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THE USE OF FORECASTING MODELS TO IDENTIFY TRENDS OF LOGISTICS DEVELOPMENT IN BUSINESS MANAGEMENT

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Abstract

Background. Knowledge about the changing market trends and the ways to identify them is the key to effective business management. The basis of mistaken decisions is a wrong interpretation of information coming from the company. With regard to logistic processes, information on the amount of incurred expenses exhibits some dependencies between them. Therefore, one way of making the right decisions is the use of forecasting models based on time series, which can be used to determine future values of a studied phenomenon. Verification of the obtained results through the determination of average forecast errors can be implemented.

Research aims. The research was conducted to determine the degree of relationship of macroeconomic indicators with the economic parameters emerging in the enterprise. The use of information obtained in this way can be applied to reduce the risk associated with entrepreneurial activity. The utilitarian purpose of this research is defining the correlation coefficient used to determine the extent to which the investigated factors are interdependent and making predictions about the future value of inventory costs.

Methodology. To implement its objectives, critical analysis of literature was applied, analysis of statistical data, a method of determining dependencies between those variables based on the correlation coefficient and the ARIMA method of forecasting based on time series, using advanced autoregression and moving average models. On the basis of the average of relative forecast errors the accuracy of the forecast for future periods can be determined.

Key findings. The main result of the analysis is to obtain information about the influence of macroeconomic factors on changes of the value of the field of logistic enterprises as well as the use of autoregression and moving average models to determine the future size of the variables in the time series. Using the ARIMA model, made on the basis of real plant data forecasts relating to the cost of inventory, showed the suitability of the method for pre-planning of the future logistics trends.

Keywords: ARIMA models, time series forecasting, correlation coefficient.

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INTRODUCTION AND BACKGROUND

Doing business is often associated with greater risk. This is especially important in coal industries, which are characterised by a large variability of demand widespread for several years and the falling level of coal prices on the one hand, and on the other hand having to bear very high costs, in particular, investment costs associated with infrastructure, exploration, modernisation of the mines, as well as protection of the territories of the deposits. In this situation, it is important to make the right decisions related to specific areas of economic activity that reduce the costs and potential losses. One such area concerns logistic activities of the enterprise. To implement the above, minimise risk and reduce the cost of business activities, it is necessary to support decisions not only basing on intuition and market knowledge, but also on objective methods of forecasting. Because of this, an attempt was made to use complex models to predict the magnitude of value-based time series, in order to anticipate changes in future time periods. The application of these models may help to optimise the management of organisational structures of enterprises, as well as to minimise adverse decisions that may put the company at a loss.

FORECASTING METHODS BASED ON TIME SERIES

The main purpose of forecasting is to support decision-making processes (Bendkowski, Kramarz & Kramarz, 2010, p. 15). Forecasting, as one of the tools used in the planning process, is of particular importance in the management of the company, because wrong identification of future trends can be devastating to the enterprise. To determine an accurate forecast for future periods it is necessary to properly implement the authentication methods of forecasting, which are characterised as the smallest forecast error. The basis of selection of the forecasting method should be:

- adopted background forecast,
- available prognostic data,
- patterns that occur in a predictable phenomenon,
- requirements for the accuracy of the constructed forecasts,

- feature of methods of forecasting,
- available computer software (Dittmann, 2003, p. 39).

The phenomena occurring in the mines can be linked to macroeconomic factors and to manifest certain regularities in the forecast time period, such as trend, seasonality, and cyclicity. Thus, it is possible to verify that the data contained in specific periods are interrelated and dependent on past data. In order to obtain higher prediction accuracy, it is necessary to use more sophisticated forecasting techniques. They can be used to obtain more accurate results for future periods.

In order to construct the forecasts and time series, stochastic processes are used, and, therefore, they represent the mileage of the phenomenon in one of many possible cases. Any convenient tool for the study of natural phenomena, there are used models that utilize the close relationship between the data. Moreover, one must take into account the random factor, which may also be created as autoregression and moving average models. Among such models we may distinguish their main types:

- autoregression models (AR),
- moving average models (MA),
- mixed autoregression and moving average models (ARMA),
- ARMA models with a trend (ARIMA).

The data from the time series show, in addition to mutual relations, as well as the trend changes, that the appropriate tool would be the use of ARIMA models.

In the field of warehousing there is a great interest on demand forecasts, customer preferences, and inventory costs. The purpose of forecasting is to reduce risk in the planning process and decision making. A bad diagnosis of future development situations and trends may act adversely to the enterprise in terms of economic efficiency and level of customer service. Decisions in management and cost of maintaining stocks can yield expected results only if they are taken on the basis of a reliable forecast model. To maintain a proper stock level, one can use appropriate methods of forecasting based on time series.

AUTOREGRESSION AND MOVING AVERAGE MODELS

Autoregression models are used for forecasting demand in short to medium periods of time, based on several dozen variables. Such a large number of variables is necessary to determine the value of the *m* parameter where *m* means “max zoom out time” (row of autoregression) in which the variables’ explanations can affect dependent variables and depends on how far in the future taking into account the most recent values of the endogenous variable in the model (Zeliaś, 1997, p. 249).

Relations between variables represent most often a linear function, therefore the autoregression model would be:

$$Y_t = \alpha_0 + \sum_{j=1}^{m} \alpha_j Y_{t-j} + u_t \tag{1}$$

where:
Y_t – endogenous variable,
Y_{t-j} – time delay values of the endogenous variable,
j – the row of delays,
α_0, α_j – model parameters.

In the process of inventory management and adjusting the corresponding infrastructure inventory the random factor plays an important role. It can be identified on the basis of historical data of the time series, as well as to determine the nature of its changes. The value of this factor is a linear combination of random components from the past. This phenomenon can be written in the form of the model in moving average, using the following formula:

$$Y_t = \mu + \varepsilon_t - \vartheta_1 \varepsilon_{t-1} - \vartheta_2 \varepsilon_{t-2} - \ldots - \vartheta_q \varepsilon_{t-q} \tag{2}$$

where:
ε_t, ε_{t-1}, ε_{t-q} – interference, random in periods t, $t-1, \ldots, t-q$,
μ, ϑ_1, ϑ_2, ..., ϑ_q – model parameters,
q – the row of delays.

To better adapt the model to the data time series it combines autoregression and moving average models. You can then get one model in the following form:

$$Y_t = \alpha_0 + \sum_{j=1}^{m} \alpha_j Y_{t-j} - \vartheta_1 \varepsilon_{t-1} - \vartheta_2 \varepsilon_{t-2} - \ldots - \vartheta_q \varepsilon_{t-q} + u_t \qquad (3)$$

The procedure for using the regression model and moving average is not too complicated. A time series that contains information about demand is checked in terms of stationarity. If the series still retains the non-stationarity it will be subjected to the differentiation operation. In case of further detection of non-stationarity, it is necessary to repeat the differentiation operation once again. Then the number of time delays, j and q is determined. This is done using the autocorrelation and partial autocorrelation. The next step is the estimation of the model parameters obtained by the least squares method or maximum likelihood method (Aczel, 2005, p. 646). After creating the model, it should be subjected to verification, i.e. to check the correlation of the residuals. If the autocorrelation coefficients of the residuals are significantly different from zero, then you must re-adjust the parameters of the model, otherwise the model can be freely used to predict the cost of holding reserves.

METHOD

The subjective range of work includes mines, which are a part of one of the three major groups in the market of hard coal production in Poland. The scope relates to the work of creating forecasts for future periods using historical data, the cost of storage and inventory. The forecast should be determined for several periods (Krawczyk, 2001). The time span of the study covers the years 2004–2010. The accepted time range is derived from the analysed trade secrets of the enterprise that due to the existing tough competition and the national and international changing conditions of the functioning of the market did not produce relevant data. The historical range of the presented data, does not exclude the validity of the analysis to verify the suitability of the forecasting methods to identify trends and values in the future. The data structure contains numeric values, the cost of inventories and storage costs in the following months the analysed years.

According to the methodology adopted in the enterprise the expenses include:

- machine and equipment in construction,
- materials in transit,
- materials in stock,
- scrap reserves,
- coal reserves;

and storage costs are classified on the basis of total costs, i.e. the costs of:

- depreciation,
- energy,
- materials,
- repairs, wages, and other costs.

The methodology of research work involves the use of data from the years 2004–2009 as the initial data that is necessary for making predictive models. Built on this basis, the model is then tested using data from 2010. The differences in the results will be used to calculate the errors between the forecast results obtained from the model and the actual data obtained from the enterprise, based on the relative average forecast error. In the process of making predictive models the main parameters will be defined, which are then used to determine the forecast for future periods. On this basis, the verification was carried out to check the suitability of the model for predictions of phenomena that may occur in the future. Furthermore, empirical data were confirmed because of their dependence on the macrofactors that may influence changes in the time series. Such an approach justifies the use of autoregression and the moving average model and also increases the reliability of the results.

RESULTS

Correlation analysis of external factors and tested time series

The cost of coal reserves that comprise the largest share in the total value of inventory is determined by such macroeconomic factors as demand for coal, which has a direct impact on the volume of coal production and the average retail price for 1 ton of coal. In turn, the volume of coal is associated directly with the volume of transportation of coal by road and rail.

Identification of the factors that can influence the variability of the cost of inventory and storage costs was made by testing their correlations with:

- the volume of coal extraction,
- the average annual retail price per 1 [t] of coal (Table 1),
- GDP in individual years,
- the production of electricity,
- the consumption of oil and petroleum products (Table 2).

Table 1. The volume of coal and the height of the average retail price per 1 [t] coal [PLN]

Year	Coal production [thousand t]	The average annual retail price per 1 [t] coal [PLN]
2004	100,087	459.67
2005	97,903	470.33
2006	95,221	491.54
2007	88,313	523.40
2008	84,345	604.62
2009	78,065	704.80
2010	76,728	719.76

Source: *Komunikaty Prezesa GUS w sprawie przeciętnej średniorocznej ceny detalicznej 1000 kg węgla kamiennego w poszczególnych latach*, http://stat.gov.pl/cps/rde/xbcr/gus/11.2_wydob_wegla_kamienn _r. xls and http://www.ogrzewamy.pl/paliwo/wegiel-kamienny (access: 1.04.2015).

Table 2. GDP in individual years [mln PLN], electricity generation, consumption of oil and oil products

Year	GDP [mln PLN]	The production of electricity in general [PJ]	The production of electricity per person [GJ]	The consumption of oil and oil products in general [PJ]	The production of oil and oil products per person [GJ]
2004	924,538	555.0	14.5	923.5	24.2
2005	983,302	565.0	14.8	931.4	24.4
2006	1,060,031	582.3	15.3	1021.2	26.8
2007	1,176,737	573.7	15.0	1068.2	28.0
2008	1,275,508	559.1	14.7	1058.6	27.8
2009	1,344,505	546.2	14.3	1045.6	27.4
2010	1,416,585	567.6	14.9	1108.0	29.0

Source: http://stat.gov.pl/obszary-tematyczne/rachunki-narodowe/ rachun-ki-regionalne/ produkt-krajowy-brutto-i-wartosc-dodana-brutto-wedlug-wojewodztw-i-podregion-ow-w-latach-2000-2010,3,1.html (access: 2.04.2015); GUS, 2011.

The volumes of transport of coal and briquettes by road and railway transport were also checked (Table 3). In both cases, in the next few years one will notice a decrease in volumes, which may lead to reduced demand for coal. The average distance of transportation of coal and briquettes by road transport in the analysed period was 125.8 kilometres, while the average distance of transport by rail amounted to 146.6 km.

Table 3. Transportation by road and rail transport of coal and briquettes

Year	The volume of road transport of coal and briquettes			The volume of rail transport of coal and briquettes		
	thousand of tons	million tkm	the average distance of transportation of 1 [t] [km]	thousand of tons	million tkm	the average distance of transportation of 1 [t] [km]
2005	23,507	3,018	128	148,550	19,570.3	132
2006	25,465	2,087	82	151,076	18,475.3	122
2007	15,295	2,191	143	75,082	11,376.8	152
2008	18,648	2,396	128	111,314	16,455.0	148
2009	16,352	2,418	148	84,266	15,124.4	179

Source: GUS, 2006–2010.

The average storage cost on a monthly basis in the period from 2004–2010 ranged from PLN 2 084 559.27 in January, PLN 1 534 616.64 in March, and PLN 2 017 940.84 in July. The highest level of average costs is reached in the period from October to December, so in the winter months and, interestingly, in July, a month that typically is the warmest month of the year. One should, however, note the great variability in the cost of storage for individual months in different years. Regardless of the month, low levels of storage costs were achieved in 2006. The highest level of average costs is reached in the period from October to December, so in the winter months and, interestingly, in July, a month that typically is the warmest month of the year. One should, however, note the great variability in the cost of storage for individual months in different years. Regardless of the month, low levels of storage costs were achieved in 2006.

In the analysis of correlation, it is considered if the correlation coefficient is less or equal to 0.3, it is vague, between 0.3 and 0.5

– average and greater than 0.5 – clear (Sobczyk, 2000). Applying these criteria, it can be noted that the correlation coefficients for the costs of storage during the period from 2004 to 2010 are very strong for the relationship August–September (0.83088) and September–October (0.86034) (Table 4).

Table 4. The correlation coefficients for individual months in the years 2004 – 2010, inventory and storage costs.

Period from 2004 to 2010	Correlation coefficient for inventory costs	Correlation coefficient for storage costs
January to February	0.99425	0.40466
February to March	0.98566	0.48359
March to April	0.99160	0.68625
April to May	0.97082	0.41293
May to June	0.97926	0.66518
June to July	0.99684	0.54939
July to August	0.99731	0.51635
August to September	0.99925	0.83088
September to October	0.97799	0.86034
October to November	0.99274	0.51780
November to December	0.99641	0.53425

Source: own elaboration.

A clear correlation (from 0.51635 to 0.68625) also occurs for all other months, except January–February, February–March, and April–May (from 0.40466 to 0.48359). Given the wide variety of factors included in the cost of storage, which are: depreciation, energy, materials, repairs, wages, and other expenditures, one can assume that the weaker correlation for these months is derived from price volatility in electricity and repairs, wages, and other costs occurring early in the year. The exact explanation of the dependence of the correlation between individual months in different years, however, requires in-depth analysis on the group level factors, which are generated in various departments of the enterprise. Due to the large frequency distribution of correlation coefficients between adjacent months, however, we can assume that this pattern will be maintained in future periods.

Noteworthy are very high correlation coefficients almost equal to 1, for individual months in the years 2004–2010, the cost of inventory (Table 4).

The correlation values of inventories-storage costs (Table 5) are weak, for the January average, and February average and vice versa.

Table 5. The correlation coefficient of inventory/storage costs

Period from 2004 to 2010	**Correlation coefficient of inventory/storage costs**
January	0.42762
February	−0.40096
March	0.27154
April	−0.09109
May	0.01834
June	0.14831
July	−0.01349
August	−0.16828
September	0.07184
October	0.10537
November	−0.30441
December	0.28784

Source: own elaboration.

Analysing the dependence of the cost of inventory and storage costs with the macroeconomic indicators strong correlation coefficient values of reserves to average annual retail price for 1 ton of coal (0.85287) and GDP (0.79264) and a strong inverse relationship with the magnitude of coal (−0.79874) were obtained. For the costs of storage there is a clear correlation only for the volumes of the rail transportation of coal and briquettes (0.77368).

Table 6. The correlation coefficient allocated to individual years on the basis of the data contained in Tables 1–3

Correlation coefficient	**Cost of inventories for the period 2004–2010**	**Storage costs in the period from 2004–2010**
Coal mining [thous. t] – from Table 1	−0.79874	−0.02515
Average annual retail price for 1 ton of coal [PLN] – from Table 1	0.85289	−0.00668

Table 6. cont.

Correlation coefficient	**Cost of inventories for the period 2004–2010**	**Storage costs in the period from 2004–2010**
Volume of road transport of coal and briquettes [thous. ton] – from Table 3	−0.46728	−0.40496
Volume of road transport of coal and briquettes [million t-km] – from Table 3	0.29536	0.77368
Volume of rail transportation of coal and briquettes [thous. tons] – from Table 3	−0.45351	−0.26389
Volume of rail transportation of coal and briquettes [million t-km] – from Table 3	−0.13364	−0.09208
GDP [mln PLN] – from Table 2	0.79264	−0.01025
Electricity production – total production [PJ] – from Table 2	−0.14411	−0.49773
Production of electricity – production per person [GJ] – from Table 2	−0.11130	−0.51224
Total consumption of oil and petroleum products [PJ] – from Table 2	0.61834	−0.23399
Consumption of oil and petroleum products – production per person [GJ] – from Table 2	0.60709	−0.23608

Source: own elaboration.

Demand forecasting based on time series

The first stage of data preparation for use in the forecasting process is to study the stationarity of the time series. Stationarity defines the time series that has a constant time variation and the average value of the process. To examine it, the unit root test (Dickey & Fuller, 1979; Pesaran, 2015, p. 332) was used. In the case of inventory costs for the set level of significance $p = 0.05$, the test showed the asymptotic p-value = 0.16. This means that the examined time series is non-stationary (Figure 1).

In this regard, the time series, you need to diversify according to the formula:

$$\Delta y_t = y_t - y_{t-1} \tag{4}$$

sets the first differences of the series to bring it to stationarity. After the diversification of a time series, the level of significance at the level $p = 0.0012$ was obtained. Thus, it is possible to consider the series as stationary. The form of time series before and after you bring it to stationarity is presented in Figure 2.

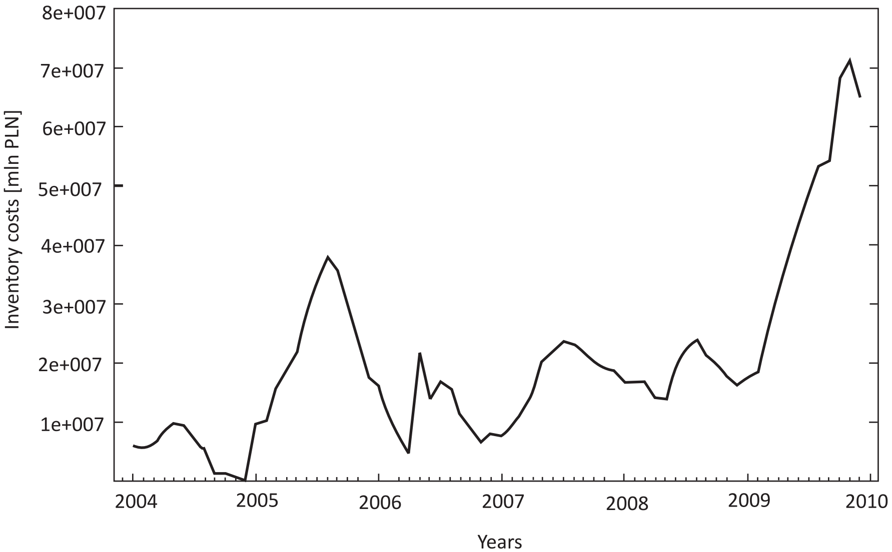

Figure 1. The primary form of time series for inventory costs in period 2004–2010 (non-stationary)

Source: own elaboration.

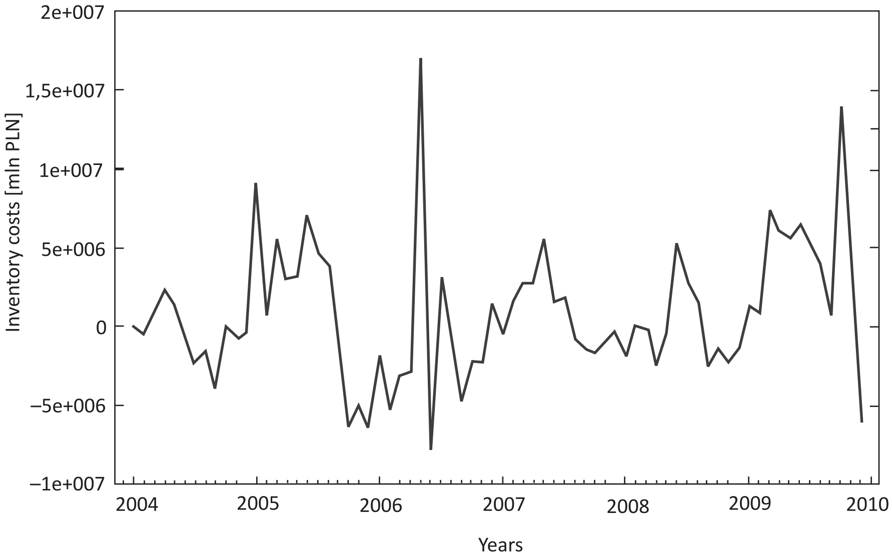

Figure 2. Time series after diversification for inventory costs in period 2004–2010 (stationary)

Source: own elaboration.

After obtaining the time series in the corresponding form, you must define the parameters of an ARIMA model (*p, d, q*).

The *d* parameter is the number of differentiation processes of the studied time series. In the case of stationarity of the series it is set to 0. Because the time series was summed to stationarity after a single differentiation, thus, setting $d = 1$.

The *p* parameter is determined on the basis of a correlogram, the ACF autocorrelation function and it is presented graphically and numerically. The schedule takes into account the autocorrelation coefficients along with their standard errors for serial logs from a specific time range.

The *q* parameter is read based on the PACF partial autocorrelation function (PACF) by Box and Jenkins' method, where the number of statistically significant parameters of the PACF function involves choosing the number of lags (BuHamra, Smaoui & Gabr, 2003, p. 805). Graphs of autocorrelation and partial autocorrelation which are necessary to determine the *p* and *q* parameters are presented in Figure 3.

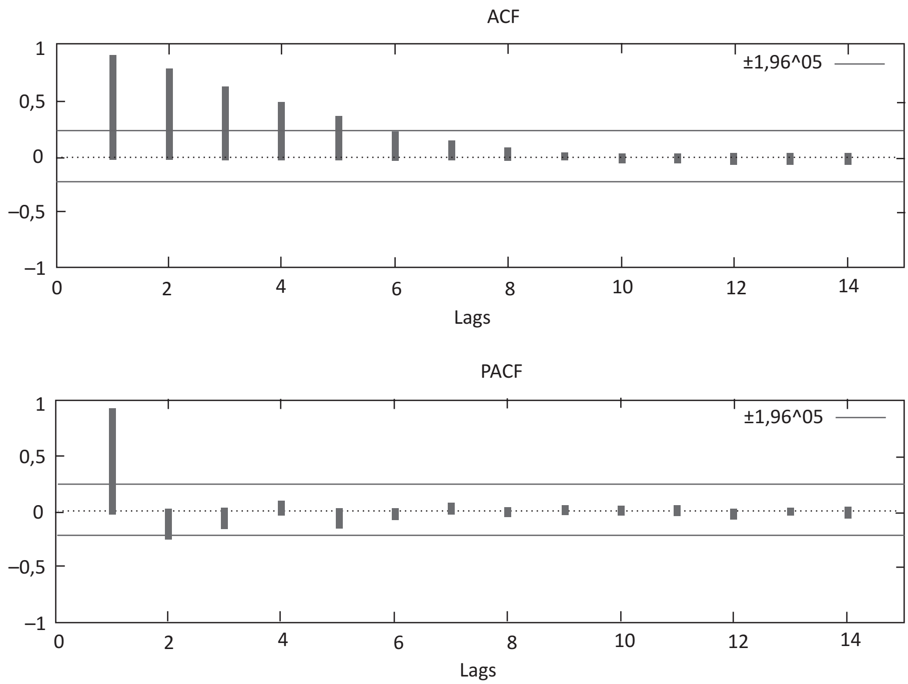

Figure 3. The autocorrelation function and partial autocorrelation of the studied time series

Source: own elaboration.

Based on the ACF and PACF functions it can be considered that the *p* parameter = 6 because so much is the delay time significantly different from zero. The other coefficients can be omitted. In addition, it can be considered from the partial autocorrelation function that the q parameter = 2. Thus, we can assume that ARIMA is the most appropriate model (6, 1, 2). Figure 4 shows selected parameters of the model of forecast for last year.

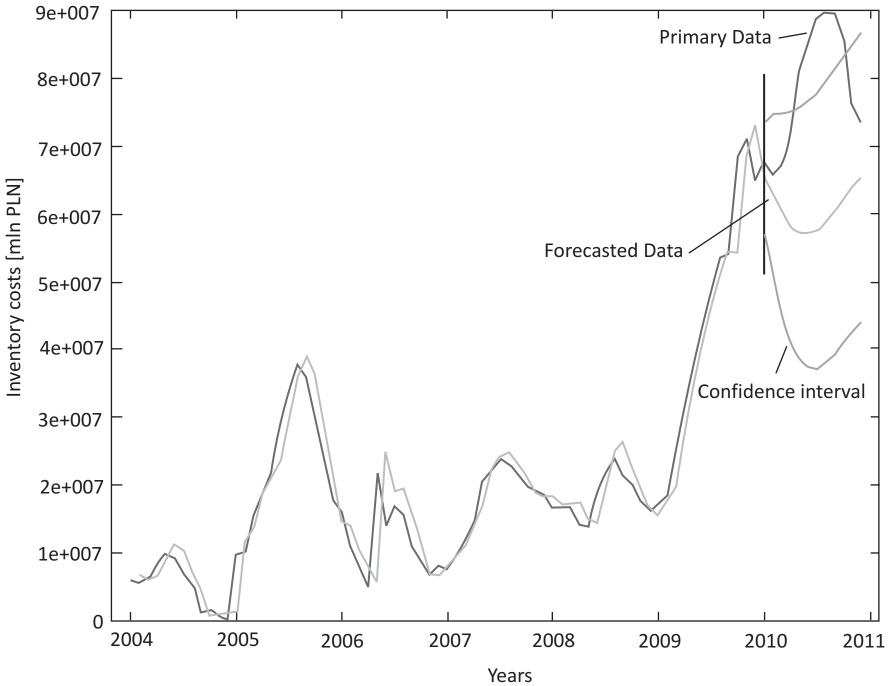

Figure 4. The 2010 forecast based on the ARIMA model for inventory costs

Source: own elaboration.

Data evaluation based on the model is similar to the original data. The model verification was conducted based on the analysis of autocorrelation of residues. This analysis showed no over-or under-estimation of expired forecasts, and, consequently, the parameters of the ARIMA model (6, 1, 2) are correct. Based on the forecast for subsequent periods, the average relative error of forecast was set at PLN 17,820,183. Given that the costs last year, quickly rose to the level of almost PLN 90 million, it is about 19.8%. Considering the fact that last year (2010) was characterized by high dynamics of inventory costs, the average of relative forecast errors is relatively large. However, it can be taken in the first months of the forecast year. This behaviour indicates precautions for using the ARIMA model for forecasting time horizon, longer than a few months. It is also worth noting that the forecast, obtained in Figure 4, in the final period of the forecast approaches real value.

CONCLUSIONS

Activities in logistics through an enterprise can be associated with greater risk, particularly in relation to demand. In anticipation of its future size, planners often make decisions based on macroeconomic statistics.

In the case of attempts to determine the magnitude of future demand for the mining coal enterprises, such factors can be, for example: the multiplicity average annual retail prices per 1 [t] of coal, GDP, volumes of production of electric energy, production of oil and derivative products, consumption of oil and oil products, etc. Anticipating future demand, one can rely on the values of these quantities in the past. Some of the listed factors are directly related to the amount of coal consumption (e.g. volumes of production of electric energy) and, hence, they may also affect the cost of inventory and storage costs, and in the case of part of the factors this influence may be indirect. In Polish conditions, which are dominated by coal-fired plants, the first group includes the amount of electricity production. An example of a group of substitute products is crude oil and fuels that are produced from it. In turn, an example of the factor from the second group may be the volume of GDP. Therefore, in the present article, we tested the influence of individual factors, by assigning correlation coefficients. Unfortunately, the method of managing available resources in the enterprise, as well as the influence of external factors, could significantly affect future predictions.

In this example, six consecutive years were used to build a model that describes the changes of demand in the enterprise. This is reflected in the maintenance costs of reserves. The last year (2010) was used as the period on the basis of which we verified the accuracy of all future values. The prognosis was determined on the basis of the autoregression and moving average models that take into account the dependencies between historical data and the random factor. The investigated time series is characterized by high variability, which is reflected in the parameters of the ARIMA model (6, 1, 2). Based on the average forecast errors, we can conclude that the risk in the field of decision support is limited. The projections presented in Figure 4 show that the farther into the future, the less accurate the forecast is.

In determining the amount of future costs, inventory and storage, you can accordingly quickly react to the changes in the market. This is done by adjusting the size of the ordered range in advance, competent management of storage space, or the use of appropriate tools of logistics management. Thus, mines competing with other players in the energy market could lower the risk of making unfavourable decisions regarding costs.

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WYKORZYSTANIE MODELI PROGNOZOWANIA DO OKREŚLANIA TRENDÓW LOGISTYCZNYCH W ZARZĄDZANIU PRZEDSIĘBIORSTWEM

Abstrakt

Tło badań. Wiedza o zmieniających się trendach rynkowych i metodach ich wyznaczania jest podstawą sprawnego zarządzania przedsiębiorstwem. Podłożem błędnie podejmowanych decyzji jest niewłaściwa interpretacja informacji pochodzących z przedsiębiorstwa. W odniesieniu do procesów logistycznych informacje o wielkości powstałych kosztów wykazują pewne zależności. W związku z tym jednym ze sposobów podejmowania trafnych decyzji jest wykorzystanie modeli prognozowania na podstawie szeregów czasowych, które wykorzystują je do określenia przyszłych wartości badanego zjawiska. Weryfikacja otrzymanych wyników może być dokonana poprzez wyznaczenie średniego błędu prognozy.

Cel badań. Celem badań jest identyfikacja stopnia powiązania wskaźników makroekonomicznych z parametrami ekonomicznymi występującymi w danym przedsiębiorstwie. Wykorzystanie uzyskanych w ten sposób informacji może posłużyć do zmniejszenie ryzyka związanego z prowadzeniem działalności gospodarczej. Celem utylitarnym badań jest wyznaczenie współczynnika korelacji wykorzystywanego do określenia, w jakim stopniu badane czynniki są współzależne i mają wpływ na budowę modelu prognostycznego.

Metodologia. Do realizacji założonych celów wykorzystano krytyczną analizę literatury, analizę danych statystycznych, metodę określania zależności pomiędzy badanymi zmiennymi na podstawie współczynnika korelacji oraz metodę prognozowania na podstawie szeregów czasowych, wykorzystującą zaawansowane modele autoregresji i średniej ruchomej. Na podstawie średniego względnego błędu prognozy można wyznaczyć trafność prognozy na przyszłe okresy.

Kluczowe wnioski. Zasadniczym rezultatem przeprowadzonej w pracy analizy jest pozyskanie informacji o wpływie czynników makroekonomicznych na zmiany wielkości z obszaru logistyki przedsiębiorstwa oraz wykorzystanie modeli autoregresji i średniej ruchomej do określenia przyszłych wielkości zmiennych szeregu czasowego. Przy wykorzystaniu modelu ARIMA wykonane na podstawie rzeczywistych danych z przedsiębiorstwa prognozy, które dotyczyły kosztów zapasów, wykazały przydatność metody do wstępnego planowania przyszłych trendów zjawisk logistycznych.

Słowa kluczowe: Modele ARIMA, prognozowanie szeregów czasowych, współczynnik korelacji.