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PLANNING OF TRANSPORTATION'S NEEDS BASED ON DEMAND FORECASTS

Summary. Rational management of transport has a major impact on the cost of the business. The starting point for this can be a forecast of demand for the products. This paper presents the process of planning of transportation of shipments based on the forecast of the orders. The monthly quantity of shipments during the 36 months was analysed. A periodic variation of this quantity was observed. The forecast for the next two months was determined using a triple exponential smoothing method. Parameters of the method were determined analytically and using artificial immune systems. In the latter case the smoothing constant and the initial values of the model were determined by optimizing the root mean square error (RMSE) "ex-post". The results were subsequently compared. A smaller error was obtained using artificial immune systems. Then the demand for transport was calculated basing on the forecast quantity of shipments.

PLANOWANIE ZAPOTRZEBOWANIA NA TRANSPORT NA PODSTAWIE PROGNOZY POPYTU

Streszczenie. Racjonalne gospodarowanie środkami transportu ma duży wpływ na koszty firmy. Podstawą do tego może być wykonanie prognozy popytu na produkty firmy. W artykule przedstawiono proces zaplanowania przewozów przesyłek do odbiorców na podstawie prognozy ilości przesyłek. Po wstępnej analizie rozkładu miesięcznej ilości przesyłek w okresie 36 miesięcy zaobserwowano okresową zmienności tej ilości. Prognozę na kolejne 3 miesiące wyznaczono stosując addytywną metodę Wintersa. Parametry metody wyznaczano analitycznie, a następnie stosując sztuczne systemy immunologiczne. W tym drugim przypadku stałe wygładzania i wartości początkowe modelu były wyznaczane na drodze optymalizacji pierwiastka błędu średniokwadratowego (RMSE) „ex post". Wyniki porównano. Mniejszy błąd otrzymano stosując sztuczne systemy immunologiczne. Następnie wyznaczono zapotrzebowanie na transport na podstawie prognozowanej ilości przesyłek.

1. INTRODUCTION

The subject of the study is reduction of the transportation cost for a company by proper planning of demand on selected services. Analyses were carried out on the real data obtained from large transport and logistics company, with branches in several countries of Europe. This company provides services including small palletised consignments. There was an analysis of the quantity of consignments on the example of a route from Poland to Austria. Then a method of forecasting the quantity of consignments was selected.

The triple exponential smoothing method is one of adaptive methods, taking into account the variability of the studied phenomena. The exponential smoothing methods originated with the work of Brown [4, 5], Holt [13], Winters [27], and Pegels [23]. At its beginning exponential smoothing methods were treated as an ad hoc extrapolation technique of one-dimensional time series. In 1960 Muth [22] proposed statistical basis for simple exponential smoothing (SES), taking into account the random walk and noise. The works of Box and Jenkins [3], Roberts [24], Abraham and Ledolter [1, 2] were further steps to introduce exponential smoothing in statistics. In 1985 Gardner published the review of papers about exponential smoothing [9]. This work has included synthesis of it and extention of Pegels' classification. Snyder presented that simple exponential smoothing methods could be considered as a model with single source of error in the same year [25]. These two articles became the basis for a lot of other works. Many works that have appeared since 1980, is dedicated to the study of the properties of empirical methods. In 1984 Ledolter and Abraham wrote about new methods of estimation or initialization [16]. In 1988 a few articles about evaluation of the forecasts were published. Jan G. De Gooijer and Rob J. Hyndman reviewed highly influential works on time series forecasting in [11].

The methods have numerous application in various problems like airline passengers [12], production planning [18]. There are also applied forecasting methods, which are based on artificial intelligence (AI). The statistic methods and neural networks are considered in work of Karlaftis and Vlahogianni [15]. Neural networks are better in solving transport problems with non-linearity. Lin, Pai and Yang present in their research [17] a logarithm support vector regression to forecasting concentrations of air pollutants in Taiwan. The coefficients of regression function were calculated using artificial immune systems. Promising results were obtained. A support vector regression (SVR) was used to forecast of urban traffic flow [14]. In order to receive an optimal parameter combination for it, the hybrid genetic algorithm – simulated annealing algorithm GA-SA was applied. A clonal selection was used with good results for the determination coefficients in the harmonic analysis [20, 21].

2. FORECAST OF CONSIGNMENTS QUANTITY

Human economic activity is subjected to various external influences. They are in varying degrees predictable [28]. Business activity requires making some assumptions about the development. There are different methods to evaluate the trend of development based on a mathematical model of the observed phenomena. In the article there are used probabilistic models, treating the investigated quantities as random variables subject to the rules of probability.

Quantity of shipments transported from June 2008 to May 2011 is presented in tab. 1.

Fig.1 shows a graph with the number of consignments during the period. The seasonal fluctuations are observed. Therefore the triple exponential smoothing method was selected for forecasting. The proposed method takes into account periodic fluctuations and eliminates random fluctuations.

2.1. Calculations

2.1.1. Triple exponential smoothing method

There is a sequence of the observations $\{y_t\}$, starting at time t = 1 with a cycle of seasonal change of length r. Calculations was performed using the following formulas [8]

$$F_t = \alpha\left(y_t - C_{t-r}\right) + \left(1-\alpha\right)\left(F_{t-1} + S_{t-1}\right) \tag{1}$$

$$S_t = \beta\left(F_t - F_{t-1}\right) + \left(1-\beta\right)S_{t-1} \tag{2}$$

$$C_t = \gamma(y_t - F_t) + (1-\gamma)C_{t-r} \tag{3}$$

Table 1

Quantity (in units) of shipments transported
from June 2008 to May 2011

Month	Year			
	2008	2009	2010	2011
I	-	712718	763419	796420
II	-	998713	883531	791206
III	-	979193	1208839	1209355
IV	-	838773	963360	926269
V	-	791399	1062298	1123164
VI	671589	664699	978011	-
VII	553294	655044	716784	-
VIII	643987	598848	722802	-
IX	942108	908706	983211	-
X	824143	715609	821804	-
XI	700428	688936	682421	-
XII	578534	534150	597535	-

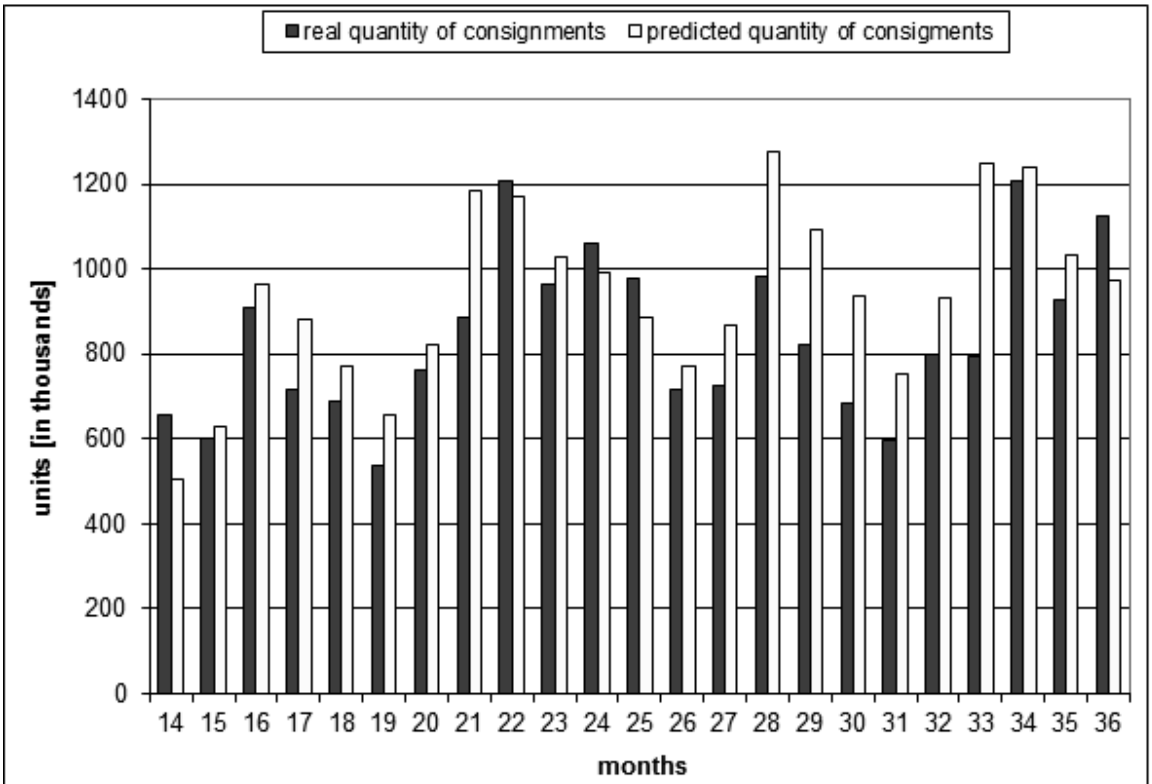


Fig. 1. A graph with the number of consignments during the period from June 2008 to May 2011
Rys. 1. Wykres wielkości przewozów w okresie od czerwca 2008 do maja 2011

$$y_t^* = F_{t-1} + S_{t-1} + C_{t-r} \tag{4}$$

where: α is the data smoothing factor, $0 < \alpha < 1$, β is the trend smoothing factor, $0 < \beta < 1$, and γ is the seasonal change smoothing factor, $0 < \gamma < 1$.

The forecast for the next period t>n

$$y_t = F_n + S_n(t-n) + C_{t-r} \tag{5}$$

The initial values of F_1, S_1, C_1, ..., C_r usually are chosen in the following way

$$F_1 = y_1 \tag{6}$$

$$S_1 = y_2 - y_1 \tag{7}$$

$$C_1 = C_2 = \ldots = C_r = 1 \tag{8}$$

The results of the calculation are shown in the Fig. 2.

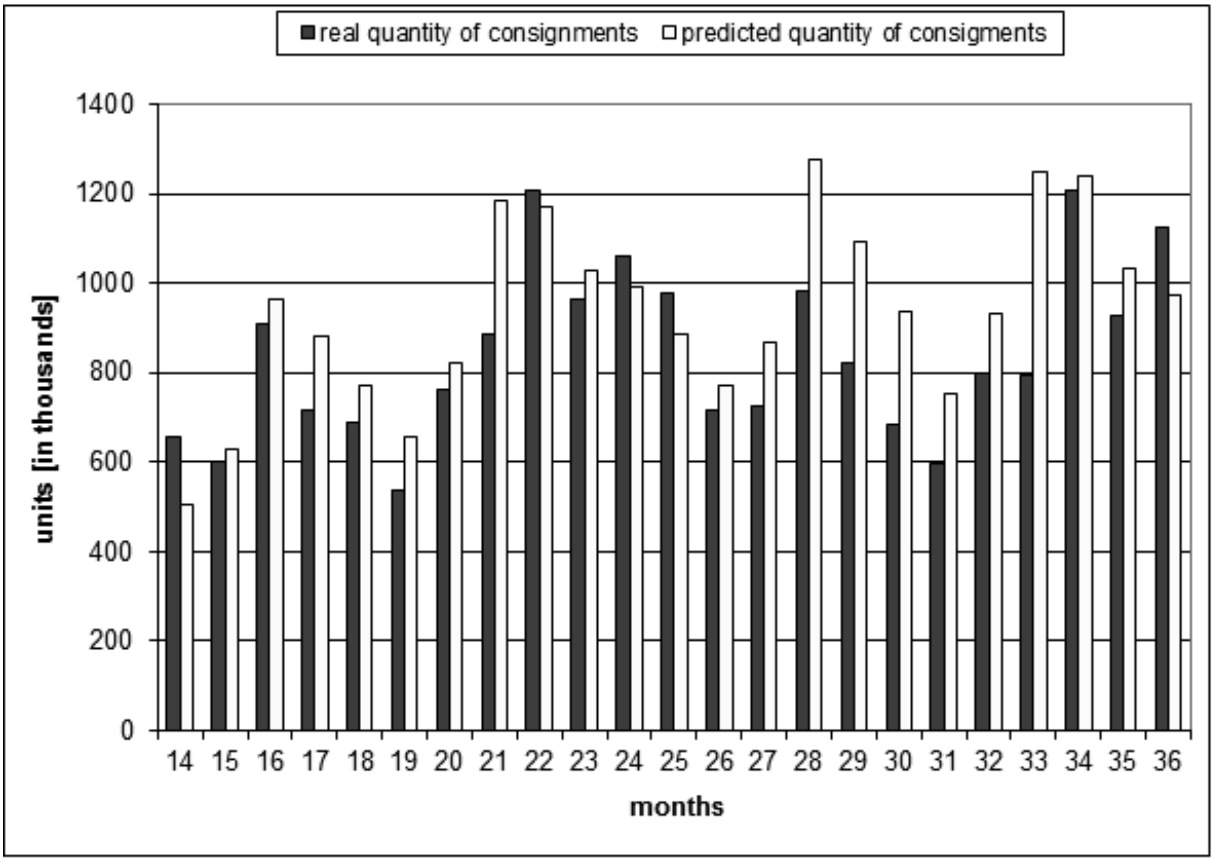


Fig. 2. The results of the triple exponential smoothing method
Rys. 2. Wykres wyników prognozowania metodą Wintersa

As follows from the Fig.2, which illustrates the dynamics of the quantity of consignments, a trend of the predicted quantity of consignments is changing. The dynamics of the entire time series affects the quality of forecast. But a random factor can appear always, which is impossible to predict.

In the performed calculations error RMSE (Root Mean Square Error) was computed

$$RMSE = \sqrt{\frac{1}{n-r}\sum_{t=r+1}^{n}(y_t - y_t^*)^2} \tag{9}$$

It was equal 176556 units.

2.1.2. Application of artificial immune system

The main disadvantage of the triple exponential smoothing method is the inconvenience of calculations. The alternative calculations were conducted where the coefficients were determined in artificial immune system (AIS) optimization.

2.1.2.1. Artificial immune system

Artificial immune systems are the methods of artificial intelligence [6, 7, 26]. The inspiration for this method is the efficient functioning of the natural human immune system [10], which reacts on attacks of antigens in live systems.

There are two types of lymphocytes B and T cells. The B cells produce antibodies, which recognise specific group of antigens. The T cells stimulate B cells (Th1 lymphocytes), recognise pathogens and eliminate them (Tk lymphocytes), prevent the over-stimulation of B – cells (suppression lymphocytes), take part in system of immune memory (memory lymphocytes).

Each antibody can recognise one kind of antigen. The B lymphocytes with antibodies, which have recognised antigen, are activated to rapidly proliferation. The great number clones are produced. The clones are subjected to mutation, which can improve the new antibodies so that they will bind antigen better. They remain in the system and later they become plasma or memory cells. The plasma cells secrete large volumes of antibodies. They are transported by the blood plasma and the lymphatic system to endangered sites in the body.The memory cells remain and are prepared to produce large amounts of antibodies in the short term, if re-appear in the body of the same type of pathogenic micro-organisms. The quantity and quality of antibodies is regulated by appropriate methods of suppression. It is kept their diversity at the same time. This process is called “the clonal selection”. The clonal selection is a natural model of optimization. Figure 3 shows a diagram of clonal selection.

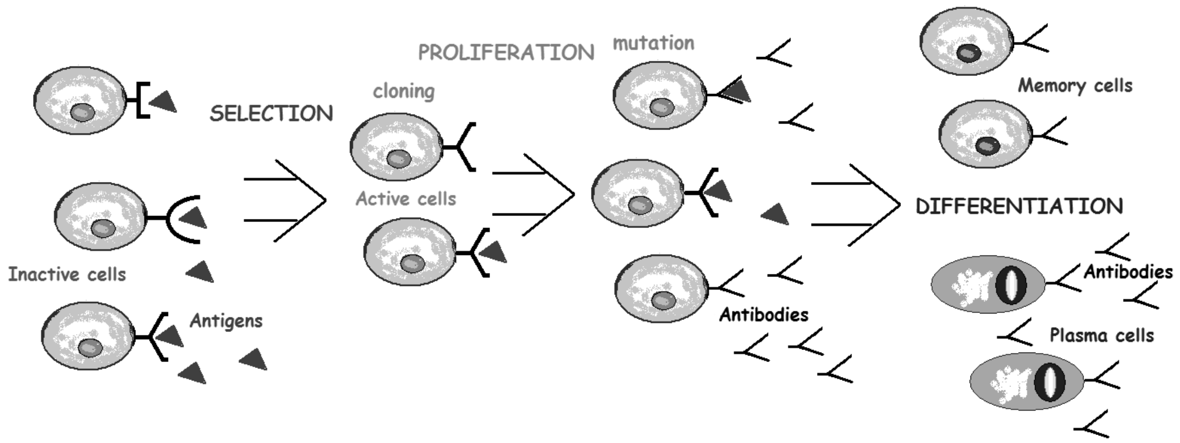


Fig. 3. Clonal selection
Rys.3 Selekcja klonalna

2.1.2.2. Numerical model

The clonal selection is used to determine the parameters in the triple exponential smoothing method to determine factors of Winters method. An antibody is proposed as a solution in the algorithms using the artificial immune system to solve the problem. In Winters method, each proposed solution is shown as a vector

$$[\alpha, \beta, \gamma, F_1, S_1, C_1, ..., C_r] \tag{10}$$

where: α, β, γ - smoothing factors, $F_1, S_1, C_1, ..., C_r$ - the initial values.

The measure of matching antibodies to the antigen is an affinity function

$$F = RMSE^{-1} \tag{11}$$

The number of clones is proportional to

$$\frac{value \quad of \quad fitness \quad function}{\sum of \quad values \quad of \quad fitness \quad function \quad of \quad all \quad population} \tag{12}$$

There is used modified uniform mutation with variable boundaries. At the start the smoothing factors α, β, γ are drawn from the interval [0, 1]. The initial values F_1, S_1 are drawn from the neighbourhood of these values. The initial values $C_1, ..., C_r$ are drawn from the neighbourhood of their average values . In the next steps all variables are drawn from the intervals

$$[variable_i - \delta^*\sigma_i; variable_i + \delta^*\sigma_i] \tag{13}$$

where: i – index of variable, σ_i – standard deviation in the population for i-th variable, δ – the time depend coefficient, $\delta \in (0;1)$. Each calculation was completed after a specified time.

A series of calculations were conducted. The resulting predictions are shown in the Fig. 4. RMSE for the best solution was equal 163 448 units.

2.2. Summary of results of calculations

To compare different forecasting methods the forecast errors RMSE were summarized for the both solutions in the tab. 2.

Table 2

The RMSE errors for all calculations

RMSE for the triple exponential smoothing method	176556
RMSE for the triple exponential smoothing method using AIS	163448

Finally, Fig. 5 shows the results of both methods of forecasting with included real demand for transport in 37 and 38 period. The forecast for the last 2 periods were made on the basis of the previous ones. RMSE for the triple exponential smoothing method with applying AIS is lower than for the classical triple exponential smoothing method.

3. PLANNING FOR TRANSPORTATION NEEDS

Shipping goods to customers is carried out by vehicles with a capacity of eight tons, which can hold 36 pallets and trucks with trailer-type with a capacity of 24 tons, which can accommodate 66 pallets respectively. The cost of transport to Austria with the first of these cars is 858.50 PLN, and the second of them 1545.30 PLN. The average number items on a palette sent to Austria is 251.

It is profitable to rent first type of vehicle up to 36 pallets. For the range from 37 to 66 pallets - the second type of vehicle. From 67 to 72 pallets - two vehicles of the first type. For greater number of pallets it is necessary to calculate the number of vehicles with trailers with the full load of pallets. Depending on the number of other left pallets

- from 1 to 6 pallets it is more profitable to replace a trailer truck by two vehicles with a capacity of 8 tons,
- from 7 to 36 pallets, the need of order a car with a capacity of 8 tons.
- more than 36 pallets the goods need to be transported by the trailer vehicle.

As it can be seen in Fig. 4, the biggest difference between the projected number of orders, and the actual was 182553 units in June 2011. Tab. 3 and tab. 4 shows the real and the predicted number of consignments, expected number of pallets and demand for transport calculated by the methods above in June and July 2011.

Fig. 4. The resulting predictions using the artificial immune system
Rys. 4. Wykres wyników prognozowania z zastosowaniem sztucznych systemów immunologicznych

Table 3

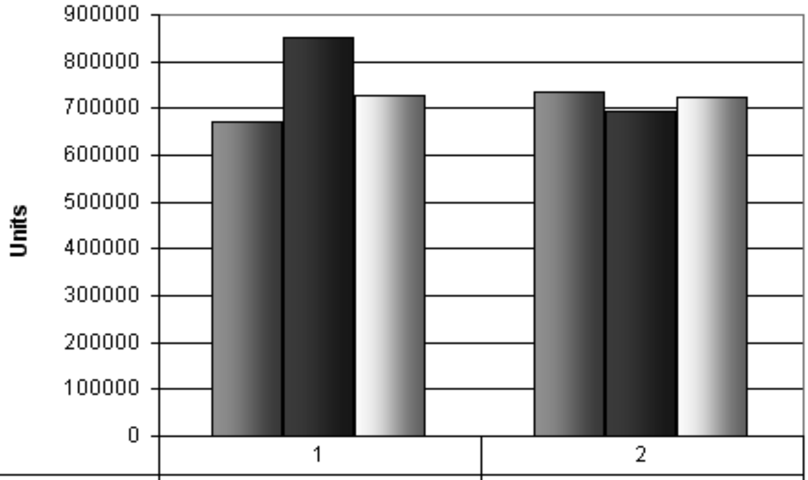
Real and predicted number of consignments, expected number of pallets and demand for transport calculated by the method above in June 2011

demand	units	pallets	vehicle with a capacity of 8 ton	truck with trailer-type with a capacity of 24 ton	cost of transport [PLN]
real	669488	2668	1	40	62670.5
predicted	852041	3395	0	54	83446.2
predicted using AIS	726662	2896	0	44	67993.2

Table 4

Real and predicted number of consignments, expected number of pallets and demand for transport calculated by the method above in July 2011

demand	units	pallets	vehicle with a capacity of 8 ton	truck with trailer-type with a capacity of 24 ton	cost of transport [PLN]
real	734047	2925	1	44	68851.7
predicted	693410	3395	1	51	79668.8
predicted using AIS	723780	2896	0	44	67993.2



	1	2
real quantity of consignments	669488	734047
predicted quantity of consigments	852041	693410
predicted quantity of consigments using AIS	726662	723780

Fig. 5. Real demand for transport and the predicted values
Rys. 5. Rzeczywiste zapotrzebowanie na transport i wartości prognozowane

The transport demand was better assessed by second method. In June real transportation costs were lower than predicted on 20775.7 PLN calculated by the triple exponential smoothing method and they were lower on 5322.7 PLN counted by the triple exponential smoothing method with applying AIS. In July real transportation costs were lower than predicted on 10817.1 PLN calculated by the triple exponential smoothing method and they were higher on 858.5 PLN counted by the triple exponential smoothing method with applying AIS.

4. CONCLUSIONS

1) The monthly quantity of shipments during the 36 months was analysed and the forecast for the next two months was determined using a triple exponential smoothing method. Parameters of the method were determined analytically and using artificial immune systems.
2) Transport costs forecasted by a triple exponential smoothing method with the use of AIS were larger from the real costs on 5322.7 PLN in June and lower from the real costs on 858.5 PLN in July.
3) Transport costs predicted by a triple exponential smoothing method were larger from the real costs on 20775.7 PLN in June and larger from the real costs on 10817.1 PLN in July.
4) The clonal selection was used to determine the parameters in the triple exponential smoothing method to determine factors of Winters method. It increased the accuracy of an "ex post" prediction error. RMSE for the triple exponential smoothing method with applying AIS is less than for the classical triple exponential smoothing method.
5) The transport demand was better assessed by the triple exponential smoothing method with applying AIS.

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