Application of Sarima Models in Information Systems Forecasting Seasonal Volumes of Food Raw Materials of Procurement on the Territory of Communities

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Abstract

The article deals with the analysis of the theory and practice of hybrid project implementation and using models to create information systems. The authors confirm expediency of the conducted research to substantiate the parameters of a SARIMA model for forecasting milk procurement on the territory of communities. The Mito platform was used to prepare data and choose appropriate methods to forecast the seasonal volumes of incoming raw materials during implementation of the hybrid projects of milk procurement on the territory of communities. The authors used methods to determine parameters of a SARIMA model based on the analysis of the diagrams of the autocorrelation functions and partial autocorrelation function. The conducted studies were used for substantiation of the SARIMA model parameters. The SARIMA model was improved for better forecasting seasonal volumes of raw materials during implementation of the hybrid projects of milk procurement on the territory of communities. It is confirmed that the obtained results of the forecast of the seasonal volumes of raw materials are of statistical significance. Applying the proposed model, the authors of the work made forecast of the seasonal volumes of raw materials during implementation of the hybrid projects of milk procurement for a specific community. The research proves that the mean square error of the forecast of the volumes of milk procurement is 0.24. The produced model can in information systems be used for precise planning of the hybrid projects of milk procurement on the territory of a community.

Keywords 1

Hybrid projects, forecasting, information systems, SARIMA model, procurement, milk.

1. Introduction

Nowadays, the project management possesses an effective tool to increase efficiency of administration of the enterprises' and organizations' performance in different fields of the economy [1-3]. Moreover, transformation of the administrative and territorial structure of Ukraine requires solving a range of problems. One of such problems is creation and effective performance of the organizational and technical systems on the territories of established rural communities with the use of intelligent models in information systems [4-6]. The mentioned communities are engaged in production of milk that is the raw materials for its further procurement and processing. Efficiency of milk procurement and processing can be significantly improved by reconsidering the process from the position of project management. Among the kinds of projects, which are currently of great concern, are hybrid projects [7-9]. Each of the periods of milk procurement can be viewed as a separate hybrid project, which is characterized by its uniqueness, originality, temporality and relevance of the performed work. However, duration of the hybrid project lifecycle, as well as the amount of involved

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resources for its implementation, depends on the volumes of raw material (milk) procurement on the territory of a community, which is characterized by seasonality.

Considering peculiarities of the hybrid projects of milk procurement on the territory of rural communities, it is necessary to perform development of information systems for managerial processes of their planning. Nevertheless, there is still unsolved managerial problem of the appropriate forecasting the seasonal volumes of raw materials during implementation of the hybrid projects of milk procurement on the territory of communities. Moreover, to make forecasting, different kinds of informations systems are implemented by using algorithms of computer-aided learning, which secure accuracy of the forecast of their variable components and project environment.

2. Analysis of published data and problem setting

Solution of the managerial problems, related with the informations systems of forecasting the project constituents and its project environment, is studied in numerous scientific works by researchers all over the world [10-14]. However, they have not considered seasonality and effect of a set of factors on the volumes of milk procurement on the territory of communities that prevent the appropriate forecasting the seasonal volumes of the raw materials procurement.

Many scientific works are devoted to the choice of algorithms and development of the models of time series forecasting with consideration of the project environment specificity [15-19]. Those works prove that application of the models of time series forecasting provides precise results of the forecast in different spheres. Time series forecasting suggests collecting historical data and analyzing them. It secures an adequate choice of the algorithm and development of a model for forecasting the project environment constituents [20-23]. Such forecasts can be made for time series of the constituents of agrarian production projects, which are characterized by variability and seasonality [24-28].

On the contrary to other numerical methods of forecasting the project environment constituents, the process of forecasting by applying time series provides substantiation of the model of forecasting future values of the project environment constituents based on the known values in the past. However, using the time series forecasting in different spheres requires choosing the appropriate model to time series with consideration of specificity of the forecasted constituent.

The researchers have recently developed a set of intellectual models, which are based on time series and provide higher accuracy and efficiency of performance of the process of forecasting the project environment constituents. Among them, the preference is given to the model of autoregressive integrated moving average (ARIMA) model. The ARIMA models provide high accuracy and efficiency of forecasting for different kinds of time series and the use of the Box and Jenkins methodology for optimization of the mentioned model [29-32]. Thereby, while developing the model is it accepted that time series is a linear value and is described by separate statistical distributions of the studied constituent of project environment. In particular, it is assumed that the studied constituent of project environment is described by the normal law of distribution [33-36].

Considering the fact that milk procurement on the territory of communities is characterized by seasonality, which is determined by a set of factors of project environment, the authors of the research have chosen the Box and Jenkins model for forecasting the seasonal time series, which is called a seasonal ARIMA (SARIMA) model [37-43]. The above-mentioned confirms expediency of the conducted research on substantiation of the SARIMA model parameters for informations systems forecasting the seasonal volumes of raw materials while implementing the hybrid projects of milk procurements on the territory of communities.

3. The purpose and objectives of the study

The aim of the work is to substantiate parameters of the SARIMA model for forecasting the seasonal volumes of raw materials while implementing the hybrid projects of milk procurement on the territory of communities with consideration of the project environment specificity.

To achieve the set goal, the following problems should be solved:

1. to prepare data and choose methods of modelling and forecasting the seasonal volumes of raw materials while implementing the hybrid projects of milk procurement on the territory of communities;
2. to substantiate parameters of the SARIMA model for informations systems, make modelling and forecast of the seasonal volumes of raw materials, received during the period of implementation of the hybrid projects of milk procurement for the set community with consideration of its project environment characteristics.

4. Preparation of data and choice of methods for substantiation of the model of forecasting the seasonal volumes of raw materials

The volume of milk production on the territory of the community, where the hybrid projects of its procurement are planned to be fulfilled, significantly depends both on production and on the natural climatic constituents of the project environment. Production constituents include the number of dairy farms, number of cows possessed by the farms, and their efficiency. Moreover, they are influenced by the periods of cow lactation that determines seasonality of milk receipt by procurement centers. The natural climatic constituents of the project environment include environmental conditions (temperature, pressure, humidity, character of precipitation, etc.). To conduct the research, the authors collected historical data on production constituents of the project environment on the territory of Zabolottsi community in Brody district, Lviv region (Ukraine) for the period of 2018-2022. The researchers also analyzed data on natural climatic constituents of the project environment for the mentioned period by studying data from the district meteorological station. The obtained data were grouped in terms of each day separately. Preparation of the data expected exclusion of some abnormal data and filling in the gaps in the data. To complete the tasks, the Mito, that is a graphic interface for fast operating sets of data, was used. It also creates a code for preparing data in Python. A piece of prepared data for substantiation of the model of forecasting the seasonal volumes of raw materials is presented in the Table 1.

Table 1

A piece of data prepared for substantiation of the model of forecasting the seasonal volumes of raw materials

Month	Milk Production	Temperature (^{o}C)	Pressure (mm)
2018-01-01 07:00:00	411	6	728
2018-01-02 07:00:00	442	2	111
2018-01-03 07:00:00	477	4	724
2018-01-04 07:00:00	510	5	724
2018-01-05 07:00:00	541	2	725
…	…	…	…
…	…	…	…
2022-03-11 07:00:00	1562	4	752
2022-03-12 07:00:00	1569	8	755
2022-03-13 07:00:00	1582	13	752
2022-03-14 07:00:00	1592	7	748
2022-03-15 07:00:00	1600	5	757

The data prepared for substantiation of the model of forecasting the seasonal volumes of milk receipt with the “Milk Production” attribute are taken as basic ones and their figures are influenced by the data on natural climatic conditions with the «Temperature (^{o}C)» and «Pressure (mm)» attributes. By using historical data, the authors of the research composed time series of the volume of received raw materials for implementation of the hybrid projects of milk procurement on the territory of the community that is demonstrated at the Figure 1.

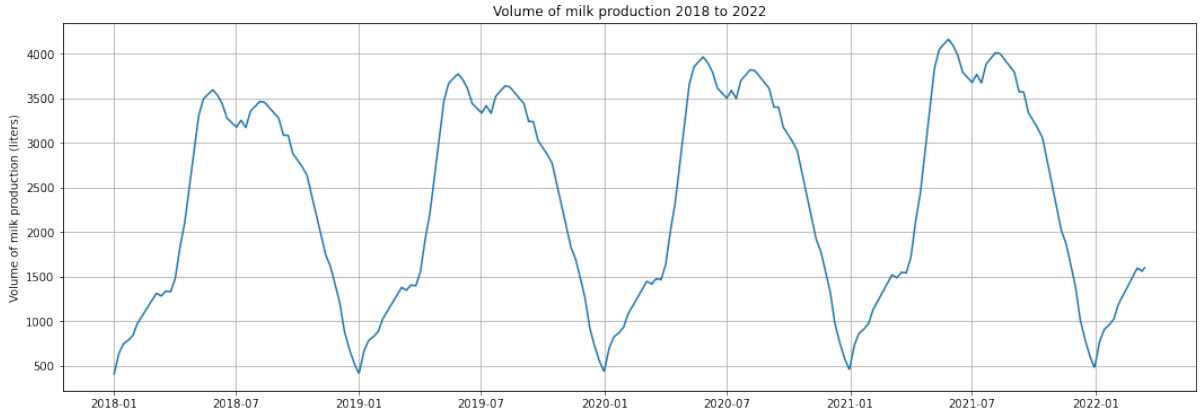

Figure 1: Trends in changes of the volumes of raw materials, received for implementation of the hybrid projects of milk procurement on the community territory

The Figure 1 clearly shows that the trends in changes of the received volumes of raw materials for implementation of the hybrid projects of milk procurement on the community territory are characterized by seasonality, and therefore, the set time series is non-stationary. The composed diagram confirms annual seasonality of the change in the volumes of raw materials, received for implementation of the hybrid projects of milk procurement on the community territory and the trend is vividly pronounced. Thus, before composing the model, the impact of seasonality and trend should be eliminated.

To substantiate the SARIMA model for forecasting the seasonal volumes of raw materials, it is necessary to add up seasonal terms in the ARIMA model. Thus, the SARIMA model can be composed as follows:

$$ARIMA(p,\ d,\ q)\cdot(P,\ D,\ Q)_m, \qquad (1)$$

where $(p,\ d,\ q)$, $(P,\ D,\ Q)_m$ – non-seasonal and seasonal constituents of the SARIMA model respectively; m – a parameter, characterizing the number of periods of raw materials receipt per a year.

The seasonal constituent of the SARIMA model is similar to a non-seasonal one, but it characterizes changes of the seasonal period. By using the prepared set of data with the volume of received raw materials for implementation of the hybrid projects of milk procurement on the community territory, the ARIMA model is finished with the changing values $(p,\ d,\ q)$. To determine parameters of the ARIMA model, the Akaike information criterion (*AIC*), which is of the following value, is used:

$$AIC\ (p)\ = 2k + n\cdot ln\left(\frac{RSS}{n}\right), \qquad (2)$$

where n – number of the sets of data for the studied period; RSS – the remained sum of squares, characterizing the variance value in the given data set that is not explained by the very regression model.

The SARIMA model with the minimum *AIC* value is considered the preferred one for forecasting the volumes of raw materials, received for implementation of the hybrid projects of milk procurement on the community territory. Furthermore, the authors used methods to determine parameters of the ARIMA model, which involved analysis of the diagrams of autocorrelation (*ACF*) and partial autocorrelation functions (*PACF*).

5. Results of substantiation of the model of forecasting the seasonal volumes of raw materials.

Substantiation of the parameters of the SARIMA model of forecasting the seasonal volumes of raw materials while implementing the hybrid projects of milk procurement for the chosen community was done with consideration of its project environment characteristics in the following sequence. First, it was necessary to identify the model class and suggested a hypothesis about its peculiarities and parameters. Afterwards, estimation of the identified model parameters was made.

While identifying class of the model, it was necessary to process the initial data and to find out any deviation from the general trend of their change. To stabilize the variance, the initial data are sometimes changed by scaling them according to the formula:

$$V_i = \frac{a_i - \min(a_i)}{\max(a_i) - \min(a_i)}, \quad (3)$$

where V_i – scaled data value; a_i – initial input data; $\min(a_i), \max(a_i)$ – minimum and maximum value of the specified data set.

Afterwards, the autocorrelation function (*ACF*) and partial autocorrelation function (*PACF*) of the changed data are applied to the diagram. Results of that stage are shown at the Figure 2.

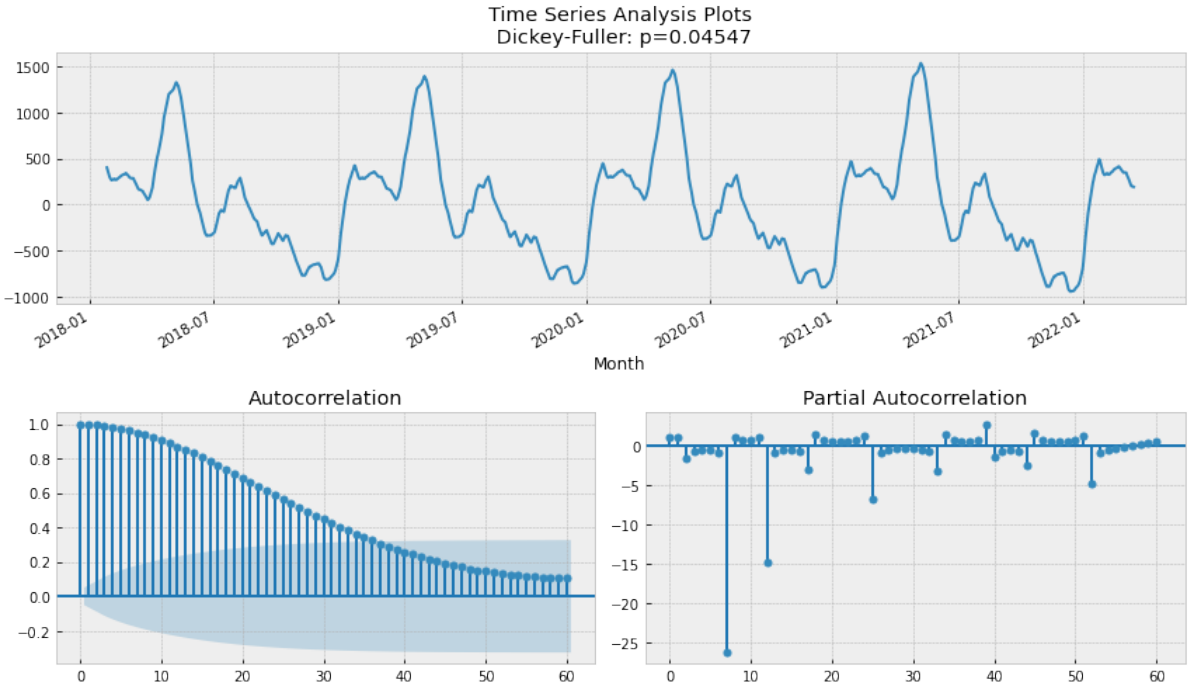

Figure 2: Results of estimation of the autocorrelation function (*ACF*) and partial autocorrelation function (*PACF*) of the data on the raw materials volumes

The obtained results (Figure 2) clearly demonstrate that the obvious seasonality has disappeared. However, the autocorrelation function still has too many significant lags. To eliminate them, the first differences are taken by subtracting the series from itself with a lag of 1. The obtained results are shown at the Figure 3.

Basing on the analysis of the autocorrelation function (*ACF*) and partial autocorrelation function (*PACF*) of the changed data, the researchers determined parameters of the $AR(p)$ and $MA(q)$ models. Moreover, analysis of the *ACF* and *PACF* diagrams provides for the opportunity to get the seasonal model value.

To make forecast of the seasonal volumes of received raw materials while implementing the hybrid projects of milk procurement for the specified community with consideration of its project

environment characteristics, the SARIMA model is applied. The average monthly value of the volumes of milk procurement with a year interval in the time series x_t can be modelled as follows:

$$\delta\left(B^{365}\right)\Delta_{365}^{D}x_t = \Theta\left(B^{365}\right)\alpha_t, \quad (4)$$

where $\Delta_{365}^{D}x_t = \left(1-B^{365}\right)x_t = x_t - x_{t-365}$, або $\delta\left(B^{365}\right)\Theta\left(B^{365}\right)\alpha_t$ are the polynomials from p and q respectively. Both items satisfy the corresponding conditions of stationarity and inversion [44-46]. Normally, it is expected that the error constituent will correlate with the set time series.

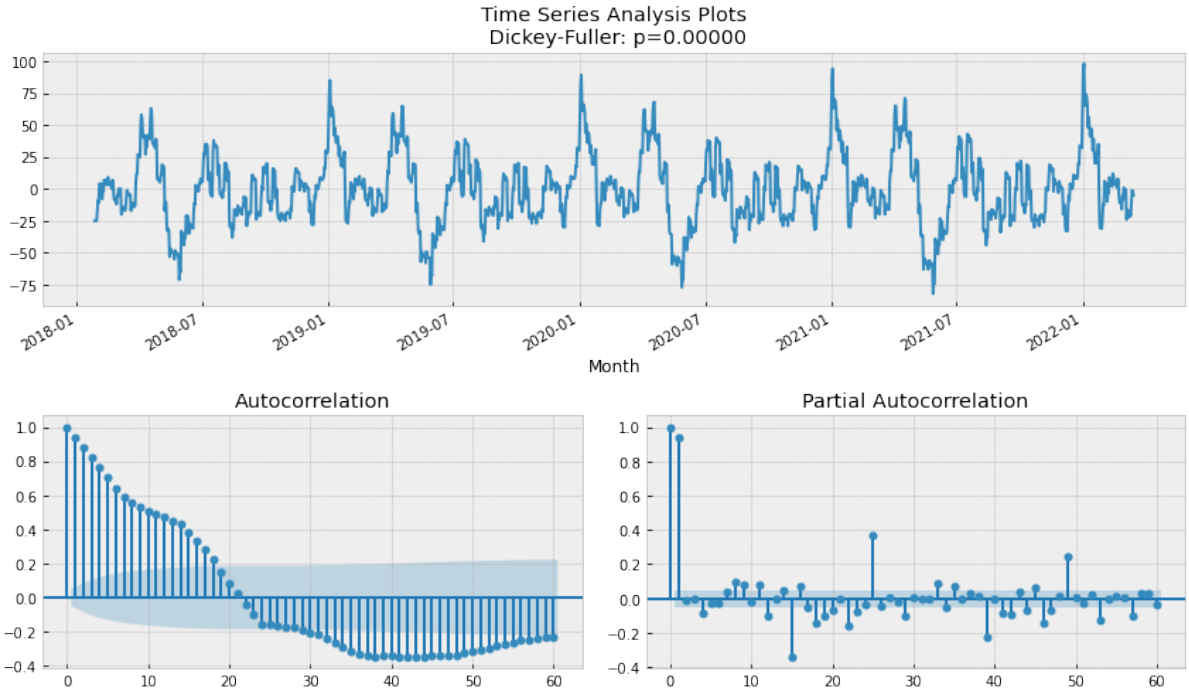

Figure 3: Results of estimation of the autocorrelation function (*ACF*) and partial autocorrelation function (*PACF*) of the scaled data on the raw materials volumes

To determine the corresponding parameters of the models of forecasting the seasonal volumes of raw materials, the method of hyperparameter optimization is used in the research. In the current study, the $ARIMA(p, d, q)\cdot(P, D, Q)_m$ model requires using six parameters, namely p, d, q, P, D, Q. The value m is set as 265, because the used data on the volumes of milk procurement are of daily gain with a year period. The *AIC* values of the chosen models are presented in the Table 2.

Table 2

The *AIC* values of the SARIMA models of forecasting the seasonal volumes of raw materials, received while implementing the hybrid projects of milk procurement on the community territory

	Parameters	*AIC Value*
0	(4, 3, 0, 1)	10091,87
1	(4, 3, 1, 1)	10098,74
2	(3, 3, 1, 1)	10118,54
3	(3, 4, 1, 1)	10156,71
4	(3, 4,0, 1)	10158,53

Referring to the Table 2, one can confirm that the SARIMA model with the parameters (4, 3, 0, 1) demonstrates the lowest AIC value. Therefore, the model should be considered as the preferred one

for forecasting the seasonal volumes of raw materials while implementing the hybrid projects of milk procurement on the community territory. Results of the SARIMA model optimization are shown in the Table 3.

Table 3

Results of optimization of the SARIMA model of forecasting the seasonal volumes of raw materials while implementation of the hybrid projects of milk procurement on the community territory

SARIMAX Results

Dep. Variable:	MilkProduction	No. Observations:	1535
Model:	SARIMAX(4, 1, 3)x(0, 1, [1], 24)	Log Likelihood	-5036.939
Date:	Tue, 26 Apr 2022	AIC	10091.879
Time:	21:37:52	BIC	10139.758
Sample:	01-01-2018	HQIC	10109.709
	- 03-15-2022		
Covariance Type:	opg		

	coef	std err	z	P>|z|	[0.025	0.975]
ar.L1	-0.4300	0.021	-20.272	0.000	-0.472	-0.388
ar.L2	-0.0211	0.018	-1.175	0.240	-0.056	0.014
ar.L3	0.4266	0.016	26.426	0.000	0.395	0.458
ar.L4	0.9639	0.018	53.017	0.000	0.928	1.000
ma.L1	1.3816	0.026	52.949	0.000	1.330	1.433
ma.L2	1.3709	0.019	72.067	0.000	1.334	1.408
ma.L3	0.9374	0.026	36.008	0.000	0.886	0.988
ma.S.L24	-0.9786	0.023	-42.981	0.000	-1.023	-0.934
sigma2	42.2587	0.891	47.430	0.000	40.512	44.005

Ljung-Box (L1) (Q):	1.26	Jarque-Bera (JB):	5961.24
Prob(Q):	0.26	Prob(JB):	0.00
Heteroskedasticity (H):	1.25	Skew:	0.11
Prob(H) (two-sided):	0.01	Kurtosis:	12.73

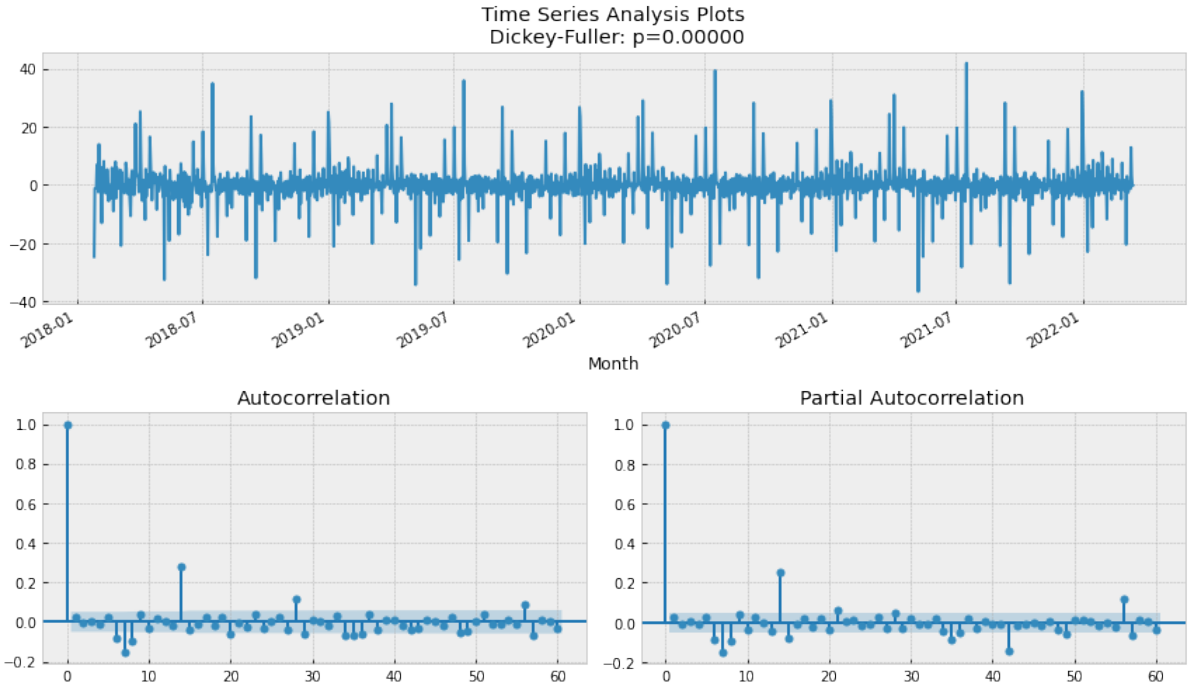

Figure 4: Results of estimation of the autocorrelation function (*ACF*) and partial autocorrelation function (*PACF*) of remains of the forecasted data on the raw materials volumes

The data presented in the Table 3 are summarized. The second column shows value factors (i.e. significance) of each function and their impact on the time series. Given all values $P > |z|$ are less 0.05, the obtained results are statistically significant.

The obtained results confirm that remains are not characterized by obvious seasonality but are the white noise. Similarly, the autocorrelation is shown at the Figure 4, and means that remains of the initial data are characterized by low correlation with the delayed data. It is determined that remains are distributed by the normal distribution law. In general, the model demonstrates adequate accuracy of forecasting the seasonal volumes of raw materials and can be used in information systems for planning the hybrid projects of milk procurement on the community territory.

6. Discussion

The chosen model can be used in information systems for forecasting time series of the change of the seasonal volumes of raw materials while planning the hybrid projects of milk procurement on the community territory. The forecast precision is principally important and therefore, it is necessary to check accuracy of the made forecast of the seasonal volumes of raw materials by comparing the forecast values with the known historical data (Figure 5).

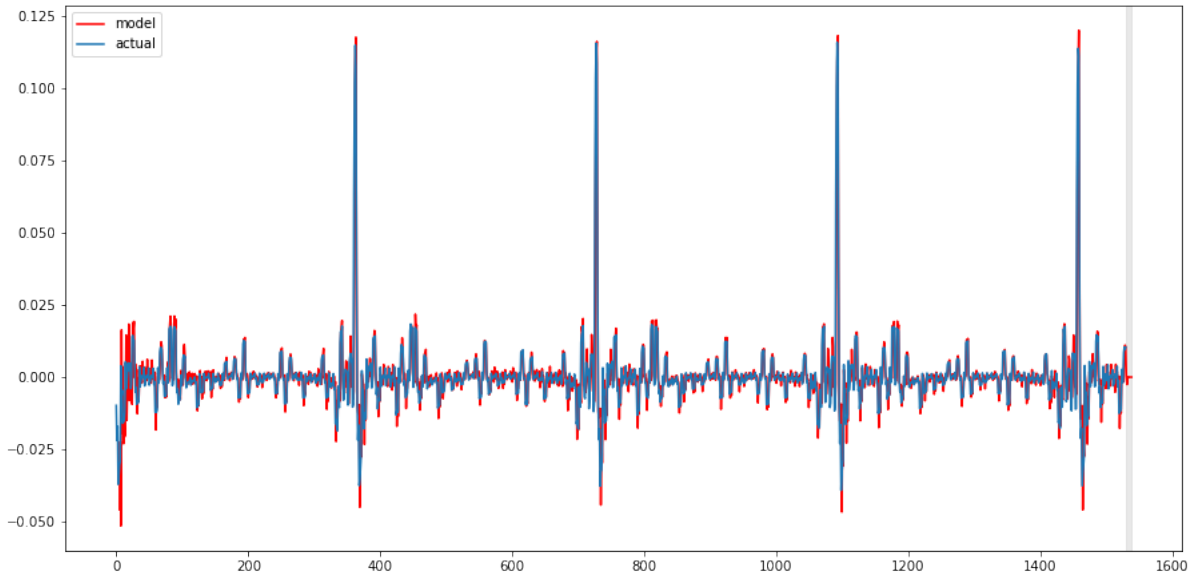

Figure 5: Results of the control for precision of the made forecast of the seasonal volumes of raw materials by comparing the forecast values with the known historical data

The model involves forecasting the volumes of milk procurement on the territory of Zabolottsi community in Brody district, Lviv region (Ukraine) for the period of 2018-2022. Statistical data on the period from January 2018 to August 2020 are used for training (training set of data), whereas the data on the period from September 2020 to March 2022 – as testing ones (testing set of data) (Figure 6).

It is determined that the mean square error (MSE) of the forecast of the volumes of milk procurement on the community territory in the period from September 2020 to March 2022 is 0.24. It confirms that fact that the MSE value is relatively low. The substantiated model demonstrates the appropriate forecast of the volumes of milk procurement on the community territory that proves precision of the testing set of data and can be used in information systems while planning the hybrid projects of milk procurement on the community territory.

Figure 6: Results of forecasting the volumes of milk procurement on the territory of Zabolottsi community in Brody district, Lviv region (Ukraine)

7. Conclusions

1. The performed analysis of the theory and practice of implementation of the hybrid projects of milk procurement on the territory of communities proves expediency of the conducted research on substantiation of the SARIMA model parameters for the development of information systems, that secures adequate forecasting the seasonal volumes of raw materials. Using the Mito platform, the researchers prepared data and chose methods for forecasting the seasonal volumes of raw materials while implementing the hybrid projects of milk procurement on the territory of communities. It is

proposed to use methods to determine the SARIMA model parameters by analyzing the diagrams of the autocorrelation function (*ACF*) and partial autocorrelation function (*PACF*).

2. The conducted research substantiates parameters of the SARIMA model for relevant information systems. It is determined that the SARIMA model with the parameters (4, 3, 0, 1) shows the lowest value of the Akaike information criterion. The SARIMA model has been optimized for forecasting the seasonal volumes of raw materials while implementing the hybrid projects of milk procurement on the territory of communities. Given all values $P > |z|$ are less 0.05, the obtained results are statistically significant. The proposed model was used to make forecast of the seasonal volumes of raw materials while implementing the hybrid projects of milk procurement for the specified community with consideration of its project environment characteristics. It is determined that the mean square error (MSE) of the forecast of the volumes of milk procurement is 0.24. The obtained model can be used in information systems for accurate execution of the processes of planning the hybrid projects of milk procurement on the community territory.

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