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Ivana Janjić [1]
Innovation Center, University of Nish

Ivana Milošević [2]
Leoni Wiring System Prokuplje

Anđela Milenković [3]
Innovation Center, University of Nish

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APPLICATION OF QUANTITATIVE METHODS FOR INVENTORY FORECASTING IN SUPPLY CHAINS ON THE EXAMPLE OF LEONI COMPANY

Abstract

In order to effectively manage the supply chain, it is important to effectively manage the inventory within it. The application of quantitative forecasting methods contributes to the accuracy and validity of forecasting and defining stock flows. The subject of this paper is to review the use of quantitative methods of inventory forecasting, namely exponential smoothing, adaptive filtering, the method of moving averages and regression analysis. The aim of the paper is to show inventory forecasting using the mentioned quantitative methods on the example of the company "Leoni Wiring System Prokuplje". The results of the research indicate that applied quantitative methods of forecasting in the supply chain provide reliable and accurate forecasts on the basis of which material orders can be defined in order to ensure the smooth functioning of production, on the example of the company "Leoni Wiring System Prokuplje".

Keywords: *supply chain, inventory, quantitative methods, forecasting*

JEL classification: C13, L62

ПРИМЕНА КВАНТИТАТИВНИХ МЕТОДА ПРОГНОЗИРАЊА ЗАЛИХА У ЛАНЦИМА СНАБДЕВАЊА НА ПРИМЕРУ КОМПАНИЈЕ „ЛЕОНИ"

Апстракт

У циљу ефикасног управљања ланцем снабдевања значајно је ефикасно управљати залихама унутар њега. Примена квантитативних метода прогнозирања доприноси тачности и валидоности предвиђања и дефинисања токова залиха. Предмет овог рада је сагледавање начина употребе квантитавних метода прогнозирања залиха, и то експоненцијалног изравнања, адаптивног филтри-

[1] ivana91ekfak@gmail.com, ORCID ID 0000-0003-3142-8467

[2] ivanica.96@hotmail.com, ORCID ID 0000-0002-4197-5539

[3] milenkovic.andjela998@gmail.com, ORCID ID 0000-0001-5779-1526

рања, методе покретних просека и регресионе анализе. Циљ рада је да се на примеру компаније „Leoni Wiring System Prokuplje“ прикаже прогнозирање залиха применом споменутих квантитативних метода. Резултати истраживања указују да примењене квантитативне методе предвиђања у ланцу снабдевања дају поуздане и тачне прогнозе на основу којих се могу дефинисати наруџбине материјала у циљу несметаног функционисања производње, на примеру компаније „Leoni Wiring System Prokuplje “.

***Кључне речи**: ланац снабдевања, залихе, квантитативне методе, прогнозирање*

Introduction

Supply chains are attracting increasing attention from theorists and practitioners. The increasing volatility of demand, shortened product life cycles as well as the increased rate of innovation, have conditioned the trend of efficient management of supply chains. In order to reach effectiveness, it is necessary that all members of the supply chain understand their importance and strive for its optimization. In recent literature, the term supply chain resilience is also mentioned, which means the ability to survive in modern business conditions. The resilience of the supply chain and its survival, as well as the techniques to achieve this goal, are the subject of consideration by all members of the supply chain, who benefit from its survival and improve their business, because without it, there is no individual progress (Anđelković et al., 2013). Also, supplies optimization is an imperative and condition for the efficient functioning of the supply chain (Anđelković & Milovanović, 2021; Negri et al., 2021).

Due to the major changes in the market, which have been present in the last few years, the management of supply chains encounters numerous challenges. The Covid-19 pandemic led to a complete disruption of supply chains, which continued in the years after the pandemic, primarily due to the emergence of the crisis in Ukraine, as a result of which a large number of sectors were affected. One of the sectors that suffered the most damage is the automotive industry. Manufacturers and suppliers (e.g. "*Leoni*", "*Fujikura*", "*Nexans*") are increasingly striving for collaboration in order to reduce the effects of the crisis. German companies in particular suffered great damage, due to their withdrawal from the market of the Russian Federation, but also due to interruptions in their production. Their car exports to Ukraine and the Russian Federation have decreased, while Chinese companies are slowly taking over the market share (Burger, 2022). The war in Ukraine has affected the global economy. There was an increase in the price of energy in Europe due to the introduction of sanctions against the Russian Federation. Also, world trade has been limited and disrupted, there have been interruptions in food supply. Forecasts by the World Trade Organization have indicated that the same unfavourable situation will continue. In addition to the impact on trade in goods, the war in Ukraine affects the exchange of services, primarily transport services. Also, the disruption of supply chains around the world is predicted to cause a major crisis.

An important aspect of the efficient functioning of supply chains is effective inventory management. The subject of this paper is an overview of the use of quantitative methods of inventory forecasting. The aim of the paper is to show and explain the implementation of quantitative methods for inventory forecasting on the example of the company "*Leoni Wiring System Prokuplje*".

1. Literature review

1.1. Concept and management of supply chains

Supply chains have always occupied the attention of a large number of theorists and practitioners. The supply chain includes the flows of information, money and knowledge that are continuously managed by the members of the supply chain. Supply chains involve a large number of entities. Manufacturers, suppliers, transporters, wholesalers, retailers, buyers are just some of the potential participants in a supply chain. As the number of members increases, so does the complexity of managing them. In order for the product to reach the final consumer, it is necessary to go through the entire supply chain, so it can be concluded that the satisfaction of the final consumer depends on all members of the supply chain, and not only on the manufacturer who produced the product. Therefore, it is necessary to effectively manage the entire supply chain in order to maximize the satisfaction of the end customers. Supply chains include three basic phases. The first phase is procurement, the second is production and the third is distribution. Within each of these phases, there are multiple participants who cooperate with each other (Felea & Alăstroiu, 2013).

Earlier, traditional supply chains were characterized by no great connection between participants and the focus was on storage and inventory. However, today, a large number of supply chain members rely on a significant connection between them. That is why there is a need for its optimization, in order to synchronize all elements that add value, but also to eliminate activities that do not add value. Today, there is also an increasing use of information and communication technologies, which help control and exchange information in the supply chain. They enable better and faster communication between members, which shortens the period from procurement to the product delivery process. In order to realize the advantages that the application of information and communication technology implies, members of the supply chain purchase software that enables the performance of the aforementioned functions. Some of them are *Vanguard Software Corporation*, *ILOGI*, *Inc* (*Mountain View, CA*), *Dra Systems*, *SynQuest* (*Atalanta, GA*) and others (Mitrović & Mitrović, 2019). Also, the application of the Internet in supply chains can increase the degree of integration. By using it, it is possible to increase operational efficiency, speed up processes in the supply chain, faster exchange of information and delivery of products, and greater control over operations. If we look at individual members of the supply chain, for example manufacturers, the application of the Internet will lead to a reduction in the risk of interruption of the production process. In addition to the aforementioned advantages, there are still obstacles and limitations, which primarily relate to the technical and social aspects of use (Lee et al., 2022).

A number of methods can be used to improve the efficiency of supply chain management. The application of cloud computing is a good solution for supply chain management. The main purpose of cloud computing is to share resources over a network, most often over the Internet. It allows resources to be: used only when needed, provisioned flexibly, measured and billed. However, there are also certain disadvantages of cloud computing. They relate to:

inadequate legal regulation, lack of clarity regarding the licenses that are needed, the problem of providing a guarantee by the provider and difficulties in managing digital identity (Regodić et al., 2019). Also, the use of scientific research methods, quantitative, qualitative or their combination, contributes to improving the efficiency of supply chain management (Yue & Xu, 2019). When it comes to supply chains, these methods gain special importance when applied to forecast inventory flows.

1.2. Inventory flows in supply chains

Inventory management is the process of continuous monitoring and control of inventory levels. All inventory can be classified into three basic categories, according to the ABC approach. Group A contains inventory that generate 70% of the company's revenue. Group B consists of inventory that generate 25% of income, while group C consists of the least valuable inventory, which participate in total income with only 5%. Classification is important because it allows management to define what level of attention should be given to different groups of inventories. It is logical that the greatest attention will be directed towards group A, because they generate the largest percentage of total revenues, then less to group B and least to group C (Priniotakis & Argyropoulos, 2018). Inventory and its optimization represent important aspects of the business of any company and the supply chain as a whole. They affect direct costs, but also every member of the supply chain, which leads to a direct impact on the time of delivery of products to consumers. This is especially important in modern business conditions, where competitiveness is based first on time and then on quality. On the one hand, a lack of inventory can lead to consumer dissatisfaction, which can lead to a change of manufacturer and a negative reputation. On the other hand, excessive inventory leads to high inventory holding costs, which is also an unfavourable situation. Therefore, all members of the supply chain strive for inventory optimization, as the primary goal of supply chain inventory management.

Efficient customer response (ECR) is the most common method of inventory management. It is especially applicable in modern business conditions, because its goal is to adapt to changing customer requirements, through the integration and cooperation of members of the supply chain. Although most authors believe that this concept appeared first in the food industry, some authors state that it originated from the fashion industry. However, due to the good results that it achieved first in the area of the food industry, its development and origin is linked precisely to this branch of the industry. The application of the ECR system enables the management of product categories, continuous replenishment of stocks and the application of technology in inventory management. However, despite the numerous advantages that this system provides, its implementation implies an expensive and long-term process. At the level of individual members of the supply chain, a change in internal operations is required. In addition, a greater degree of cooperation and integration is needed, which all affects the complexity of the application of this system (Stanković & Popović, 2009).

In modern business conditions, the application of algorithms and algorithmic procedures is increasing, which are combined in order to predict the trend of a certain phenomenon, such as, for example, inventory movements, based on the analysis and comparison of a large amount of data. Quantitative forecasting methods mostly rely on data. When choosing a quantitative method, it is necessary to consider a large number of factors such as the context of the forecast, then the relevance, but also the availability of historical data used in the forecast, the target degree of accuracy, as well as the time period of the forecast. Quantitative methods can be combined with human judgment, which provides a number of advantages. A survey of 240 US corporations found that only 11% use forecasting software, and 60% routinely adjust generated forecasts based on individual judgment. Research shows that the synergy of these two methods leads to greater accuracy and less probability of creating errors in the analysis process compared to the independent results that both prediction models provide (Zellner et al., 2021). There is a large number of quantitative forecasting methods, however, the four most popular in theory and practice stand out, namely exponential smoothing, adaptive filtering, the method of moving averages and regression analysis.

1.3. Methodology

The following quantitative methods were used for forecasting inventory flows in the supply chain:

a. exponential smoothing;
b. adaptive filtering;
c. moving average method and
d. regression analysis.

Exponential smoothing is a simple technique used to "smooth out" most residual effects (Gelper et al., 2007). Exponential smoothing is considered by some scientists to be a naive method of forecasting. However, today it is used in many areas, starting from inflation forecasting to forecasting related to tourism management needs. Exponential smoothing has a significant place because of the simplicity it exhibits compared to much more complex and sophisticated approaches in forecasting. The starting idea is that there is a certain regularity in the behavior of the observations along with random fluctuations in the series. By applying the exponential smoothing procedure to the available data, a smoothed series with damped random fluctuations is obtained. Such a flattened series indicates the underlying tendency present in a given time series. The series of smoothed values is then used as a baseline for forecasting future values of the time series. That, together with the fact that exponential smoothing uses only the last values of the series, makes the method a useful tool for forecasting future trends in time series (Lepojević & Janković-Milić, 2011).

The application of the *adaptive filtering technique* involves two phases. The first phase is adjusting a set of weights to historical data, and the second is using those weights to make a forecast. It is also necessary to calculate the standard error associated with this forecast. The weights are adjusted to reduce the error observed with the forecast. The sum of the weights must be equal to number one (Đorđević et al., 2011).

The method of moving averages is most often used to determine the trend (T) if the cyclical component does not exist, or to determine the product of the trend and the cyclical component (TC) if the cyclical component exists. A moving average is an artificial construction of a time series in which each original data of the time series is replaced by the arithmetic mean of that data, a certain number of previous data and the same number of subsequent data. The total number of members whose arithmetic mean is sought is odd, and represents the order of the average. Thus, if we replace each original time series data with the arithmetic mean of that data, one previous and one subsequent data, we get a three-member moving average. If we replace each original data of the time series with the arithmetic mean of that data, two previous and two subsequent data, we get a five-member moving average.

For the selected period of length L (even or odd number of years), we calculate the arithmetic averages of consecutive values of the occurrence for the selected length and by centring the average we replace the corresponding empirical data of the time series. Moving averages can be formed based on 3, 4, 5 and more members of the time series that determine the order of the moving averages. Moving averages of odd, third order are formed from three time series data (Đorđević, 2009).

Regression analysis is a statistical study in which two or more mass phenomena are observed and the connections between them are analysed, as well as the shape and direction of those connections. The basic task of regression analysis is to assess the form of dependence (regression model) between observed phenomena, that is, to show how the studied phenomenon (dependent variable) changes on average with the change in the value of other phenomena (independent variables). In practice, there is often a situation where it is necessary to establish a functional relationship between two or more variables, where a visual representation is reached through a graph. First of all, in the first step, the values of the variables that are put into a relationship, and which depend on each other, are collected. After that, the variables are displayed in the coordinate system, and by connecting the points, a curve is created that shows the dependence of the entered variables. The most common approximate curves are straight line, parabola, cubic parabola, 4th order parabola, hyperbola, exponential curve, geometric curve, logistic curve, etc. (Bogićević, 2013). The appropriateness of the regression model is checked using the coefficient of determination, while in the multiple regression equation, the unknown quantities are actually regression coefficients that are determined based on the measured values of the objective function using the "method of least squares" (Ilić & Mijailović, 2014).

The data on the basis of which the analysis was made were taken from the SAP and FORS systems of the company LEONI Wiring Systems Southeast d.o.o. Prokuplje. For the purposes of data processing, the SPSS statistical package for the social sciences (Statistics Statistical Package for the Social Sciences), version 22.0, was used.

The research is based on the following hypothesis:

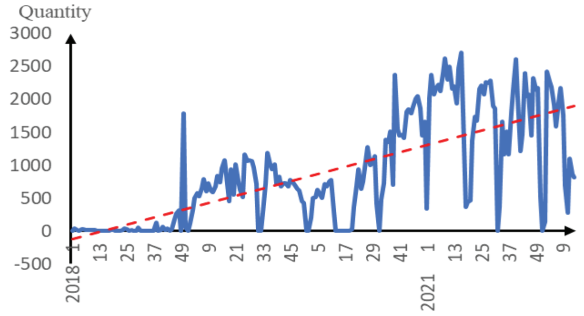
Quantitative methods of forecasting in the supply chain provide reliable and accurate forecasts on the basis of which materials can be ordered so that optimal inventory is maintained for the smooth functioning of production.

4. Research results and discussion

4.1. Forecasting inventory flows on the example of material "sibo" from the supplier MTA Advanced Automotive Solutions

Supplier MTA Advanced Automotive Solutions (MTA) is one of the most important suppliers of Leoni. The MTA supplier material - "sibo" - is a fuse housing that is an integral part of every cable manufactured by the Leoni Company. The forecasting of the amount of "sibo" material that needs to be procured from the MTA supplier was carried out on the basis of empirical data of the ordered amount of "sibo" material in the period from 2018 to the 14th week of 2022 (Figure 1).

Figure 1: Empirical data - ordered quantities of "sibo" materials in the period from 2018 to week 14 in 2022



Source: Authors

SPSS software was used for forecasting. The values of the smoothing constants are generated by the software itself and provide optimal forecasts. In order to evaluate the accuracy of the forecast and help in the selection of the forecast that should be used, three popular measures for determining the accuracy of the forecast have been established - the coefficient of determination (R-squared), the mean absolute deviation (MAE) and the standard error of the forecast (RMSE).

Table 1: Indicators of model fit

Model	No. of Predictors	Model Fit statistics		
		R-squared	RMSE	MAE
Orders MTA	0	0.691	453.23	259.753

Source: Authors

According to the data from Table 1, the coefficient of determination is 0.691. This coefficient shows that the selected smoothing model explained 69.1% of the total variability in the supply of "sibo" materials of MTA suppliers. The RMSE value shows the average deviation of the forecasted values from the empirical data. In this case it is 453.23. The mean absolute deviation (MAE) is 259.75 and shows the mean absolute deviation between the empirical and forecast values.

Table 2 shows data on the forecast for the procurement of "sibo" materials in the period from the 15th to the 17th week in 2022. In addition to the point values, the table also contains data for the 95% confidence interval of the forecast values. It is noticeable that all forecast values, made for the period from the 15th to the 17th week in 2022, are identical. This result arose because exponentially smoothed forecasts start from the assumption that there is no trend in the time series. Therefore, this example clearly illustrates the risk of forecasting further deliveries of MTA suppliers in the long term, and hence one should be very careful in these forecasts, except in the case that it is necessary to make a forecast for a short-term period. The advantage of this smoothing method is that it is not demanding on the length of the time series and is fully automated. Hence, it is widely used in situations where it is necessary to form a forecast in a relatively short period of time. The main disadvantage of exponential smoothing is that it does not allow the treatment of series with trend and season.

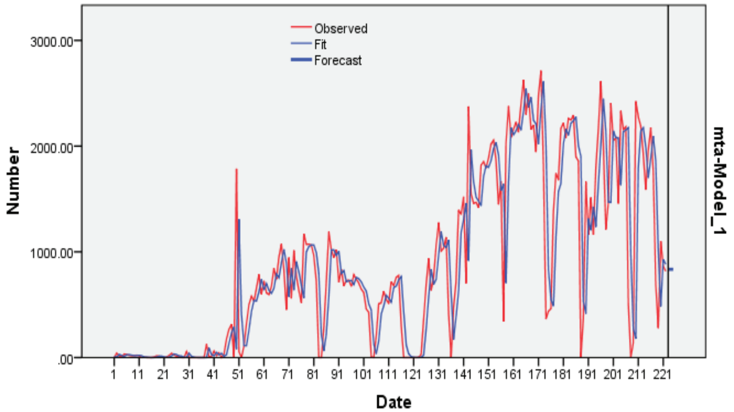
Table 2: Data on the forecast of procurement of "sibo" material from the MTA supplier in the period from the 15th to the 17th week in 2022

Model		15th W 2022	16th W 2022	17th W 2022
Order MTA	Forecast	835.21	835.21	835.21
	UCL	1728.42	1935.97	2110.16
	LCL	-58	-265.54	-439.74

Source: Authors

In Figure 2, the direct and forecast values of MTA suppliers are shown, it is clearly evident that there are no large deviations between empirical data and direct values, which indicates that the applied forecasts are also valid.

Figure 2: Empirical data, smoothed and forecasted values of "sibo" material from the MTA supplier



Source: Authors

Examining Figure 2, it is noticed that the deliveries of "sibo" material from the MTA supplier have a growing tendency, and therefore the suitability of the model based on the approach that considers the presence of a trend in the data should be checked. In this sense, the results of Holt's data smoothing approach are presented below. From Table 3, it can be seen that the coefficient of determination is 0.588. Therefore, the selected smoothing model explained 69.1% of the total variability of the "sibo" material delivery. The RMSE value shows that the average deviation of the predicted values from the empirical data is 454.34, while the mean absolute deviation (MAE) is 262.30.

Table 3: Indicators of model fit according to Holt's approach

Model	No. of Predictors	Model Fit statistics		
		R-squared	RMSE	MAE
Order MTA	0	0.588	454.339	262.299

Source: Authors

In Table 4, data on the forecast of procurement of "sibo" material from MTA suppliers in the period from the 15th to the 17th week in 2022 according to Holt's approach are presented.

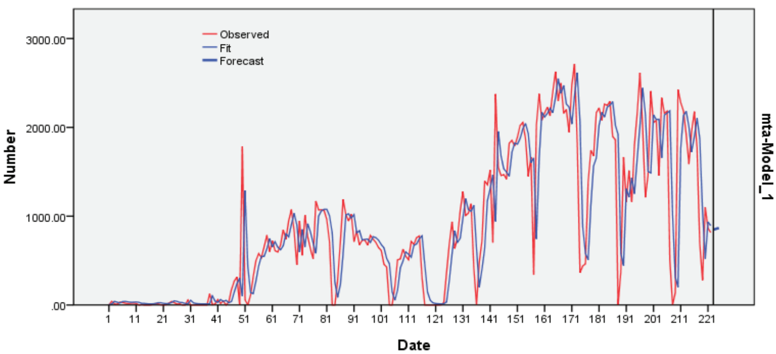
Table 4: "Sibo" material procurement forecasts for the period from the 15th to the 17th week in 2022 according to Holt's approach

Model		15th W 2022	16th W 2022	17th W 2022
Orders MTA	Forecast	849.47	858.62	867.78
	UCL	1744.88	1951.74	2127.96
	LCL	-45.95	-234.5	-392.4

Source: Authors

Table 4 gives the score point values and the corresponding 95% confidence interval of the predicted values. In contrast to the forecasted values using exponential smoothing, here a growing trend is observed in the forecasted values of "sibo" material from the MTA supplier for the mentioned period. The reason for this is the fact that Holt's approach starts from the assumption that there is a trend in the time series.

Figure 3: Empirical data, smoothed and forecasted values of "sibo" material from MTA supplier according to Holt's approach



Source: Authors

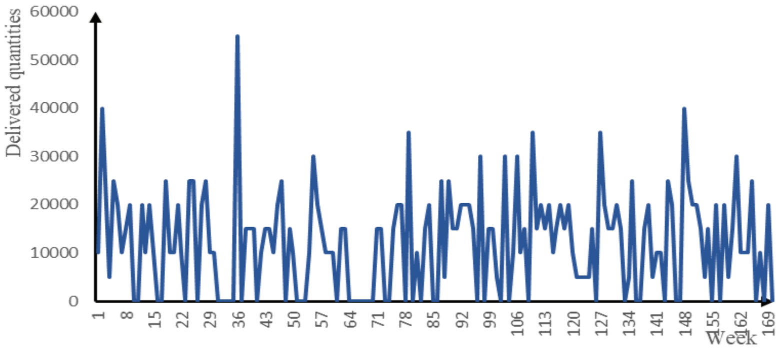
From Figure 3, the empirical values of the observed phenomenon, the corresponding smoothed values and the forecasted values can be seen. It is noticeable that there are no large deviations between the empirical data and the smoothed values.

If we compare the results obtained by exponential smoothing and Holt's method, contrary to expectation, we conclude that all three indicators of representativeness of the model support the choice of exponential smoothing as an excellent quantitative method for forecasting the delivery of "sibo" material from the MTA supplier. Namely, the measure of explained variability is higher with exponential smoothing, and the corresponding deviation measures are smaller compared to Holt's approach. This proved the hypothesis on which this research is based, that quantitative methods of forecasting in the supply chain provide reliable and accurate forecasts on the basis of which materials can be ordered so that optimal inventory are maintained for the smooth functioning of production, in the case of exponential smoothing.

4.2. Forecasting the delivery of the supplier "Hirschmann" to the company "Leoni" in 2022 using adaptive filtering

Deliveries from the supplier "Hirschmann" include several different components. For forecasting purposes, a component was selected, which is managed under the "Leoni" number "418009681". The forecast was made on the basis of empirical data from Figure 4, which shows the delivery of the supplier "Hirschmann" in the period from 2019 to the 14th week in 2022. The source of the data shown in Figure 4 is the FORS ERP system used in the "Leoni" company.

Figure 4: Deliveries of the component "418009681" in the period from the 1st week of 2019 to the 14th week of 2022



Source: Authors

From Figure 4, it can be seen that the delivery of material "418009681" is not characterized by the presence of a trend. Also, it can be noticed that there were no deliveries in all weeks in 2020. The reason for this is the disruption caused by the Corona virus pandemic.

Due to the relatively large number of weeks in which the delivery of this component was missing, which can be seen in Table 5, weekly data were grouped into quarterly ones.

The thus obtained quarterly delivery values were further used as a basis for applying adaptive filtering methods and forecasting the delivery of component "418009681" in the second quarter of 2022.

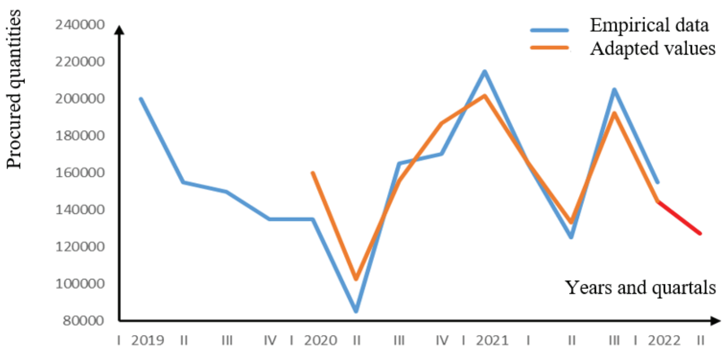
Table 5: Delivery of component "418009681" in the period from the first quarter of 2019 to the first quarter of 2022

Years and quarters	Delivered quantities	Adapted values	Error	Coefficients			
				w_1	w_2	w_3	w_4
I 2019	200000						
II	155000						
III	150000						
IV	135000			0.25	0.25	0.25	0.25
I 2020	135000	160000	-25000	0.208	0.083	0.202	0.188
II	85000	102573.5	-17573.5	0.17	0.045	0.159	0.144
III	165000	155543.9	9456.13	0.361	0.349	0.464	0.482
IV	170000	186949.6	-16949.6	0.219	0.276	0.347	0.365
I 2021	215000	201638.8	13361.2	0.376	0.428	0.426	0.49
II	165000	165554.2	-554.233	0.142	0.243	0.246	0.398
III	125000	133269	-8269.02	0.038	0.108	0.139	0.294
IV	205000	192400.1	12600	0.177	0.291	0.378	0.482
I 2022	155000	144657.7	10342.4	-0.009	0.178	0.228	0.288
II		127174.2	-127174	-0.214	-0.093	0.063	0.07

Source: Authors

By applying the adaptive filtering method to the quarterly deliveries of this component in the period from the first quarter of 2019 to the first quarter of 2022, a forecast for the second quarter of 2022 was obtained.

Figure 5: Empirical data and adapted values for the component "418009681"



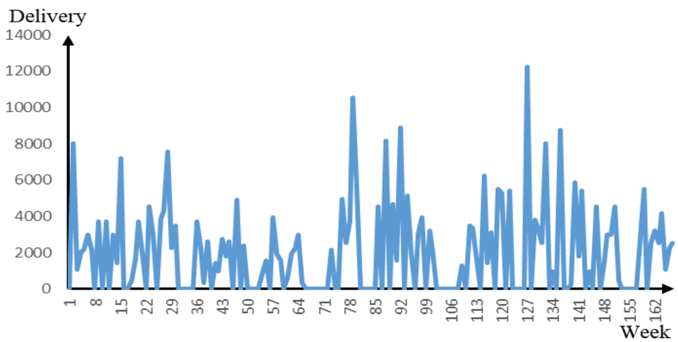
Source: Authors

Based on Figure 5, it can be noted that there is a relatively high degree of matching between the empirical and adapted values of quarterly purchases. This represents a kind of confirmation of the validity of the forecast of materials under Leoni number "418009681" for the 2nd quarter of 2022 and once again shows that the quantitative method of adaptive filtering is an excellent method for forecasting optimal inventory flows, which also confirms the hypothesis of this research.

4.3. Forecasting the delivery of the component "491048880" from the supplier "Coroplast" in 2022 using the moving average method

The graphic representation (Figure 6) of the delivery of the component "491048880" (waterproof tape) of the company "Coroplast" in the period from the 1st week of 2019 to the 11th week of 2022 indicates the absence of a trend when it comes to these data. Also, it is noticeable that there have been no deliveries for several weeks, due to the pandemic caused by the Corona virus.

Figure 6: Deliveries of the component "491048880" of the company "Coroplast" in the period from the 1st week of 2019 to the 11th week of 2022



Source: Authors

In the forecasting of deliveries of the component "491048880" of the company "Coroplast", four-member moving averages were used first, and then thirteen-member moving averages (because 13 weeks represent one quarter of the year). Next, appropriate measures of representativeness were determined (mean absolute deviation and standard error - mean square deviation) and compared to see which forecast was better.

Table 6: Four-way moving averages and measures of representativeness for deliveries of the component "491048880" of the company "Coroplast"

Years and weeks	Delivery size	Moving averages	Absolute deviation	Squared deviation
2019 1	0		315	198450
2	8040			445.47
3	1080			
4	2040			
5	2160	2790	630	396900
6	3000	3330	330	108900

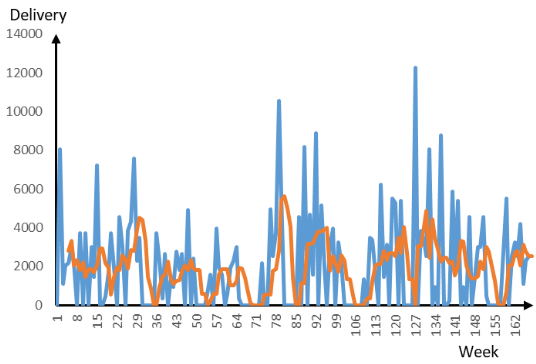
7	2160	2070	90	8100
8	0	2340	2340	5475600
9	3720	1830	1890	3572100
10	0	2220	2220	4928400
…	…	…	…	…
2022 8	4200	2070	2130	4536900
9	1080	3120	2040	4161600
10	2280	2760	480	230400
11	2520	2520	0	0
12		2520		

Source: Authors

From Table 6, it can be seen that the forecasted value for the 12th week of 2022 is 2520, and the mean absolute deviation of moving averages from empirical data is 315, while the standard error - the average deviation of moving averages from empirical data is 445.47.

Below is a graphical presentation of empirical data and four-hour moving averages of the waterproof tape "491048880". On the basis of Figure 7, it can be observed that the given moving averages well approximate the movement of deliveries of this component, so it can be considered that the forecasted value for the 12th week of 2022 is good.

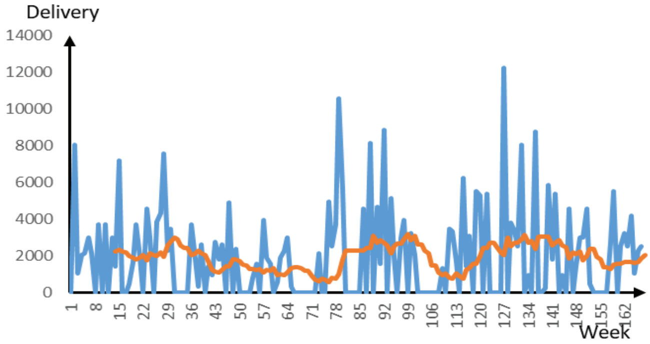
Figure 7: Empirical data and four-member moving averages for the component "491048880" of the company "Coroplast" in the period from the 1st week of 2019 to



Source: Authors

In the next step, thirteen-member moving averages were determined (Figure 8) and the delivery of this component was forecasted for the 12th week of 2022. The results are shown in Table 7.

Figure 8: Empirical data and thirteen-member moving averages for the component "491048880" of the company "Coroplast" in the period from the 1st week in 2019 to the 11th week in 2022



Source: Authors

The forecasted delivery value is 2049.23 while the mean absolute deviation is 724.61 and the standard error is 727.09.

Table 7: Thirteen-member moving averages and measures of representativeness for deliveries of the component "491048880" of the company "Coroplast"

Year and week	Delivery size	Moving averages	Absolute deviation	Squared deviation
2019 1	0		724.61	528667.5
2	8040			727.09
3	1080			
4	2040			
5	2160			
6	3000			
7	2160			
8	0			
9	3720			
10	0			
11	3720			
12	0			
13	3000			
14	1440	2224.61	784.615	615621.3
15	7200	2335.38	4864.65	23664483
16	0	2270.76	2270.76	5156393
…	…	…	…	…
2022 9	1080	1633.84	553.84	306745.56
10	2280	1680	600	360000
11	2520	1855.38	664.61	441713.6
12		2049.23		

Source: Authors

If the measures of representativeness of four-member and thirteen-member moving averages are compared, it is noticed that the values of both measures, mean absolute deviations and standard errors, in the case of four-member moving averages are smaller than those of thirteen-member moving averages. Hence, forecasts obtained on the basis of four-term moving averages are better than forecasts based on thirteen-term moving averages and that the hypothesis of this work was confirmed in the case of moving average method.

4.4. Application of regression analysis in forecasting the required number of workers based on the order number of cables G2X project

For the purposes of formulating a regression model that would describe the relationship between the number of workers engaged in the production of cables for the G2X project, on the one hand, and the order of cables from the G2X project by the customer, on the other hand, data was collected on the number of workers engaged in the production of the segment G2X in the period from 2019 to the 14th week of 2022 (Table 8), as well as data on orders for cables of the G2X segment (Table 9). The data was taken from the SAP system used by the human resources department for employee attendance. Also, the SAP system is used by the department for production planning and control, through which it receives orders from its premium customer. The number of hired workers in the observed period represents the dependent variable, while the size of the orders represents the independent variable.

Table 8: Empirical data on the number of workers who worked on the G2X segment in the period from 2019 to 14 weeks of 2022

Number of workers who worked on the G2X segment from 2019 to the 14th week of 2022				
Year	*2019*	*2020*	*2021*	*2022*
January	269	284	1093	880
February	293	309	1074	1082
March	344	295	1037	992
April	391	0	1050	957
May	476	284	1211	
June	429	274	975	
July	444	248	997	
August	381	176	1030	
September	453	540	977	
October	418	882	948	
November	396	818	908	
December	350	803	905	

Source: Authors

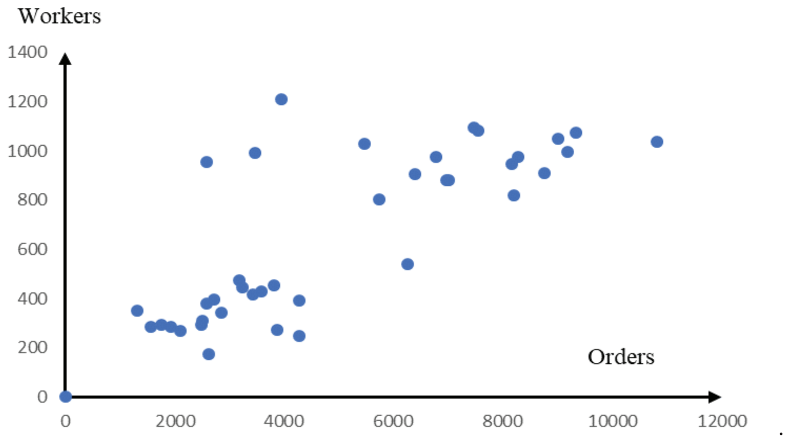
Table 9: Empirical data on the number of G2X cables ordered by the customer in the period from 2019 to the 14th week of 2022

Cable orders on the G2X project by the customer in the period from 2019 to the 14th week of 2022				
Year	*2019*	*2020*	*2021*	*2022*
January	2098	1928	7481	7006
February	2497	2510	9345	7541
March	2860	1755	10821	3470
April	4284	0	9018	2596
May	3179	1567	3948	
June	3583	3867	8280	
July	3248	4273	9189	
August	2585	2621	5468	
September	3824	6252	6773	
October	3438	6965	8156	
November	2730	8200	8764	
December	1310	5738	6402	

Source: Authors

The SPSS program was used for data processing. In order to check whether there is a linear relationship between the number of workers and the size of orders, the data on the values of these two series during the observed period are presented graphically in the form of a scatter diagram. According to Figure 9, there is a direct linear connection between these two phenomena, i.e., with the increase in orders, the number of hired workers also increases.

Figure 9: Workers and order size in the period from week 1 of 2019 to week 14 of 2022



Source: Authors

Table 10 provides data on the correlation between the variables. According to the data in the table, we conclude that there is a strong correlation between the number of hired workers and the size of orders. This coefficient is statistically significant.

Table 10: Pearson correlation

	Order size
Number of workers	0.793 (.000)

Source: Authors

In order to get a clearer picture of the value of the observed variables that were taken into consideration during the analysis, descriptive measures were determined, which is shown in Table 11.

Table 11: Descriptive statistics

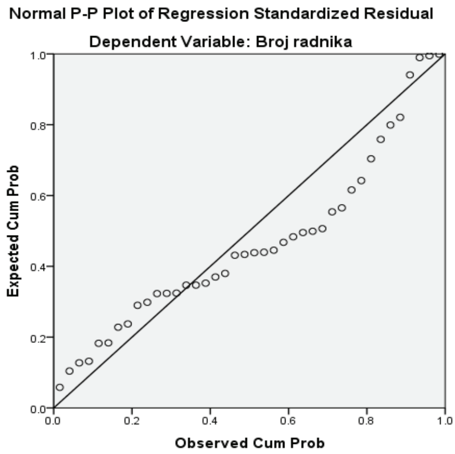
	Arithmetic mean	Standard deviation	Size of samples
Number of workers	641.8250	343.38645	40
Order size	4889.2500	2751.57928	40

Source: Authors

According to these data, the average number of employed workers in this period was 642, with a standard deviation of 343, while the average order amount was 4889, and the standard deviation was 2752.

Before formulating the regression model itself, it is necessary to check whether the assumptions for conducting the regression analysis are met. In that case, Graph 6 indicates that the assumption of a linear relationship between the observed variables is met. The assumption that the stochastic term is equal to zero on average was checked by determining the unstandardized values of the residuals in SPSS, and then those values were summed in Excel and it was obtained that the sum is equal to zero. This assumption is fully fulfilled. The verification of the assumptions related to the residuals was started by reviewing the Normal Probability Plot (P-P) diagram - Figure 10, and the Regression Standardized Residual Scatterplot - Figure 11. On the Normal P-P Plot diagram, it can be seen that the points representing the standardized values of the residuals do not lie very close to the imaginary diagonal that is extending from the lower left corner to the upper right corner. It should be noted that there are certain problems with the fulfilment of the assumption related to the normal distribution of residuals.

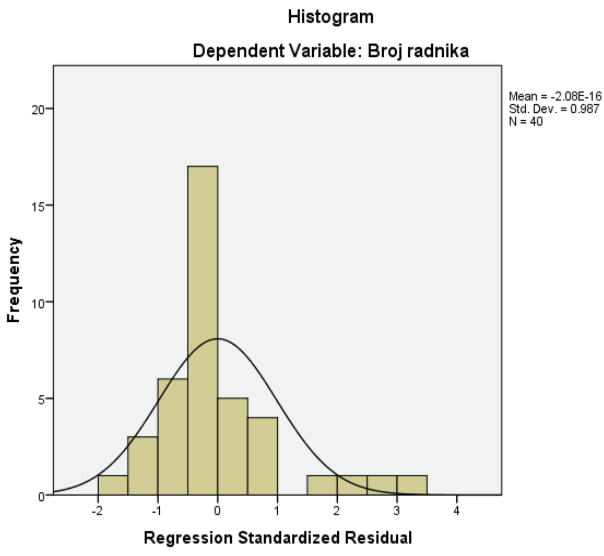
Figure 10: Normal probability plot (P-P pilot)



Source: Authors

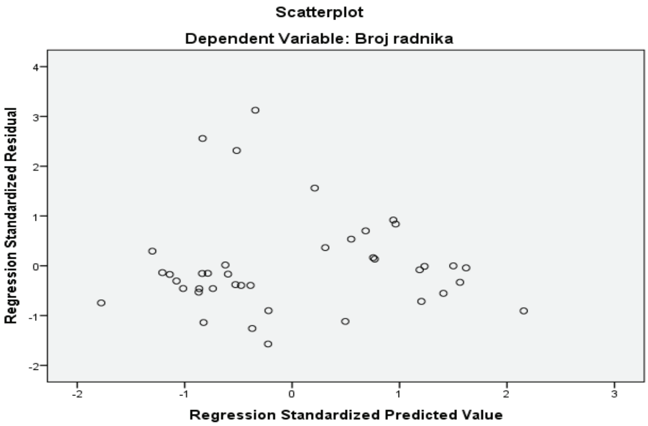
Figure 11 confirms the statement that there are certain deviations of the residuals from the normal distribution. After the standardization of the residuals, their graphic representation via histogram clearly points to certain deviations from the Gaussian curve, thus providing another clear confirmation that there is a certain violation of the assumption of normality of the residuals.

Figure 11: Histogram Regression Standardized Residual



Source: Authors

In Figure 12, it can be seen that not all points (residuals) are approximately correctly distributed within the given rectangular surface, and that most of them are clustered in the centre around point 0, but also that a certain number deviates from it. Accumulation of these points in the form of some geometric figure and deviation from the uniform distribution in the centre of the rectangle indicates that some of the initial assumptions related to the distribution of residuals have been violated. Also, based on Figure 12, one can consider if there are any atypical points. Namely, these are cases whose standardized residuals fall outside the range of ±3.3. According to Figure 12, there is no indication that atypical points are occurring.



Source: Authors

Bearing in mind the results of the verification of the fulfilment of the assumptions for carrying out the regression analysis, it is possible to state that there is no serious violation of these assumptions, with the exception of the assumption related to the normality of the residuals, and that the model as such is sustainable, that is, it is possible to continue with the assessment and evaluation of the model itself.

Since the fulfilment of the assumptions of the regression model has been checked and it has been established that it is possible to carry out the regression analysis procedure, the parameters of the model are determined in the next step. According to Table 12, the value of the regression constant is 157,941, which indicates that the company must employ 158 workers at any given time. The estimated value of the slope coefficient is 0.099. This value shows that if the order of G2X segment cables were to increase by 100 pieces, it would be necessary to hire 10 new workers. The estimated values of the corresponding constant and coefficient are statistically significant.

Tabel 12: Coefficients

Model	Unstand. Coeffi.		Stand. Coeff. Beta	t	Sig.
	B	Std. Error			
(Constant)	157.941	68.980		2.290	0.028
Order size	0.099	0.012	0.793	8.025	0.000

Source: Authors

As already mentioned, there is a strong correlation relationship between the dependent variable and the independent variable (according to *Pallant (2013)*), there is a strong relationship between the variables if the correlation coefficient is above 0.5), which can be seen from Table 13. Also, this table shows that changes in the number of hired workers are explained by 62.9% changes in order sizes. If the stricter criterion given as the corrected coefficient of determination is interpreted, it is somewhat smaller and according to it the degree of explained variability is 61.9%.

Table 13: Representativeness of the model

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.793	0.629	0.619	211.91270
Dependent Variable: Number of workers				

Source: Authors

A kind of evaluation of the validity of the model and the indicator of the explained variability can be found in Table 14. The evaluation of the statistical significance of the coefficient of determination was carried out through the analysis of variance. This test tests the hypothesis that the coefficient of determination takes the value 0. As the value in column Sig. is 0.000, it is a confirmation that the coefficient of determination does not differ from zero, so the model is statistically significant.

Table 14: ANOVA test

Model		Sum of Squares	df	Mean Square	F	*Sig.*
1	Regression	2892190.096	1	2892190.096	64.404	0.000
	Residual	1706465.679	38	44906.992		
	Total	4598655.775	39			
Dependent Variable: Number of workers						
Predictors: (Constant), Order size						

Source: Authors

It can be noticed that in this part of the paper, once again, the hypothesis of this research has been confirmed in the case of regression analysis.

Conclusion

Customer demands for faster and reliable delivery have created a need for fast, flexible and timely flow of information and products along the entire supply chain. In this sense, supply chain management is becoming increasingly important and only through continuous improvement of processes and activities, supply chain members can ensure lower costs and higher levels of customer satisfaction. One of the elements that plays a key role in achieving this goal is inventory. Inventories are part of the working capital necessary for the smooth functioning of production and require the involvement of large financial investments that cause a significant amount of capital costs. For the successful management of the supply chain, it is necessary to have a good organization, a good plan and a forecast about the exact required supplies and their flows, so that the resources are used rationally. Then, forecasting plays the most important role in supply chain management.

This research shows the application of quantitative methods of inventory forecasting, namely exponential smoothing, adaptive filtering, moving average methods and regression analysis, on the example of the company "Leoni Wiring System Prokuplje". The results of the research indicate that the hypothesis on which the research is based has been confirmed, i.e., that applied quantitative forecasting methods in the supply chain provide reliable and accurate forecasts on the basis of which materials can be ordered so that optimal stocks are maintained for the smooth functioning of production, on the example of the company "Leoni Wiring System Prokuplje".

Given that inventory requires the involvement of large financial investments that cause a significant amount of capital costs, it is important to determine the optimal flows and quantities of inventory. Therefore, quantitative methods are a useful tool for reliable forecasting of inventory in order to maintain them at an optimal level. In this sense, the importance of this paper is that it shows the way of applying quantitative methods for inventory forecasting and contributes to the existing literature in that area. Research should continue and apply forecasting using qualitative methods or a combination of quantitative and qualitative methods, in order to reach the most accurate forecast.

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