Współczesna Gospodarka

IN MARI VIA TUA

Contemporary Economy
Electronic Scientific Journal
http://en.wspolczesnagospodarka.pl/

Vol. 10 Issue 1 (2019) 69-78
ISSN2082-677X
DOI 10.26881/wg.2019.1.07

FORECASTING PRODUCTION VOLUME IN A PLASTICS ENTERPRISE

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Abstract

The functioning of production enterprises is based on satisfying the needs of customers through the timely manufacture of products in accordance with the demand existing on the market. The availability of the offered range of products is guaranteed by a correct preparation of forecasts of potential orders. This article presents a multiple-regression-method-based tool supporting the planning of production volumes in an enterprise depending on the calendar month. Reliability analysis of the developed model through the analysis of residuals and their autocorrelations and partial autocorrelations is also presented.

Key words: multiple regression model, production scheduling, readiness, forecasting

JEL classification: C2, C22.

Introduction

Knowledge of the level of demand for products is extremely important in the functioning of production enterprises. This allows proper material requirements and production capacity planning to ensure the appropriate volume of manufactured goods in order to meet the customer’s needs. All the above activities are carried out within the production system functioning in a given enterprise, understood as a purposefully organized and designed man-operated material, energy and information system. One of its essential features should be its readiness to carry out the tasks assigned to it.

The term ‘readiness’ has its source in the theory of exploitation of technical objects (Żurek et al., 2017; Borucka, 2018) and means the ability to remain in a state allowing to perform the required functions and tasks at a given moment or interval of time and under accepted conditions. It is often used both in relation to machine and equipment elements (Świderski et al., 2019), but also in relation to vehicles as overall reliability structures (Borucka, 2018). It is assumed that this term is most widely used to refer to systems characterized by sudden life-saving interventions and rapid reactions, e.g. emergency ambulance service (Borucka, 2018), but it is also used in systems with fixed schedules of supply of raw materials and materials (Żurek et al, 201; Borucka, 2018) or those performing passenger transport tasks (Borucka, 2014).

In relation to production systems, readiness is understood as the ability to ensure smooth flow of raw materials and other components with the use of means of transport, using analyses of this ability and factors that may hamper the movement of resources, including traffic accidents (Skoczyński et al., 2018; Świderski, 2018; Borucka, 2018) or congestion in urban traffic (Mitkow, 2018; Brzeziński et al. 2018). The mere assurance of the correctness of flows requires the readiness of machines and equipment, as well as the human user, whose degree of preparation is an inseparable element of reliability of the entire system (Wielgosik, 2016; Mikosz, 2008).

The aim of this article is to present a multiple regression method as a classic cause and effect model used to forecast the production volume in the plastics industry, as well as analyse the developed model based on the verification of the normality of residuals distribution and the function of their autocorrelation.

1. Characteristics of the research subject

The subject of the research is the production system of enterprise A, which operates in the plastics industry and manufactures plastic garbage bags. They are manufactured from raw materials obtained from plastic waste recycled into granulate for the production of new articles, which supports the management of used plastics (Mikosz, Borucka 2008). Production takes place in two main technological lines: production of regranulate and production of garbage bags in a three-shift system of 8 hours each. The manufacturing process itself is carried out in three main stages:

– mixing: preparation of an appropriate mixture by the mixer operator in accordance with the product data sheet (feeding the appropriate quantity of individual components, i.e. original granulate, regranulate, dye, moisture scavenger and other additives),
– extrusion-blowing: the mixture is delivered to extruders, where it is heated to high temperatures and then melted and "blown" in a special head outside in the form of a so-called balloon, which is formed by means of appropriate machine parts into a so-called poly tubing and wound on a paper or metal core. The finished poly tubing roll is removed from the machine by the extruder operator and transported close to the roll bag machines,
– cutting and sealing: finished poly tubing rolls are loaded into roll bag machines where the poly tubing is unrolled, and when passing through individual sections of the machine, each bag is sealed and perforated. The last section of the machine (winder) winds the set number of bags onto the roll, and the machine operator attaches a paper label and packs the roll into a cardboard box.

The following analysis will be carried out on the basis of data on the production volume of 20L garbage bags, representing a sample of 700 observations collected between 2015 and 2017.

2. Prognostic model with the use of multiple regression methods

The general objective of multiple regression, as a cause-effect method, is to quantify the relationships between many independent variables (in the analyzed case it is the production time) and a dependent variable (production volume). It is an extension of the simple regression model and takes the form (1):

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_n x_n + \varepsilon \qquad (1)$$

where:

β_0 – absolute term,

β_n –model parameters – regression coefficients

x – independent variable – subsequent months,

y – estimated production volume,

ε - random error.

The first step is the decomposition of the time series (Bielińska, 2007), in order to identify its basic elements related to the development trend, periodic component and random fluctuations. Visual inspection of the actual data presented in the graph (Fig.1) was carried out.

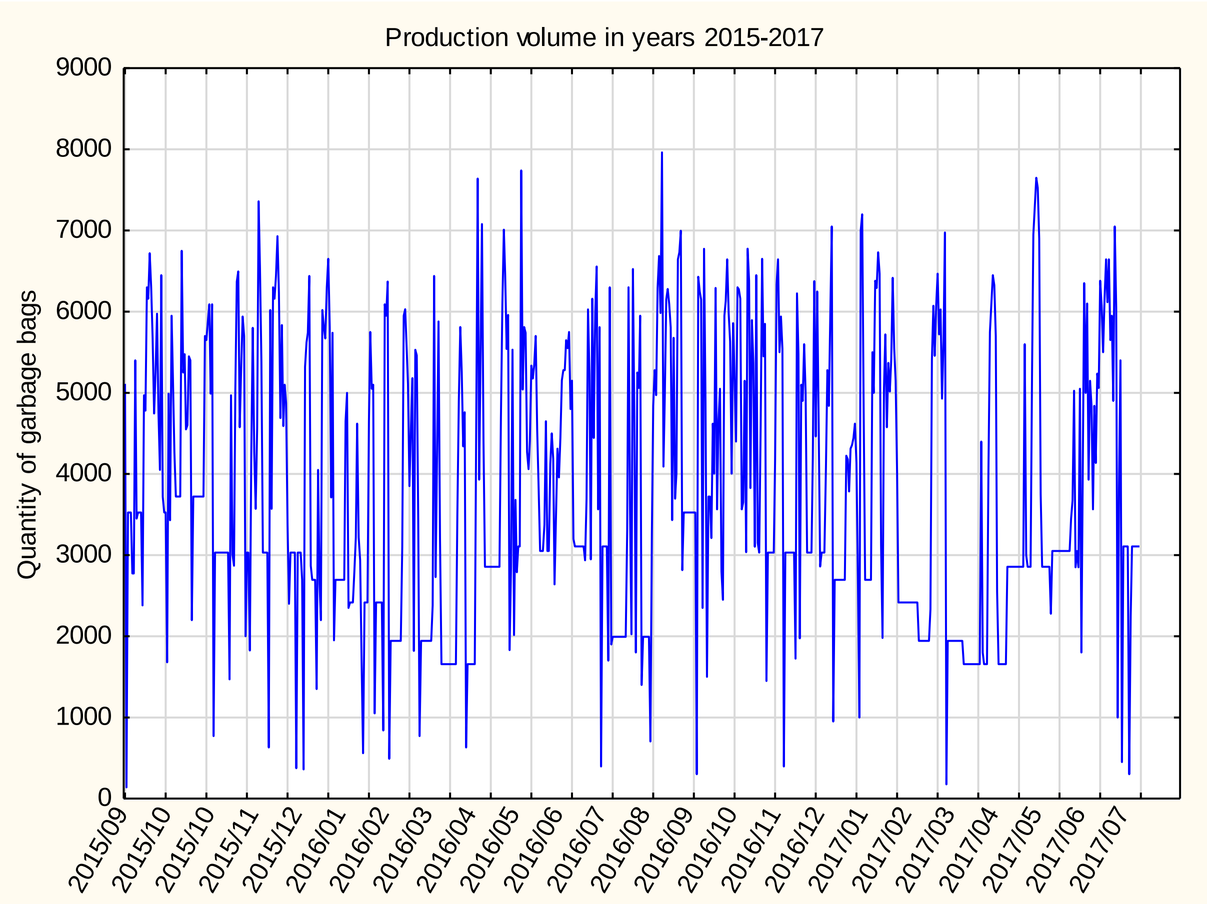

Figure 1: Production volume of garbage bags in the years 2015-2017.

Source: the author's own work.

The analysis of the graph shows high variability in terms of production volume on individual days and in individual months, as well as a lack of clear trends and outliers. The irregularity of the production process stems from many factors related to demand fluctuations on the market, but also to the operating environment, i.e. production for storage, which forces the decrease in the production level in the case of accumulation of excessive stocks. Other parameters influencing production are random machine breakdowns, as well as necessary to perform activities related to cutting tool adjustment or restoring broken tubing to its initial state, which shorten the operating time fund.

This variability is shown by the basic statistical measures calculated for all observations collected and broken down by month (Table 1).

Table 1: Values of selected measures of descriptive statistics.

Month	Number of observations	Average	Median	Minimum	Maximum	Deviation Standard	Coefficient of variation
January	62	3781.65	2694.97	360	7200	1651.42	43.66
February	57	3478.07	2417.68	560	6732	1624.08	46.69
March	62	3041.37	1943.97	175	6975	1791.69	58.91
April	60	2706.84	1657.25	630	6450	1683.53	62.19
May	62	3943.94	2857.25	1830	7740	1736.78	44.03
June	60	4018.40	3943.50	1800	6350	1049.14	26.10
July	62	4158.96	3630.00	300	7050	1696.01	40.77
August	31	2958.89	1994.03	704	6525	1629.15	55.06
September	60	4524.52	4070.50	140	7963	1623.07	35.87
October	62	4682.17	4642.00	1500	6775	1269.31	27.11
November	60	4043.13	3127.00	396	6776	1618.31	40.03
December	62	4178.86	3816.00	375	7360	1604.60	38.40
Sum	**700**	**3831.91**	**3488.00**	**140**	**7963**	**1685.27**	**43.98**

Source: the author’s own work

The results obtained show that the averages in individual months differ significantly from each other, assuming also different values than the average for all observations. The highest indications are for September and October. In the analysis of monthly seasonality, a frame chart showing the variability of production depending on the period of the year was helpful (Fig. 2).

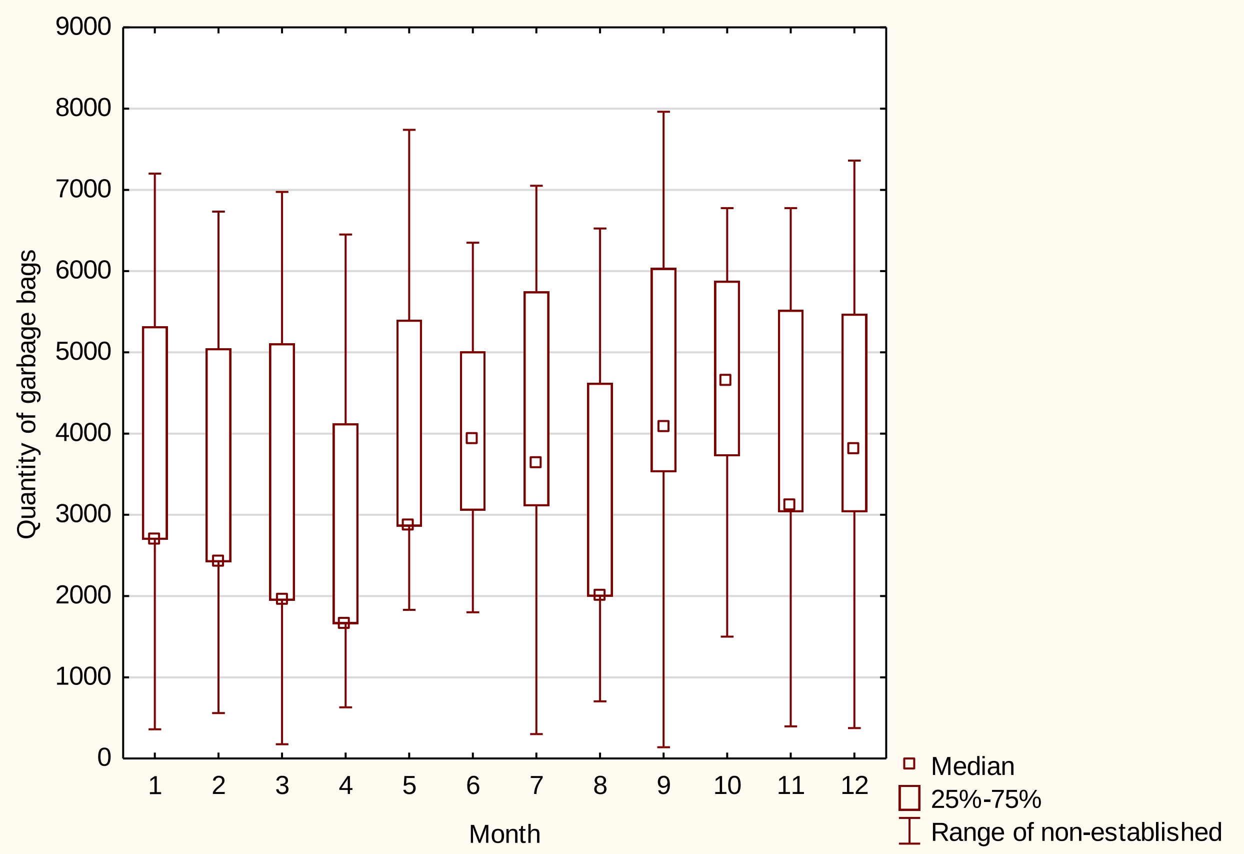

Figure 2: Average production volume in individual months of the year.

Source: the author's own work.

The article proposes a method of estimation of production volume using a multiple regression method, which will be determined on the basis of calendar variables, i.e. subsequent months of the year. As these variables are qualitative, they need to be re-coded into binary variables in order to be correctly applied in the model. Estimation is possible only if one of the variables for the identified category is omitted (Mitkow, 2018). It is assumed in the literature that the one with the lowest average value should be eliminated.

In accordance with the assumptions of the multiple regression method (1), the model parameters were estimated together with the values of test statistics and the obtained probability level *p*, and their compilation is presented in Table 2. The April variable was omitted.

Table 2: Values of selected measures of descriptive statistics.

N=700	b	Stand. error	t(347)	p
W. free	2706.84	205.69	13.16	0.00
January	1074.81	288.53	3.73	0.00
February	771.23	294.69	2.62	0.01
March	334.53	288.53	1.16	0.25
April	1237.10	288.53	4.29	0.00
May	1311.56	290.88	4.51	0.00
June	1452.12	288.53	5.03	0.00
July	252.05	352.41	0.72	0.47
August	1817.68	290.88	6.25	0.00

September	1975.33	288.53	6.85	0,00
October	1336.29	290.88	4.59	0,00
November	1472.01	288.53	5.10	0,00

Source: the author's own work

Not all estimated coefficients of the regression model are statistically significant, but their removal could significantly hinder their interpretation, so it was decided to leave them in the model.

Finally, the multiple regression model takes the form (2):

$$y = 2706{,}84 + 1074{,}81x_1 + 771{,}23x_2 + 334{,}53x_3 + 1237{,}10x_5 + 1311{,}56x_6 + 1452{,}12x_7 + 252{,}05x_8 + 1817{,}68x_0 + 1975{,}33x_{10} + 1336{,}29x_{11} + 1472{,}01x_{12} \quad (2)$$

3. Model verification and forecast estimation

The last stage is model diagnostics, which consists in checking whether the assumptions concerning the residuals are fulfilled (Sokołowski, 2016). In a properly constructed model, they should have normal distribution and there should be no autocorrelation between them. In the analyzed case, the study of normality of distribution showed that they were not characterized by normal distribution and therefore by a random nature. In the Shapiro – Wilk test performed, the value of the test statistic was 0.90834, which means that with a probability value of p=0.00 there are no grounds to accept the H0 hypothesis that the sample comes from a normal distribution. Fig. 3. presents the residuals distribution histogram

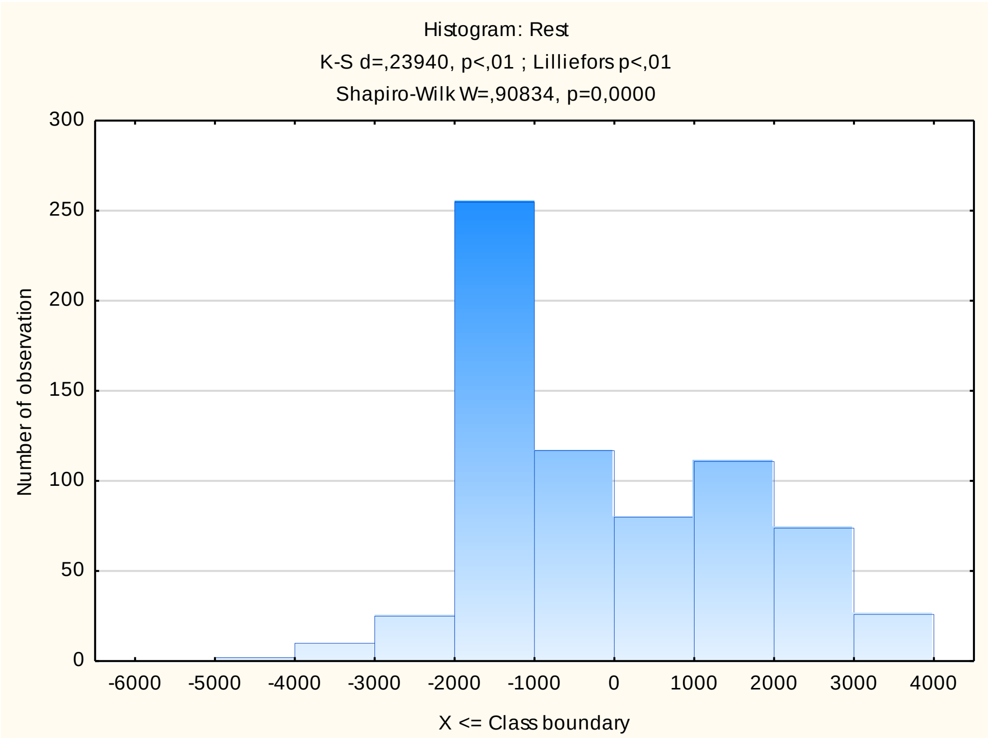

Figure 3: Model residuals distribution histogram.

Source: the author's own work.

The analysis of autocorrelation and partial autocorrelation of residuals showed the existence of significant relationships, which is indicated by the existence of relationships (unexplained by the model) between individual dependent variables, as shown in the diagrams below (Fig. 4 and 5).

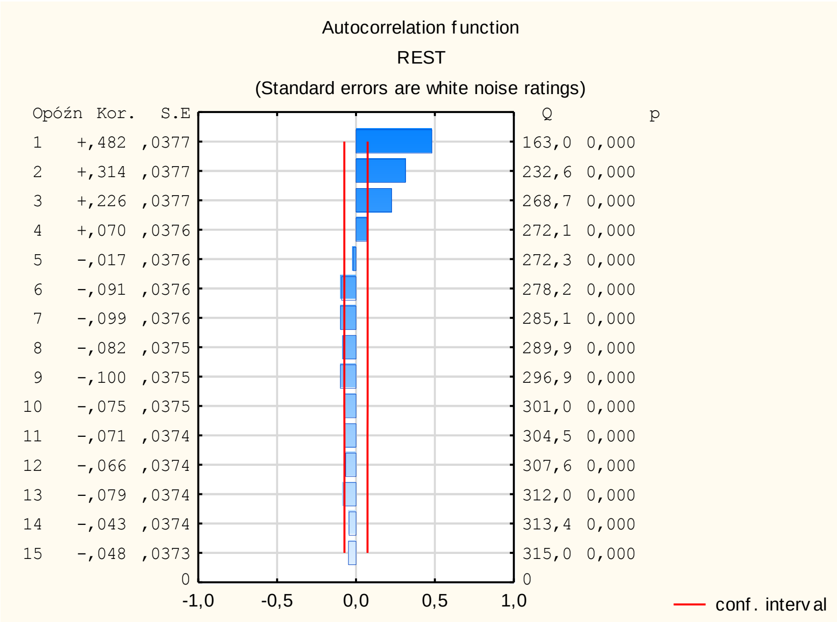

Figure 4: Chart of autocorrelation functions for the model residuals.

Source: the author's own work.

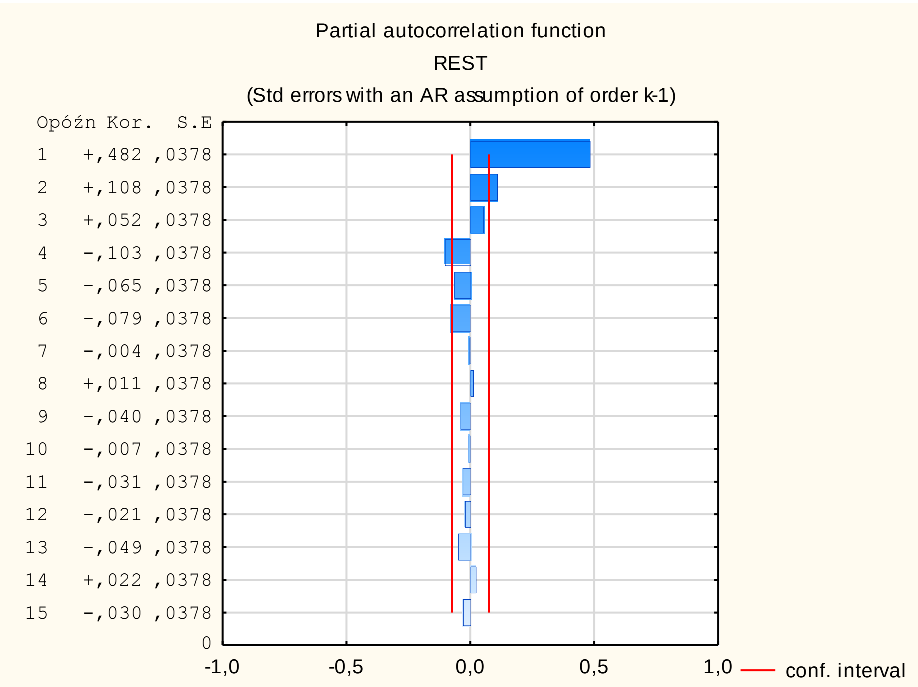

Figure 5: Chart of partial autocorrelation functions for the model residuals.

Source: the author's own work.

Statistically significant correlations can be observed in both charts, which leads to the conclusion that errors in production volume prediction based on the presented model are interdependent and do not have a random distribution, which indicates the existence of unspecified dependencies. This situation is related to a number of other variables that have a significant impact on production, e.g. maintenance, shortages of raw materials or machine breakdowns, but which are not included in the model. On this basis, it should be considered whether more reliable results would be achieved for the initial assumptions made by using other estimation methods based on time series analysis, e.g. autoregressive or moving average methods.

Conclusions

Summing up, the aim of the article was to present an example of the practical application of the multiple regression method for forecasting production volume in a plastics enterprise. However, the developed model does not meet the requirements for its reliability, as the analysis of the residuals shows the existence of significant dependencies, which were not included in the model. On this basis, it can be concluded that the estimation based on the month of manufacture is insufficient and a number of other factors arising from production should be taken into account during the construction of the model, including those related to the machinery operation system (failure analysis and downtimes related to maintenance activities) and parameters related to untimely supply of raw materials and materials necessary for manufacture.

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FORECASTING PRODUCTION QUANTITY IN A ENTERPPRISE FROM A PLASTIC INDUSTRY

Abstract

The functioning of production enterprises is based on satisfying the needs of customers by timely production of products in accordance with the demand on the market. The availability of the offered assortment is guaranteed by proper preparation of forecasts of potential orders. The following article presents a tool supporting production volume planning in an enterprise depending on the calendar month based on the multiple regression method. The analysis of the credibility of the developed model was also presented through the analysis of residues and their autocorrelations and partial autocorrelations.

Keywords: multiple regression, production scheduling, readiness, forecasting

JEL classification: C2, C22.

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