THE POSSIBILITIES OF OPTIMIZATION OF THE STEEL COIL INVENTORY IN THE PROCESSING COMPANY

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Abstract

The paper is dedicated to the problems of optimization of the inventory of steel coils in a processing company supplying the B2C market. It aims to describe and analyse the possibilities and barriers of inventory optimization with respect to the linkages with coil suppliers within the supply chain in metallurgy. The conducted targeted scientific literature review focussed on inventory optimization models resulted in selection and application of a modification of the standard Q - model, altered for the particular conditions of the solved problem, which is described and evaluated in the article.

Keywords: Inventory, supply chain, metallurgy, steel coil

1. INTRODUCTION

The top management of a medium-sized engineering company focusing on manufacturing of a specific range of metallic assembled products for businesses and final users (hereinafter referred to as the company) found out that the value of the inventory almost doubled in 2014 compared to 2013. Although this growth of the inventory was partly caused by an increase in the production in the given year, the identified fact was an impulse for the management to assign a task to examine the possibilities of inventory optimization in the given company. Therefore, the paper describes and analyzes, on the example of a case study, the possibilities and barriers of inventory optimization, with respect to the links and the level of cooperation with the suppliers of coils within the supply chain in metallurgy. The possibilities of developing cooperation between the manufacturer of metallurgical products and other elements of the supply chain are affected not only by which part of the chain the direct purchaser is in, what function it performs and how it uses the products, but also by what customers it serves and how it has decided to satisfy them [1].

The research aimed to analyze the way of inventory management in the company and to identify the possibilities of decreasing the inventory and the potential optimization, especially in view of the capital holded in the inventory and cooperation in supply chain. Inventory models providing extensive expertise for inventory management and optimization in the corporate practice were chosen as the theoretical background for solving this problem. The applied research methods and sources included a targeted literature review focused on inventory optimization models, in-depth interviews conducted with the managers of the given company in accordance with a questioning scenario, and application of a modified stochastic inventory model.

2. THEORETICAL BACKGROUND

The selection of the right inventory managing system is a strategic decision that will fundamentally affect the operation of the whole industrial company [2]. Problems with quantitative methods applications and the reasons for their potential failure can be explained, on the one hand, by the wrong approaches of the managers as their users and, on the other hand, by the frequent shortcomings on the side of IT specialists and model processors [3]. The essence of the inventory policy is looking for such a method of replenishing, holding and using inventory which ensures their economically effective (optimal) function in supply systems [4]. Individual inventory models are then quantitative descriptions and solutions in different specific situations. The professional literature includes a lot of references to various types of optimizing inventory models [5], [6], [7], [8], [9]. The most widely used classifications include division into deterministic and stochastic models.

Deterministic models assume that all the model variables are fixed and are not subject to random fluctuations. This type of models is applied in practice only rarely, and they usually serve just as the foundation for more realistic sophisticated models. On the other hand, stochastic models consider the variables as random quantities with assumed or empirically determined distribution of the probability of their possible range. From all stochastic models, most professional literature mentions two basic model types:

1) Inventory replenishment orders are placed in a constant planned amount of Q, always as at the date of reaching a certain controlled volume of inventory, which is marked as the “reordening point”. The source of uncertainty in this model is the period between placement and receipt of an order, when the demand and the actual date of delivery might fluctuate. The reorder point value will depend on lead time and the expected daily demand [10]. The scholarly literature mostly calls this type of model a Q-model (fixed order-quantity system).
2) Inventory replenishment orders are placed in fixed, usually regular periods, where the ordered quantities can again be changed in accordance with the reached level of the current inventory as at the moment of the order placement. The model counts with the upper limit of the inventory P, to which the inventory is always replenished. That is why this model is often called a P-model (fixed order-period system). The risk of demand fluctuations in this model is higher than in a Q-model, as it applies to the entire ordering cycle, and an incorrect demand forecast cannot be rectified until the following ordering cycle.

From the point of view of the practical use, it is possible to remark that even these two models in their basic form are not applied in practice very often. The reasons can be found in the relatively strict conditions of their applicability. These conditions, which are often barriers of their practical use, include, above all:

- Randoml fluctuations of the actual demand with approximately normal probability distribution. The method of verification of the normality can be applied to the previous periods [4], but even confirmation of this hypothesis does not guarantee that the demand will behave to same way in the following periods. Similarly, it is necessary to approach random fluctuations in the delivery dates.
- The volume of the order (which means also of the delivery) can be chosen in an arbitrary continuous quantity. However, in reality this is usually a discontinuous quantity and it is reduced by a number of limitations according to a particular situation, e.g. the minimum volume of an order, the size of transport batches, the supplier’s capacity, etc.
- Setting and measuring of the costs that are the main criterion for inventory optimization might be another source of problems with applications.

A reasonable classification of costsfor inventory models has been defined e.g. by Albright, Winston [5]. First group are ordering costs, which include the fixed order costs, but also the fixed costs of setup of production facilities in the case of manufacturing of the given product. These costs are independent of the volume of an order or a production batch in the case of manufacturing. Another type of costs is marked as unit purchasing or production cost. Such costs are also called variable. In the case of purchase, they can refer to the amounts for a unit of the purchased material or product, and in the case of manufacturing the variable cost of raw materials, or variable wages. These costs are mostly considered as constant per unit of measure unit of a raw material or product. Sometimes the unit purchasing cost is not constant but changes according to a quantity discount schedule. The third group of costs are defined as holding or carryina costs. These costs should stimulate companies to hold lower inventory. They contain two basic components: financial and other costs. Financial costs are basically opportunity costs or the interest on the capital holded in the inventory. Other costs then include the cost of storing itself, e.g. lease or warehouse write-offs, storemen’s wages and salaries. The last group of costs is then defined as shortage or penalty costs. These costs are most difficult to estimate and measure. The consequences for the company may be extremely different from a total loss of sales and customers to the possibility of accomplishment of a delivery additionally as soon as the missing inventory is restored.

However, the fact is that it is difficult to identify and estimate most costs in practice in either case. Therefore, the models are modified for their practical application to do without the criterion function of minimization of the total costs. Such a model has been formulated e.g. in [4]. If the volume of inventory is limited by the available capital, it is then enough to minimize the number of orders, or to minimize the average inventory while observing the limited number of orders. Similar experience has been acquired by authors of the diploma thesis [11], for which a cost-free modification of a Q-model was formulated [12].

3. OPTIMIZATION OF THE STEEL COIL INVENTORY IN THE PROCESSING COMPANY

What is typical for metallurgy is vertical integration of companies, which forms a strong group with a very strong negotiation position in the given supply chain. In view of relatively small purchases of steel coils, the company is forced to use intermediaries. They are big trading companies which set also the main conditions of cooperation. The company had to adapt to these conditions of cooperation in view of the supplier's and subscriber's strong position even though it means for the company to maintain extensive inventory of steel coils on input. An analysis of the volume of inventory identified that it is steel coils, which are at the same time the basic feedstock, what makes up the largest part of the total value of inventory. The company uses about 30 types of them. Therefore, the research was mainly focussed on this feedstock. Steel coils are purchased on the basis of a demand forecast 2 months in advance, and they are stored in the company premises. The coils differ in thickness and other features, and they are only partly and to a limited extend replaceable. An analysis of the way of inventory management showed that it is the inventory of steel coils where there is the point of disconnection between the push and pull management systems. The thing that the company products are only manufactured on the basis of orders, but the inventory of steel coils for manufacturing has to be maintained according to the demand forecast, roughly for the period of two months. These two findings resulted in formulation of two working hypotheses:

H1: The steel coil inventory can be decreased by making the company demand forecast more accurate.

H2: The steel coil inventory can be decreased by suitable application of an optimization inventory model.

The demand forecast is formulated by the responsible worker of the company on the basis of his experience considering the development of confirmed orders of the company products without a systematic analysis of the time series of needs for the respective types of steel coils in the previous period. These analyses and future need prognoses arising from these analyses still have not been performed in the company. Also, the company has not applied any inventory optimization models yet.

3.1. Hypothesis H1 verification

In the experimental analysis, steel coils were represented by a steel coil of size 0.7x1000 mm (hereinafter referred to as SC1), which is used for manufacturing of products most often and to the largest extent. The time series analysis involved data on the consumption and purchase of SC1 in 2012-2014 divided by month. The elementary representation of the time series is in **Figure 1**.

Figure 1 implies that the time series does not show any significant trend but, on the other hand, it shows very strong fluctuations in the consumption in individual months. As the company was restructured in 2013 and there was a production hike, we focussed our analysis on the years of 2013 - 2014 only. We tried time series smoothing by the linear trend function, and in view of the character of the data, we also applied the adaptive method of exponential smoothing. To assess the quality of smoothing for forecasting the future demand, we designed an experiment where the smoothed data for 2013 were first used for forecasting the expected values in individual months of 2014, and these were then compared to the actual 2014 values. For the outcomes of this comparison, see **Figure 2**.

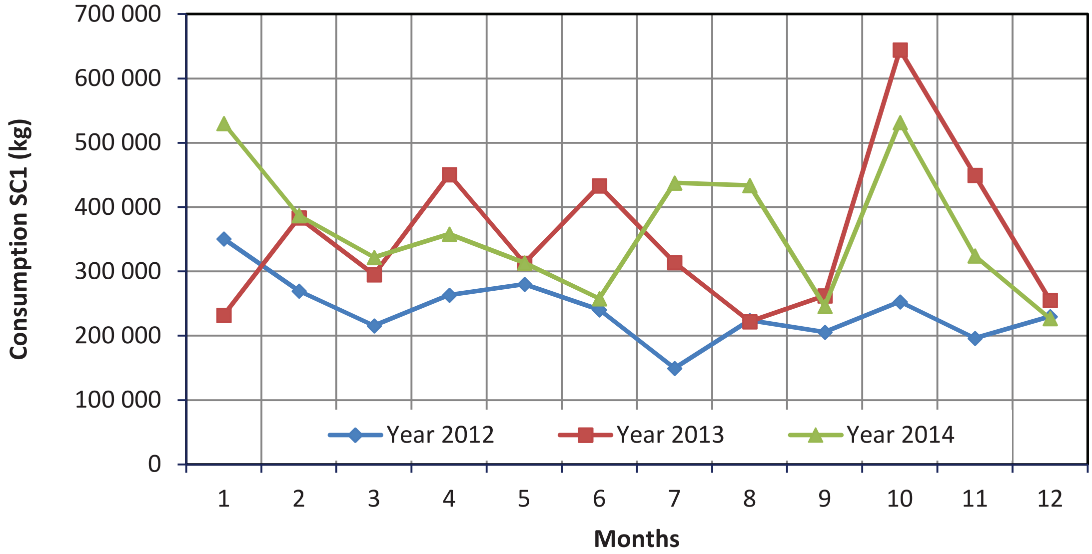

Figure 1 Consumption of SC1 in the years 2012-2014 divided by individual months

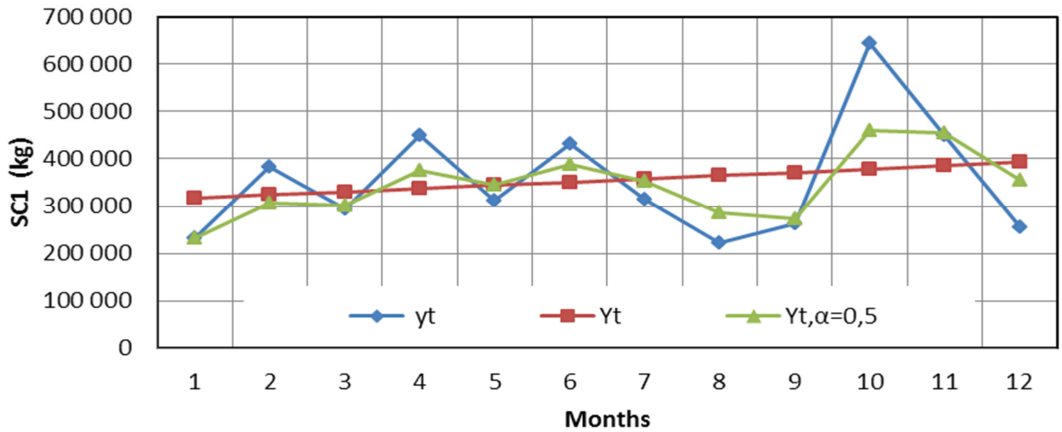

Figure 2 Comparison expected Y_t and actual y_t values of the consumption SC1 in year 2014

The quality of the estimates of SC1 consumption can be evaluated using variances or standard deviations of the residues defined through differences between the actual value y_t and the estimated value Y_t according to the forecast. The calculations of residual variances showed that the estimation error of standard deviation with respect to the trend forecast Y_t was 98 444kg, i.e. 27% of the average monthly demand. Although in the exponential smoothing with the constant of alpha α = 0.5 the residual deviation was only 60 261kg, this estimate is usable for one period ahead only. For the reason of significant fluctuations in the actual monthly consumption of SC1, it is possible to reject the hypothesis that more accurate demand estimates can contribute to a decrease in the inventory of the examined SC1 material.

3.2. Hypothesis H2 verification

Hypothesis H2 aimed to explore the possibility of application of any of the inventory optimization models in the company conditions. The analysis of the steel coil ordering process in the company resulted in the following findings.

The company always orders steel coils for the two months, roughly one month in advance. The manager of the respective department first requests the suppliers' price lists for the following period. Then he uses the information system to identify the current steel coil inventory, the demand for individual types in the previous two months and in the ordering months of the previous year, and on the basis of the obtained information he estimates the requirements for the following period. The minimum ordering quantity is 65 tonnes, i.e. 1 railway car. Although the maximum quantity is not specified by the supplier, the company is limited by the capacity of its own warehouse, which is 2000 tonnes. The material is transported to the company in trucks, but the supplier does not despatch the entire order at once. The entire order is divided into two months with binding effect. The date of the first delivery is usually fixed, but the following deliveries and their distribution in time fall within the competence of the supplier. As the company does not have the dates of deliveries under control and also as the need for individual coils for production is not regular and even, this leads to the fact that the company is forced to keep relatively high safety stocks of individual items.

The above analysis implies that the way of steel coil inventory replenishment and using correspond to the combined stochastic model with specific properties. The system of ordering for the period of 2 months 1 month in advance is relatively stable. The specifics reside in the fact that the dates and volumes of individual deliveries within the entire order are not agreed. From the point of view of the cost definition, not all the relevant costs are monitored. From the costs specified in Chapter 2, the company only knows the ordering costs, such as the price of the purchased material, the cost of storing is not allocated to the respective items, and from the other costs, it is potentially possible to quantify the cost of the capital holded in the inventory. The other cost items seem to be negligible or just hard to identify. For these reasons we chose, for verification of the possibility of inventory optimization, the cost-free model, where the main optimization criterion is a decrease in the average inventory of the stored items.

To verify the possibility of optimization according to a modified model, we also chose the SC1. The matrix of the basic data included, for each day of the examined period 2013 - 2014, a complete balance of the SC1 inventory divided as follows: date; initial inventory + delivery receipt - material issued for production = inventory at the end of the day. The calculated statistical characteristics of the entire process of the inventory movement in the given period are presented in the **table 1**.

Table 1 Statistics report of SC1 inventory movement in period 2013 a 2014

Inventory SC1 management process statistics	2013	2014
Average value of deliveries, kg	34 551	34 105
Standard deviation of deliveries, kg	20 135	20 574
Number of implemented deliveries	124	131
Average interval between deliveries, days	2.94	2.79
Average quantity of delivery ex stock, kg	18 826	19 358
Standard deviation of issuance, kg	10 425	12 057
Number of ex stock delivery	226	225
Average interval between ex stock delivery, days	1.62	1.62
Average value of day inventory SC1, kg	51 602	63 327

The table particularly implies that the process of ordering and using the SC1 inventory shows an extraordinarily large variability, and the dates of acceptance of deliveries are not synchronized with the dates of issuance of the material for production in any way. Therefore, holding the SC1 inventory roughly on the level of double the average volume of the deliveries seems to be, in the given situation, the only possibility. In spite of that, the company was short of SC1 several times during the monitored period, and they had to use an alternative material. If we add the fact that neither the delivery times nor the volumes of individual deliveries were under the control of the company, it is obvious that even application of an optimization model cannot result in the required decrease in the average inventory of the examined SC1 material. As for the other steel coil items, it is possible to expect a similar result. For these reasons, we can reject Hypothesis H2 as well.

4. CONCLUSION

Although the research did not bring the expected outcomes in the form of a demonstrable decrease in the average inventory in the company, an obvious benefit for the company can be seen in mapping of the process of ordering and using of steel coils in the company, and identification of the main reasons preventing, in the current conditions, more effective inventory management. Apart from the relatively strict and not easily meetable conditions of applicability of inventory optimization models specified in the theoretical part, the application of also a modified inventory model is also prevented by the identified extraordinarily large variability in the process of inventory ordering and using. The other barriers of more effective inventory management in the company include the proved impossibility of making demand forecasting more precise using the time series analysis, and currently also the fact that the company practically cannot influence synchronization of the steel coils delivery dates with the dates of delivering of the material into production with respect to the customer orders. This is the result of the currently relatively unfavourable position of the company in the given supply chain. In view of the relatively small orders of steel coils, the company uses intermediaries, who set up the main conditions of cooperation on the side of the inbound logistics and, at the same time, as the last production segment of the given supply chain, the company mostly delivers its products to central distribution warehouses of retail chains, who set up the cooperation conditions on the side of the outbound logistics. This requires the company to be highly flexible and adaptable to the changing demand and to execute orders perfectly. Therefore, it is necessary to seek a solution in closer forms of cooperation within the entire supply chain. Here the company can take advantage of its experience with cooperation with foreign customers.

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