ANALYSIS OF FORECASTING METHODS REGARDING CIRCULATION OF GOODS, BASED ON THE EXAMPLE OF COMPANY KOCHLOEFFEL POLSKA SP. Z O.O

Bogna Mrówczyńska, Michał Sokołowski
Department of, Faculty of Transport,
Department of Logistics and Mechanical Handling
40-019 Katowice, Krasińskiego 8
e-mail: bogna.mrowczynska@polsl.pl

ABSTRACT

The storage problems of food products, which result from seasonal variations in demand are discussed in the paper. Selected forecasting methods were examined in the context of efficiency. Due to seasonal demands the analysis was focused on forecasting methods regarding seasonal fluctuations. There were used Winter's model, seasonality indices and harmonic analysis. To determine coefficients in harmonic analysis, an analytic method as well as artificial immune systems was selected. The results of each calculations were put together and compared.

1. INTRODUCTION

Nowadays the activities of corporation, as well as every human initiative are exposed to intense competition. It is necessery to accurately predict what could possibly happen on the market. To predict demand variations regarding corporation's products and services, forecasting methods are used which make the demands predictions scientifically grounded. [1]. Inadequate decisions result with massive, unnecessary financial costs, which could be due to wrong preparation to current situation.

The process implementation of forecasts into company operations is multiphased and requires many initial assumptions. Wrong forecast in relation to current situation could lead to serious consequences. It could be too little goods storage in the warehouses in relation to requirements of appropriate clients or on the contrary too much accumulation of goods which leads in so-called freezed capital [4].

The article examined efficiency of selected forecasting methods, based on the example of corporation Kochloeffel Polska Sp z o.o.

2. CHARACTERISTICS OF THE CORPORATION KOCHLOEFFEL POLSKA SP Z O.O.

Kochloeffel Polska Sp z o.o. is a fast-food restaurant network. It functions on the Polish market since 1995. Currently the company has 8 restaurants in Poland, all located in the Silesian voivodship.

There rotation of foods in the company is quite frequent. The restaurants have medium sized warehouse resources and the products time of expiration is short, therefore it is very important to order the appropriate amount of them. The ordering process for all products, during every season of the year is estimated from formula:

$$Z_n = X_{sr} \cdot d - S_m - Z_{n-1} \quad (1)$$

where:

Z_n – current order; X_{sr} – average sale from previous days (last 14 working days); d – amount of days the order is realized for; S_m – amount of goods in the warehouse (current); Z_{n-1} – previous order.

This is quite a simplified ordering formula. The above pattern is not going to work if the sale of one of the products goes according to a trend or seasonal fluctuations. Forecast built on the average sale from the previous period tends to be delayed, if the demand has a constant increase or decrease. Due to company form of activity (gastronomy) sale of majority products is characterized by certain fluctuations. The demand for a product depends on the season of the year and the climatic changes. The implementation of appropriate forecast model to the system of order supply management allows to optimize warehouse supply and lowers the costs of goods storage.

3. SELECTED FORECASTING METHODS

The forecasts that were made, were based on the french fries sale in years 2006-2008 in "Conieco" restaurant located in Tarnowskie Góry. Table 1 there are monthly sales from this period, and figure 1 presents chart of french fries sale. As it is possible to observe the sale of french fries is characterized by seasonal fluctuations and some repetitions. The lowest demand is visible in the winter period. In September of all years a considerable increase in sale can be seen. This products is not an exception, the other goods have the largest sale in September too. It happens because in the middle of September a 3 day long festival named "Gwarki" takes place in Tarnowskie Góry. During the fair a significant increase in sale of all products can be observed.

Table 1 Monthly sale of french fries [kg] in years 2006-2008

Year 2006	Sale [kg]	Year 2007	Sale [kg]	Year 2008	Sale [kg]
January	1458	January	1724	January	1761
February	1339	February	1598	February	1716
March	1633	March	1984	March	1942
April	1945	April	2280	April	2137
May	2190	May	2087	May	2103
June	2243	June	2326	June	2170
July	2023	July	2254	July	2309
August	2276	August	2496	August	2473
September	2731	September	2941	September	3122
October	2133	October	2047	October	2273
November	1796	November	1572	November	1958
December	2054	December	1971	December	2270

To analyze a time sequence characterized with seasonal fluctuations a few forecasting methods were used. Their measurement of efficiency are forecast errors. Provided that larger supplies are concerned with accumulating goods in the warehouse and „freezing" money spent on them, shortage of supplies is connected with immediate break of sale, which leads to loss of possible profits. It is accepted that forecast error should never be negative (shortage of supplies). On the other side permitted positive forecast error should be as small as it is possible. To analyze the sale of french fries in years 2006-2008, methods were used [1]:

- seasonal indices
- Winter's
- harmonic analysis

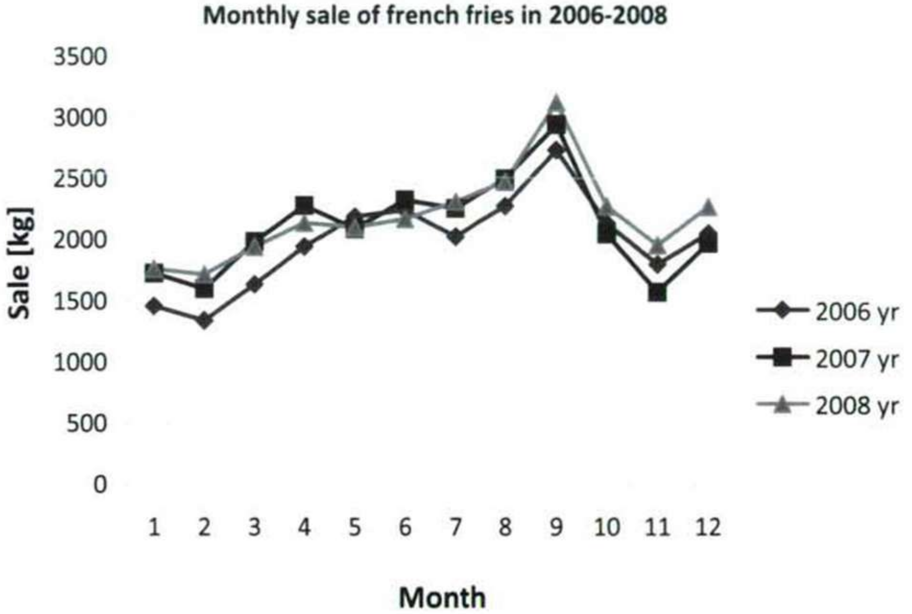

Figure 1. Monthly sale of french fries [kg] in years 2006-2008

In addition the first two methods were divided to additive and multiplicative models. Expired forecasts for additive model in seasonal indices metod were calculated from formula:

$$y^{*}_{ti} = \hat{y}_{ti} + s_i \quad (2)$$

where:

y^{*}_{ti} - forecast for moment / period t,

$\hat{y}_{ti}$ - theoretical values of forecasted variable calculated from trend model, which is expressed by function:

$$\hat{y} = 12{,}832x + 1855{,}3 \quad (3)$$

Seasonal indices in additive model are calculated from:

$$s_i = z_i - \frac{1}{r}\sum_{i=1}^{r} z_i \tag{4}$$

where:
s_i – seasonal indicator for i-phase of cycle; r – number of phases in cycle;
z_i – crude indicators of seasonality y.
For multiplicative model the formulas are very similar:

$$y_{ti}^* = \hat{y}_{ti} \cdot s \tag{5}$$

$$s_i = \frac{z_i}{q} \tag{6}$$

Forecasts for time moment t for additive model in Winter's method were calculated from formula:

$$y_t^* = F_{t-1} + S_{t-1} + C_{t-r}, \qquad \text{for } t > r \tag{7}$$

where:
smoothed assessment of level (average value) for moment/time period t:

$$F_t = \alpha \cdot (y_t - C_{t-r}) + (1-\alpha) \cdot (F_{t-1} + S_{t-1}) \tag{8}$$

smoothed value of trend growth for moment/time period t:

$$S_t = \beta \cdot (F_t - F_{t-1}) + (1-\beta) \cdot S_{t-1} \tag{9}$$

assessment of the seasonality index for moment/time period t:

$$C_t = \gamma \cdot (y_t - F_t) + (1-\gamma) \cdot C_{t-r} \tag{10}$$

where:
y_t - value of forecasted variable for moment/period t; α - smoothing level parameter of forecasted variable with values in range $(0,1] \rightarrow \alpha \neq 0$; β - parameter of growth smoothing caused by development tendency with values in range $(0,1] \rightarrow \beta \neq 0$; γ - parameter of seasonality index assessment with values in range $(0,1] \rightarrow \gamma \neq 0$; r - seasonal cycle length (number of phases of each cycle).
For multiplicative model the formulas are as following:

$$F_t = \alpha \cdot \frac{y_t}{C_{t-r}} + (1-\alpha) \cdot (F_{t-1} + S_{t-1}) \tag{11}$$

$$S_t = \beta \cdot (F_t - F_{t-1}) + (1-\beta) \cdot S_{t-1} \tag{12}$$

$$C_t = \gamma \cdot \frac{y_t}{F_t} + (1-\gamma) \cdot C_{t-r} \tag{13}$$

$$y_t^* = (F_{t-1} + S_{t-1}) \cdot C_{t-r}, \qquad \text{for } t > r \tag{14}$$

In forecasting using harmonic analysis, the harmonic function changes it's form. The way it changes depends whether in the time series occur random fluctuations around constant level and trend. In case the time series has a certain development tendency and seasonal fluctuations, model of the harmonic analysis can be presented as sum of the harmonics [2,5]:

$$y_t = f(t) + \sum_{i=1}^{n/2}[\alpha_i \sin(\frac{2\pi}{n}it) + \beta_i \cos(\frac{2\pi}{n}it)] \tag{15}$$

where:

$f(t)$ - linear function of trend in accordance with formula (2); i - harmonic number; α_i, β_i - parameters; n - number of measurements (months).

For time series with number of observations equal to n, number of harmonics is $\frac{n}{2}$. Analysis includes n=36 months, so there are 18 harmonics in the model. To determine them, values a_i and b_i for individual harmonics are needed.

$$a_i = \frac{2}{n} \cdot \sum_{t=1}^{n} y_t \cdot sin\left(\frac{2\pi}{n}it\right), i = 1,...,\frac{n}{2} - 1 \tag{16}$$

$$b_i = \frac{2}{n} \cdot \sum_{t=1}^{n} y_t \cdot cos\left(\frac{2\pi}{n}it\right), i = 1,...,\frac{n}{2} - 1 \tag{17}$$

In addition to calculate share variance of forecasted variable by individual harmonics, indices were calculated:

$$\omega_i = \frac{a^2 + b^2}{2 \cdot s_{\bar{y}}^2} \quad for \ i = 1,2,...,\frac{n}{2} - 1 \tag{18}$$

$$\omega_i = \frac{a^2 + b^2}{s_{\bar{y}}^2} \quad for \ i = \frac{n}{2} \tag{19}$$

where:

$s_{\bar{y}}^2$ - ariance of time series with eliminated trend.

Harmonics with numbers 1, 3, 6, 9 and 12 have a total share of 93,23%. The forecast model was simplified to consist only 5 most important harmonics of the formula:

$$\begin{aligned} y_t^* = {} & 1855{,}3 + 12{,}832 \cdot t + 96{,}36 \cdot \sin(\frac{2\pi}{36}t) - 32{,}61 \cdot \cos(\frac{2\pi}{36}t) - 277{,}28 \cdot \sin(\frac{2\pi}{36}3t) - \\ & - 236{,}73 \cdot \cos(\frac{2\pi}{36}3t) - 30{,}41 \cdot \sin(\frac{2\pi}{36}6t) - 127{,}17 \cdot \cos(\frac{2\pi}{36}6t) + 159{,}83 \cdot \sin(\frac{2\pi}{36}9t) + \\ & + 101{,}45 \cdot \cos(\frac{2\pi}{36}9t) + 43{,}01 \cdot \sin(\frac{2\pi}{36}12t) + 176{,}78 \cdot \cos(\frac{2\pi}{36}12t) \end{aligned} \tag{20}$$

Forecasting errors of french fries sale for all models were put together in table 3 and figure 2.

4. APPLICATION OF ARTIFICAL IMMUNE SYSTEMS IN FORECASTING

The model of harmonic analysis described In point 2 could also be expressed as following:

$$y_t = a_0 + a_1 t + \sum_{i=1}^{m} [a_{2i} \sin(\frac{2\pi i}{n} t) + a_{2i+1} \cos(\frac{2\pi i}{n} t)] \qquad (21)$$

Coefficients a_j, j=0, 1, 2, ...2m+1 of harmonic function can be selected using the artifical immune systems.

Artifical immune systems are algorithms which simulate the behavior of defense systems found in most living organisms. Natural immune system is the resistance of living organisms to bacteria and other external regimes [9]. It is also known as the immune system which has the ability to learn and adapt to changing environment. The living organism's defense system involves lymphocytes B and T. The antibodies are formed from lymphocytes B which are adapted to fight the antigen by cloning, mutation and selection. Immune system can be divided generally to nonspecific immunity (congenital) and specific immunity (adaptive). The type of congenital does not evolve or modify. Cells of the nonspecific immunity protect the organism until the adaptive immunity cells are developer. It is an immunity that evolves over time. The system also stores information about past threats.

Artificial immune systems are build on the model of the natural immune system. [4, 7, 8]. Artificial immune systems mimic the process of antibodies production by B lymphocytes. Antigen is the problem solved, on the other hand the solution is the antibody best suited to antigen and preferably recognizing it. The measure of fit is the objective function that is equal to the inverse of the errors from (22), (23) and (24). It is larger the smaller the forecast error is. Antibodies can be generated in many ways. In the used algorithm, antibodies are sets of coefficients $\{a_i : i = 0, 1, ... 2m+1\}$, which are real numbers drew from predefined intervals.

The whole process of determining the function's coefficients (21) goes through clonal selection. The base population is subjected to cloning. New antibodies are subjected to mutation which slightly changes them. For each antibody and it's clone the value of adaption function is determined. Then these values from every antibody and it's mutant clone are compared. The worse from the pair are removed. The next step is suppression . For each antibody the most similar ones are found and the worse are replaced with new ones.

The calculations were made for various numbers of parameters and different criteria. At the beginning of the calculations, some limiting ranges were made. The calculations were repeated several times at set conditions. Among the obtained results the best one was selected – the one with the smallest error value, which was taken as a criterion of optimization. If the parameter achieved to the extreme value of the interval, the boundaries were moved. If the parameter value changed in a narrow range, the boundaries were modified to surround those values. This pattern was repeated, until there was no visible improvement in the results obtained. Then the number of parameters were increased or decreased to compare with previous calculations. Some results obtained with artificial immune systems algorithm are presented in table 2.

5. DISCUSSION OF CALCULATIONS - COLLATION OF RESULTS

To compare individual forecasting methods, the most common ex post errors were used. MAE (Mean Absolute Error), RMSE (Root Mean Square Error) and MAPE (Mean Absolute Percentage Error):

1) Mean Absolute Error

$$MAE = \frac{1}{n}\sum_{t=1}^{n}\left|y_t - y_t^*\right| \tag{21}$$

2) Root Mean Square Error

$$RMSE = \sqrt{\frac{1}{n}\sum_{t=1}^{n}(y_t - y_t^*)^2} \tag{22}$$

3) Mean Absolute Percentage Error

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\frac{\left|y_t - y_t^*\right|}{y_t}\cdot 100\% \tag{23}$$

where:

n – number of cases (observations); y_t – value of time series for a moment/period of time t; y_t^* – predicted value of y for a moment/period of time t.

The results presented in table 2 were obtained using variant of optimization =2 (oriented on MAPE error). The comparison had sense only when referred to one type of error. During the calculations it was observed that with increasing number of parameters the ex post errors were decreasing.

Table 2 Some results obtained with artificial immune systems algorithm

Nr of calculation	Nr of parameters	Generation	Time [s]	Ex post error		
				MAE	MRSE	MAPE
1	20	4262	13	105	161	4,63%
2	26	8837	38	55	83	2,49%
4	38	933	4	33	46	1,56%

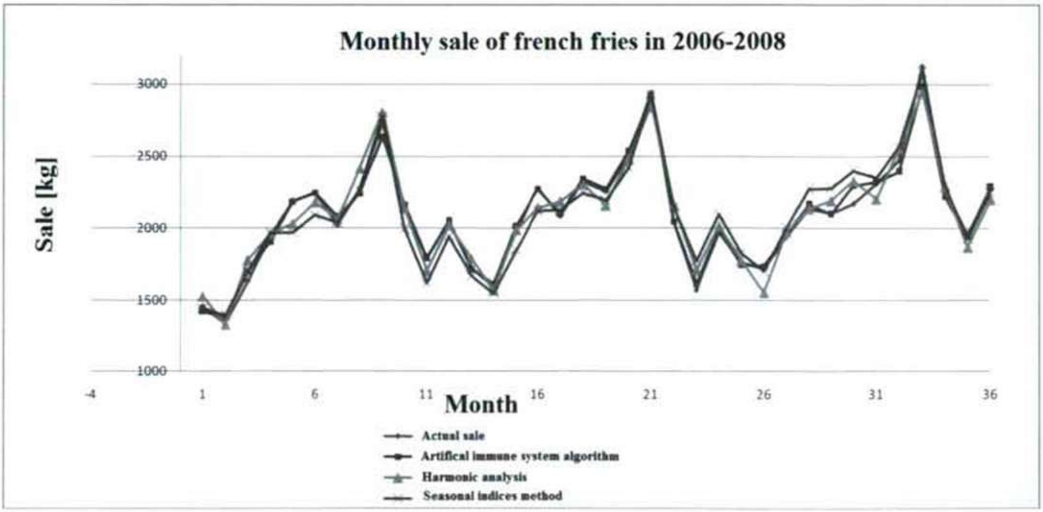

Figure 2. Comparison of expired predictions for model of seasonality indicators, harmonic analysis and artificial immune systems algorithTable 3 Summary of ex post errors for individual forecasting methods

Ex ante error	Seasonality Indicator Method		Winters method		Harmonic analysis	Artificial immune systems
	Additive model	Multiplicative model	Additive model	Multiplicative model		
MAE	85	89	167	266	**75**	**33**
RMSE	106	109	211	349	**91**	**46**
MAPE	4,19%	4,43%	8,14%	12,68%	**3,61%**	**1,56%**

The smallest MAPE error that was obtained was 1,56% in the algorithm of artificial immune system for 38 parameters. Comparing to harmonic analysis (3,61%), the error is smaller by 2,05%. Applicationof artificial immune systems to determine the coefficients of harmonic function gave the best forecasting model from among those that were used in this work.

6. SUMMARY

The article examined the effectiveness of selected methods of forecasting demand based on the example of company Kochloeffel Polska Sp z o.o. and monthly sale of french fries in years 2006-2008. Six forecasting models were presented: Winters method – additive and multiplicative model, seasonality indicators – also additive and multiplicative model and harmonic analysis with it's coefficients determined analytically and using artificial immune systems. Of all the forecasting methods used in this work, the most accurate was harmonic analysis with the coefficients of the harmonic series determined using artificial immune systems. In this forecast MAPE error was 1.56% over three years. The Winters method turned out to be the worst , and in particular the multiplicative model, for which the MAPE error was 12.68% over three years.

REFERENCES

1. Dittmann P. : Forecasting in the enterprise. The methods and their applications., Kraków, 2008. (in Polish).
2. Zeliaś A., Pawełek B., Wanat S. : Economic forecasting: theory, examples, tasks. Wydaw. Naukowe PWN, Warszawa, 2004(in Polish).
3. Wierzchoń S.T. : Artificial Immune Systems. Theory and Applications. EXIT 2001 (in Polish).
4. Góralczyk A. : Frozen capital. CEO, 04/2004.
5. Castro L.N., Zuben F.J.: Artificial Immune Systems, Part I – Basic Theory and Applications, Technical Report, TR – DCA 01/99, December, 1999
6. Castro L.N., Zuben F.J.: Artificial Immune Systems. Part II – A Survey of Applications, Technical Report, TR – DCA 02/00, February 2000.

7. Gołąb J., Jakóbisiak M., Lasek W., Stokłosa T., Immunology, PWN 2008 (in Polish).
8. http://www.statystycy.pl/f28_metody_prognostyczne.php (16.05.2010r.)
9. http://www.swo.ae.katowice.pl/_pdf/289.pdf (13.08.2010r.)