link for which specific regression analysis methods are used: elementary methods and analytical methods [5].

The concept of regression expresses a statistical type of connection, namely the regression on average regarding the behavior of some variables. Regression analysis is used to:

- estimating the values of one variable considering the values of another / other variables;
- evaluation of the extent to which the dependent variable can be explained by the independent variable or by a set of independent variables;
- identifying a subset of several independent variables that must be taken into account for estimating the dependent variable.

A regression model, in general expression, can be written as follows:

$$y = f(x_1, x_2, \dots, x_n) + \varepsilon, (1)$$

where:

y - dependent variable (resultant), random;

x_1, \dots, x_n - independent variables (factorial), non-random;

ε - random error or residual variable. The random variable ε sums up the influences of the variables not included in the model on the variable y.

The multiple regression method is considered an explanatory method, because it explains the variation of a complex phenomenon, analyzed, depending on the variation of some variables considered independent, exogenous [6].

Multiple regression analysis is useful in constructing econometric models. An economic and social phenomenon is influenced by the combined action of several factors. Considering several explanatory variables for the analyzed phenomenon will lead to the identification of a model that reproduces the real behavior as close as possible to reality [7].

The purpose of the econometric analysis is to estimate and predict the average value of the variable *y*, based on the known or fixed values of the explanatory variables. Multiple regression analysis allows estimating the parameters of the econometric model, analyzing the correlations between variables, testing the significance of explanatory variables [8].

In order to explain the variation of the nonconformity dependent variable according to its covariance with the independent OEE variables, unplanned interruptions and personal qualification, a statistical model of multiple regressions defined by the relation will be used:

$$y = a_0 + a_1x_1 + a_2x_2 + \dots + a_kx_k + \varepsilon, \tag{2}$$

where:

y = variable to be explained;

*x*₁ = explanatory variable 1;

*x*₂ = explanatory variable 2;

...

*x*_{*k*} = explanatory variable *k*.

*a*₀, *a*₁, ..., *a*_{*k*} = model parameters.

ε = specification error, unknown (difference between true and specified model);

n = number of observations.

Table 1. Values of independent and dependent variables

Nonconformities (pieces)	Unplanned interruptions (minutes)	OEE %	Personal qualification%
70.00	2800	72.52%	99.9833%
40.00	177	79.56%	99.9876%
30.00	0	82.23%	99.9904%
0.00	0	81.10%	99.9922%
0.00	0	83.11%	99.9926%
0.00	781	78.19%	99.9922%
0.00	2626	73.92%	99.9924%
0.00	2306	74.66%	99.9931%
0.00	2786	73.55%	99.9923%
20.00	2160	75.16%	99.9931%
60.00	0	85.56%	99.9927%
20.00	1763	73.88%	99.9917%

Table regression is shown in Table 2. This was performed using the computer program Microsoft Excel using the commands Data Analysis/Regression.

The identified model is:

$$\text{Nonconformities} = 755935.1401 + 0.0204 \text{Unplanned interruptions} + 723.033 \text{OEE} - 756570.941 \text{Personal qualification}, \tag{3}$$

adjusted values are presented in Fig.1.

Table 2. Regression table of the Nonconformities function

SUMMARY OUTPUT

<i>Regression Statistics</i>					
Multiple R					0.842
R Square					0.709
Adjusted R Square					0.599
Standard Error					15.956
Observations					12
<i>ANOVA</i>					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	4963.202	1654.400	6.498	0.015
Residual	8	2036.797	254.599		
Total	11	7000			
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	
Intercept	755935.1401	176664.637	4.278	0.0026	
Unplanned interruptions	0.0204	0.011	1.762	0.116	
OEE	723.033	327.155	2.210	0.058	
Personal qualification	-756570.941	176757.902	-4.280	0.0026	

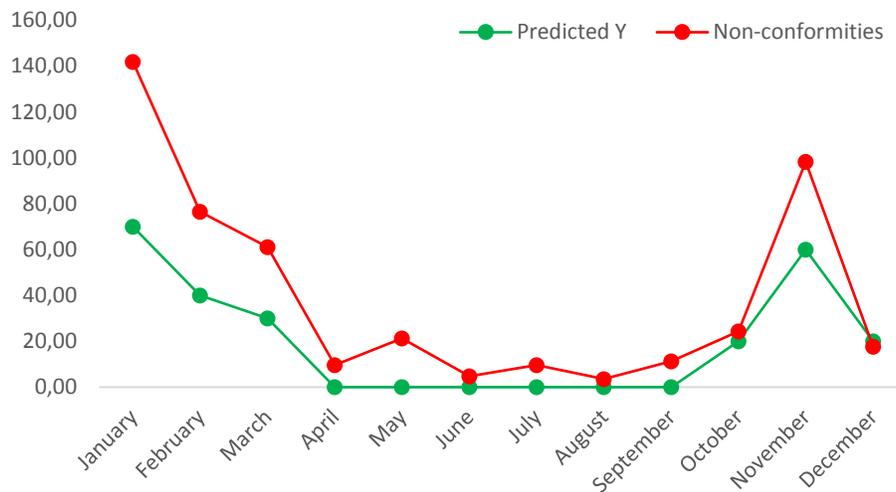


Fig.1 Evolution of nonconformities achieved by the company in the period january-december and their adjustment.

It can be seen that the coefficients of the model are significantly different from 0 as indicated by Student calculated ratios, that are higher than the theoretical value of the Student table, the values P-value that is less than 5%. Besides global significance test, there are analyzed the significance tests of

individual coefficients for each explanatory variable in the model.

Student ratio for each regression coefficient is compared with the theoretical Student value for $\alpha = 5\%$ and 8 degrees of freedom which is 2.18, calculated in Excel using TINV function. Student

theoretical ration of 2.18 is less than value calculated (2.21; 4.28), and this shows that each of the variables: OEE variables and personal qualification helps in explaining the variation of variable y, ie nonconformities; as for the variable - unplanned interruptions the Student theoretical ration of 2.18 is higher than 1.762, meaning the variable does not contribute significantly to the explanation variation of the variable nonconformities, and it can be withdrawn from the model.

Fisher theoretical value for 3 and 8 degrees of freedom for a significance level $\alpha = 5\%$ is 4.066, calculated in Excel using FINV function. Overall regression is significant because $F^* (6.49) > F_{theoretic} (4.66)$, in order we can say that the regression model is well built. The calculated F^* corresponds to a significance level of 0.015%, much lower than 5%, as shown Significance F in Table 2.

Also, the coefficient of determination show a very good linear model that explains the phenomenon of the change in the four analyzed variables according to the explanatory variables in an amount of 84.2%.

3 Conclusions

Performance analysis of a company has a decisive role in setting the strategy followed especially during the financial crisis. Performance should be assessed and measured both with respect to results (outputs of the tasks) and the behaviors (work process entries).The increasingly frequent use of statistical correlation method is justified by the increasing need of reflection in a appropriate numerical form the interdependence of the phenomena analyzed in terms of the nature, direction and the intensity of the links which is manifested in a certain period of time or in dynamic.

Statistical analysis consisted of an investigation of the behavior of known variables and the development of an equation or model to explain the relationship between the environment of variables. In this situation, the income on the product is the result of conjugation many influencing variables, but not all the determined ratios have the same importance, the action of some of them compensating each other.The main objective of regression analysis is to explain and forecast variance of the dependent variable based on its covariance with the independent variables.

Satisfying customer needs is an essential requirement for the organization to survive and achieve performance.Thus, this paper has tried to

define the notion of customer satisfaction, to emphasize the importance of meeting customer requirements of the enterprise and to achieve a multifactorial regression analysis of factors contributing to clients performance. In this respect, we conducted a case study on a company that produces bearings, taking into account nonconformities as a component of the entity's manufacturing performance. The model built was a well-chosen one, representative and shows that two of the explanatory variables OEE variables and personal qualification, contributes to explaining the variation in y, ie non-conformities. The independent variable unplanned interruptions does not contribute significantly to the explanation variation of the variable non-conformities, and it can be withdrawn from the model.

Investing in the qualification of the employees and in technology would decrease the number of nonconformities in manufacturing, the identified model shows that there is a direct correlation between these factors.

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