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Optimising a Model of Minimum Stock Level Control and a Model of Standing Order Cycle in Selected Foundry Plant

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Abstract

It has been found that the area where one can look for significant reserves in the procurement logistics is a rational management of the stock of raw materials. Currently, the main purpose of projects which increase the efficiency of inventory management is to rationalise all the activities in this area, taking into account and minimising at the same time the total inventory costs. The paper presents a method for optimising the inventory level of raw materials under a foundry plant conditions using two different control models. The first model is based on the estimate of an optimal level of the minimum emergency stock of raw materials, giving information about the need for an order to be placed immediately and about the optimal size of consignments ordered after the minimum emergency level has occurred. The second model is based on the estimate of a maximum inventory level of raw materials and an optimal order cycle. Optimisation of the presented models has been based on the previously done selection and use of rational methods for forecasting the time series of the delivery of a chosen auxiliary material (ceramic filters) to a casting plant, including forecasting a mean size of the delivered batch of products and its standard deviation.

Keywords: Computer-aided foundry production, Logistics, Stock control models

1. Introduction

One of the most important elements of the logistics management system in a company is the management of the inventory of raw materials and supplies necessary to ensure the continuity of the production process. Many authors claim [1, 2, 4] that the process of inventory management of reserve supplies is the overall activity related with the rational choice of the size and structure of the inventory and its movement to ensure fully effective meeting of the needs in the scale of a given enterprise.

Cost approach to inventory management mainly consists in minimising of costs, which are related with the maintenance of certain level of the stock of various raw materials, tools or products. In this definition, the stress is put on the optimal level of inventory, that is, the level that allows reducing the costs of capital frozen in inventories, the cost of the storage of the inventory and of its protection. Inventory management system is one of the enterprise sub-systems. It includes control, regulation, warehouse processes and physical flow of materials, components, and semi-finished and finished products to the production system, and in and out of the system. The process should ensure proper level of resources, and controlled and planned flow of raw materials from suppliers.

The formation of inventory levels in the supply area requires taking clear decisions relating in particular to the optimal size of the batches of supplies, the optimal delivery cycle, the choice of input materials, for which a reserve should be kept in inventory and defining the situation in which the decision can be taken to give up storage of the inventory.

2. Description of the problem

Each stock, the maintainance of which is reasonably justified may consist of:

- ✓ safety (reserve, buffer) stock, the level of which is determined primarily by the length of the delivery period necessary to restore the required stock volume and the estimated probability of exceeding the delivery size and time. It is part of the minimum inventory, also known as an emergency stock (determining the time when placing of an order is absolutely necessary) created in the event of the occurrence of a much greater demand than expected, or to eliminate the adverse effects of prolonged order lead time. The emergency inventory level indicates the necessity of preparing immediately an order and forwarding it to the supplier,
- ✓ rotating (current) stock, the level of which is usually assumed to be half size of the supplies and which results from the current consumption rate,
- ✓ excess stock (overstock), which increases the variable costs of maintaining the inventory, but brings no added value to the whole process.

Here it should be added that the maximum stock is an upper level of the inventory at the time the delivery is being received or the level of the inventory covered by a supplementary order, while the delivery cycle is the period of time that separates the two consecutive deliveries.

Optimising the costs of the stock creating and maintaining was described on the example of a medium-sized foundry plant in which one can successfully use the inventory control methods based on statistical forecasting in the area ofsupply of the auxiliary casting materials which include ceramic filters. After a detailed diagnosis of the system of material requirements in this foundry plant, the authors have found that the complex plan of material requirements using very expensive software can be replaced quite successfully with simple to estimate delivery schedules. This required the determination of:

- ✓ in terms of quantity – the order quantity *Q*, that is, the optimal size of supply,
- ✓ in terms of time – the order lead time, necessary to estimate the deadline for placing an order of a size *R*, that is, establishing the optimal order cycle.

These parameters are interdependent. Given that the ordered quantity *Q* and the size of delivery cycle *R* can be either constant or variable, four groups of the inventory control methods based on statistical forecasting can be distinguished. From the family of these methods, after a thorough analysis of the problem leading to a conclusion that all assumptions related with the knowledge of the volume of demand, stability of prices and costs resulting from the order quantity or time, the stock homogeneity (ceramic filters) and the availability of capital had been satisfied, methods based on the optimal order quantity Q_{opt} were selected.

The data on the foundry demand for ceramic filters in the first 16 months of the analysis were introduced into a spreadsheet and a scatter chart of the time series was plotted (Fig. 1).

	A	B
1	No of months	y_t [pieces]
2	1	353
3	2	358
4	3	361
5	4	366
6	5	369
7	6	371
8	7	372
9	8	376
10	9	383
11	10	391
12	11	393
13	12	400
14	13	401
15	14	403
16	15	404

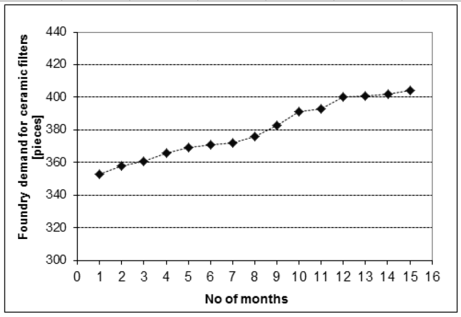

Fig. 1. A fragment of the data sheet showing the demand for ceramic filters and a time series chart

3. Research method

After a thorough analysis of the demand for ceramic filters, the first of the models proposed to the foundry supply managers was based on the level of inventory determining the moment of ordering. In this model, two quantities forming the basis for control of supply have to be estimated, namely the emergency stock level *A* and the order quantity *Q*. Additionally it can be stated that in a car, the reserve indicator is the device showing the emergency level of fuel. To estimate the emergency stock level *A*, the following relationship is applicable:

$$A = \hat{y} \cdot \overline{T} + k\hat{s}\sqrt{\overline{T}} \tag{1}$$

where:

$\hat{y}$ - the estimated size of the demand forecast in the individually adopted time unit (e.g. one year),

$\overline{T}$ - the average reported lead time in the case of own orders, expressed in the adopted time units, regarded as a forecast of the next delivery,

$\hat{s}$ - standard error of prediction,

k - the quantity resulting from the accepted risk factor, i.e. running out of stock, read from the array of normal distribution function.

From the equation (1) given above it follows that to determine the emergency level of the inventory it is necessary to make a preliminary ex-ante estimation of the mean forecast size. After a detailed analysis of the time series of demand (Fig. 1) it was decided that to estimate the mean forecast size, an econometric model based on the linear trend function can be used with full success. The regression function coefficients of the model are estimated by the method of the smallest sum of squared residuals using the Excel internal functions *NACHYLENIE(..)* and *ODCIĘTA(..)* (Fig. 2).

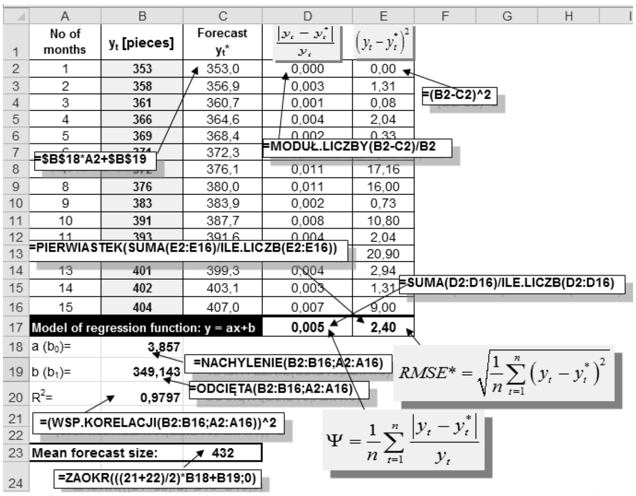

Fig. 2. Estimation of the mean forecast size with calculation of the forecast errors

The estimated coefficients of the linear regression function (cells B18 and B19 - Fig. 2) were used to determine the predictive model comprising the expired forecasts (cells C12:C16). The estimated value of the coefficient of determination R^2 (cell B20 - Fig. 2) indicates that about 98% of the actual demand for filters in a foundry plant can be explained with the obtained predictive model.

Calculation of expired (apparent, ex-post) forecasts allowed comparing these predictions with the actual values of the time series, thus enabling the determination of the forecast error. The estimation of an error in the adopted method of forecasting was based on the mean expired forecast error Ψ (cell D17 - Fig. 2) and on the root mean square error RMSE * (cell E17 - Fig. 2) of expired forecasts that can be used in equation (1) as a standard error of forecast.

Using the resulting prediction model, the forecast of demand quantity in the adopted time unit, i.e. over one year, necessary to estimate the emergency stock level, was expressed as a mean for the next 12 months of the foundry plant operation (cell C23).

The second quantity to be established in the presented model based on the stock level determining the moment when an order has to be placed is the order quantity Q, which is assumed to be at the level of an optimal order quantity Q_{opt} since ordering the batches of other sizes would generally result in increased cost of the inventory storage. The optimal order quantity (Q_{opt}) was calculated from the following formula:

$$Q_{opt} = \sqrt{\frac{2P \cdot k_z}{k_u}} \qquad (2)$$

where:
P - the expected annual demand quantity,
k_z - the cost of purchasing one single batch of filters, regardless of the batch size (the fixed shipping cost),
k_u - the annual holding cost per a unit filter in stock, usually defined as a product of multiplication of the cost coefficient of holding the stock r and a unit filter purchase price c, hence, $k_u = rc$.

Figure 3 shows the methodology used in determination of the optimal batch supply (cell E15) and the emergency stock level (cell E19) for the specific data that relate to the purchase of ceramic filters.

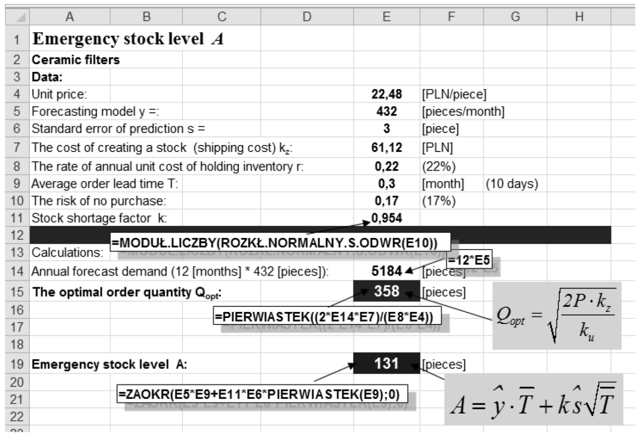

Fig. 3. Calculation of the optimal batch supply and the emergency stock level of ceramic filters

As follows from the submitted solution, orders should be placed in the days when the number of filters in stock drops to A = 131 pieces. The number of filters that should be ordered in this case, that is, the estimated optimal size of the delivered batch of filters (reduced by the amount of any possible stock in transit) will be: Q_{opt} = 358 pieces.

The second proposed model for calculation of the goods in stock is based on a constant order cycle. With this method, the inventory level is checked at fixed, regular intervals. In determination of the maximum stock level S, it is assumed to meet the anticipated demand over a period which is a total of the optimal order cycle T and the average lead time R_{opt} (i.e. $T + R_{opt}$) plus a safety margin, which assumes collecting of goods in the event of a positive deviation from the expected demand. Thus, in the model of standing order cycle, the sizes of the individual supplied batches vary and are directly dependent on the difference between the standard maximum stock level S and the true stock level on the date of ordering.

To determine the optimal order cycle R_{opt} it is recommended to use the optimal order quantity Q_{opt} and the annual forecast demand $\hat{y}$ (outflow from stocks) in a unit time. The maximum stock level S can be calculated from the following formula:

$$S = \hat{y} \cdot \left(\overline{T} + R_{opt}\right) + k\hat{s}\sqrt{\overline{T} + R_{opt}} \qquad (3)$$

where:
R_{opt} - the optimal order cycle; other symbols in this formula are the same as in equation (1).

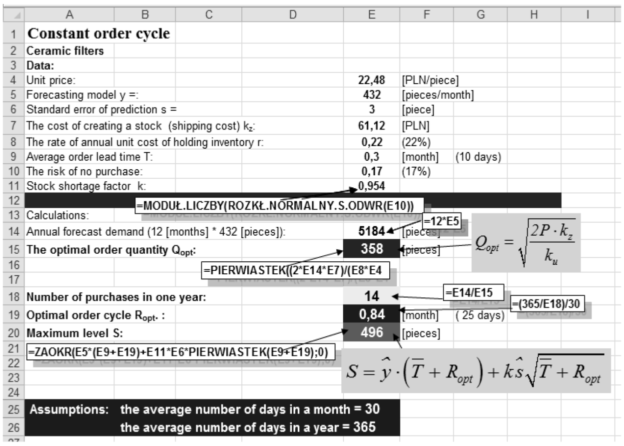

Fig. 4. Determination of the optimal order cycle and maximum stock level of ceramic filters

Knowing the optimal quantity to purchase Q_{opt}, is 358 pieces, it has been estimated that the number of purchases in one year should be equal to approximately 14 (cell E18 - Fig. 4). So, this means that, after rounding, the optimal order cycle (purchase cycle) will take approximately 0.84 of the month (i.e. R_{opt} = about 25 days), and the maximum stock level of filters should amount to about 496 pieces (cell E20 - Fig.4). Thus, the optimal purchasing policy will be ordering the quantities that will replenish the inventory to a maximum level of S = 496 pieces, with purchases taking place at approximately 25 day intervals.

The methodology shown in Figure 4 used to determine the optimal order cycle is based on a preliminary estimate of the number of purchases in one year. This cycle can also be determined multiplying the number of days in a year (assumed 365) by the value of Q_{opt} and dividing by the value of the forecast annual demand.

4. Summary and conclusions

The differences in the proposed conventional models for the inventory control, simple to implement owing to the use of a spreadsheet, consist in the fact that in the model based on an emergency stock level A, the order cycle is variable and the quantity ordered is constant (at least over a long period of time). In the model of standing order cycle, the order cycle is constant and the variable is the delivered batch size.

In the development of models for the execution of orders, special attention should be paid to the two aspects. The first one is related with the result of classification of the value of the goods ordered, usually based on the ABC method [3]. For goods of Class B, which include the ceramic filters, both of the proposed methods are applicable with an equal success, but as regards goods of Class A (the most valuable), the authors suggest to use the model based on an emergency stock level, and for goods of Class C (the cheapest), the model of fixed order cycle.

Another important aspect is the choice of the best method of forecasting, as results of the forecasting are precisely this parameter on which the two presented models are based. It should be remembered that in practice, because of its diversity and a high degree of complexity, the choice of the optimal method of forecasting can be a task quite difficult for the beginners in logistics.

It should also be noted that in addition to the presented models of ordering, there are also models only partially corresponding to classical solutions or designed as a combination of several traditional forms of ordering, to mention for example introducing - as an additional protection against depletion of inventory – the emergency stock level A to the model of standing order cycle.

The presented simple practical solutions using different models of procurement have already produced a fairly significant financial benefits.

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