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Inventory Management Method with Demand Forecast in e-Commerce

Kenji TANAKA[1] and Daishi SAGAWA
The University of Tokyo

Abstract. In the last decade, while the whole retail market has been sluggish, e-commerce (EC) has steadily expanded its market share. However, EC has a higher logistics cost than other retail formats, in particular, inventory management is a problem. In EC, the demand for goods tends to fluctuate greatly depending on its price because the price comparison in EC is much easier than that of other retail formats, and it makes the inventory management more difficult. Since the demand for goods fluctuates greatly due to price setting, EC companies suffer losses from the disposal of goods due to excessive inventory or from the loss of sales opportunities due to under stocking their inventory. Conventional methods, such as periodic ordering and quantitative ordering, are not appropriate to cope with the fluctuation of demand in EC. Thus, an inventory management method which can correspond to the fluctuation of demand due to price change is required. This paper proposes a demand forecast inventory management method which predicts demand by using planned pricing data and decides order timing and order quantity based on the prediction. This paper shows that the demand forecast inventory management method we propose can reduce inventory costs by 10% compared to periodic ordering by applying the method to the actual sales data and inventory data of an EC company.

Keywords. Cost Modeling, Analysis and Engineering, Decision Supporting Tools and Methods, Supply Chain and Logistics

Introduction

E-commerce (EC) has steadily expanded its market share, increasing from 1.79% in 2008 to 3.11% in 2012, 1.7 times in four years. The sales of EC also continue to rise, reaching 9.5 trillion yen in 2012 from 6.1 trillion yen in 2008. [1] However, EC has a sales logistics cost ratio of 11.9%, which is more than twice as large as other retailers such as co-op and convenience stores. The fact that the logistics cost is higher than other retail industries is a challenge. This is partly due to EC's being forced to logistically oriented toward customers with short lead time in order to improve the level of service to customers. [2] Patil (2014) also revealed that inventory management plays an important role in order to enhance customer satisfaction. [3]

Since EC companies strongly receive the influence of comparison with other companies more strongly than other retailers, sales fluctuations due to price changes are very large, making it difficult to estimate the appropriate inventory quantity. It is a factor increasing the inventory cost of EC.

[1] Corresponding Author, Mail: tanaka@tmi.t.u-tokyo.ac.jp.

In this research, inventory control method corresponding to fluctuations of sales due to price change is proposed in order to reduce the ordering cost and the storage cost. This research aims to develop an inventory method which predicts sales fluctuation due to price change and decides ordering frequency and order quantity based on the prediction.

1. Literature Review

As research on the inventory method, Kamei (2009) optimized the ordering interval of periodic indeterminate quantity orders and the size of the truck used for transportation, but demand forecast is not considered in the research[4]. Li (2014) made a model to determine the quantity, locations, order times considering returns, but demand change due to the price change is not considered.[5]

Although research of Hoshino (2008) [6] and De - Bi Tsao (2000) [7] are based on the assumption of forecasting demand, the ordering method is targeted only for periodic indeterminate quantity orders. Irregular indeterminate order that flexibly respond to changes in demand by changing the timing of order based on forecasts, are not considered. The research of Niwa (1977) [8] is a research on irregular indefinite amount order under the assumption that future demand is given, but there is no discussion on actual inventory method operation, such as determination of the number of safety stocks considering prediction error.

The purpose of this research is to construct a model that proposes inventory method (ordering timing) considering logistics cost based on sales forecast considering price change.

2. Models

2.1. Overview

The overall process of the inventory management method we propose is shown in Figure 1. There are 3 steps in the process. The operations performed in each step are listed below.

- A) Demand forcast of N days : To forecast demand of N days forward from the date when calculation is performed based on the past daily demand data, price data.
- B) Order timing determination : To determine the order timing based on the results of demand forecast so that the sum of the storage cost and order cost is minimized. The order quantity of each order is temporarily determined in this process, which is to be corrected by following steps.
- C) Demand forcast error feedback : To calculate the correction quantity which is used to collect the temporary order quantity considering the prediction error of the previous term and the safety stocks.

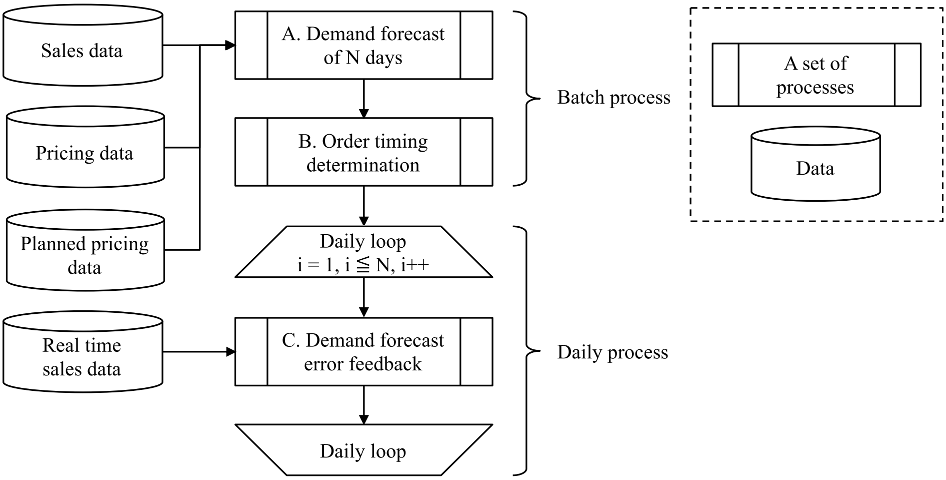

Figure 1. Process of inventory management method with demand forecast.

Details of each step are described in the following sections.

2.2. *Demand forecast of N days*

The process of demand forecast of N days is shown in Figure 2. First, several types of sales prediction regression formulas are created from the sales data of the past quarter. Next, from the created regression equation, the regression equation which is most applicable to the past sales data is selected. Finally, by substituting the schedule price data into the selected regression equation, the sales forecast value of the target period is calculated.

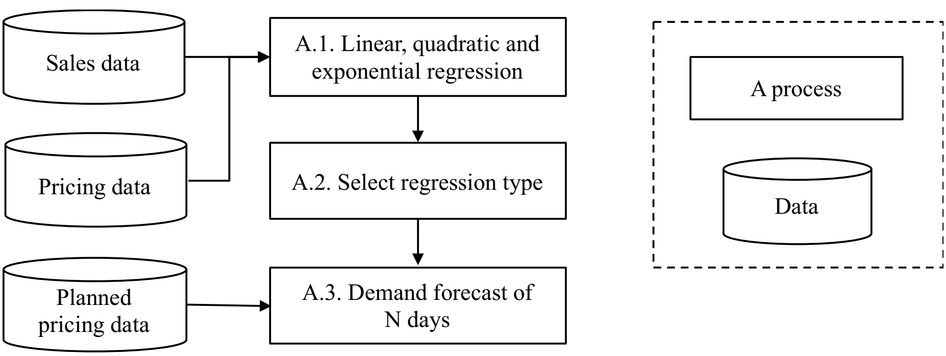

Figure 2. Process of demand forecast of N days.

The operations performed in each step are listed below.

A.1. Linear, quadratic and exponential regression : To perform regression analysis of three types of linear, quadratic, and exponential for each day of the week for past sales data. In regression analysis, the pricing data is used as an explanatory variable.

A.2. Select regression type : To select a regression equation with the maximum correlation coefficient R from the three regression equation.

A.3. Demand forcast of N days : To apply the schedule price data to the selected regression equation and obtain the demand forecast value up to N days ahead.

2.3. Order timing determination

This section defines the storage cost and the order cost, and build an inventory method that minimizes the sum of inventory cost and ordering cost when there is sales as forcasted. The process of oder timing determination is shown in Figure 3.

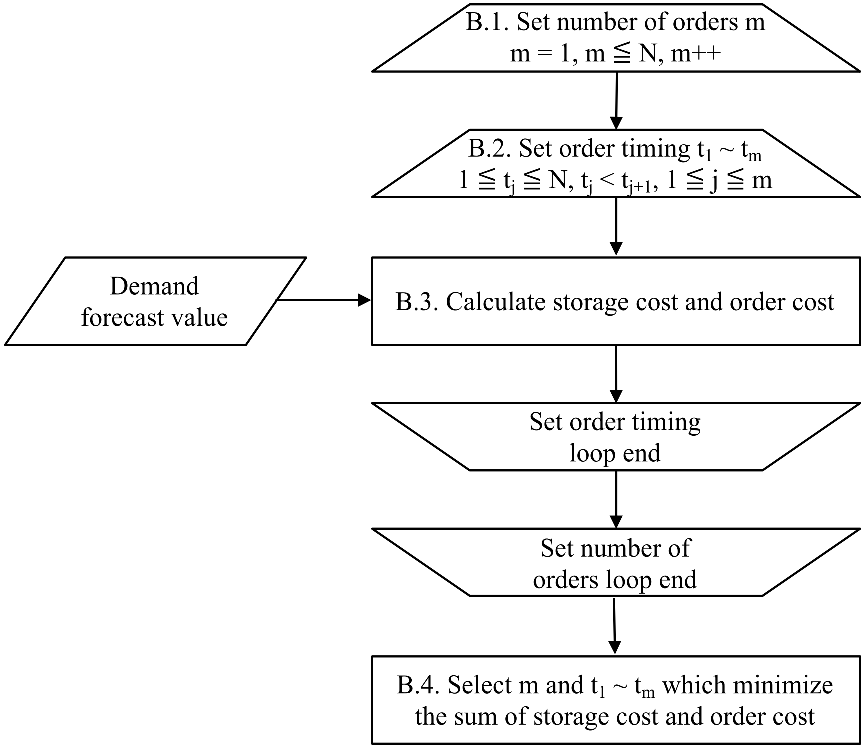

Figure 3. Process of order timing determination.

The operations performed in each step are listed below.

B.1 Set number of orders m : To set m which represents the number of orders in the period (N days).

B.2 Set order timing t_1~t_m : To set th order timing t_1~t_m. For all the combination of t_1~t_m, the storage cost and the order cost are calculated. The number of combination of t_1~t_m is ${}_NC_m$.

B.3 Calculate storage cost and order cost : The storage cost (C_S) and the order cost (C_O) are defined as follows.

$$C_S = HS_{MAX} \tag{1}$$

$$C_o = E\mathrm{m} \tag{2}$$

- C_s : Storage cost [yen/period]
- H : Cost for storing 1 unit of inventory during target period [yen /unit/period]
- S_{MAX} : Maximum number of stocks during the target period [unit]
- C_o : Order cost [yen/period]
- E : Cost per ordering [yen / times]
- m : Number of orders during target period [times/period]
  In order to obtain S_{MAX}, the number of stocks during the target period is required and is defined as follws.

$$S_{est}(t) = S_{0j-1} + O_{est,j} - (\hat{d}(t) - \hat{d}(t_j)) \qquad (t_j \leq t < t_{j+1}) \tag{3}$$

$$O_{est,j} = \hat{d}(t_{j+1}) - \hat{d}(t_j) + S_{0j} - S_{0j-1} \tag{4}$$

$$S_{0j} = k\sigma\sqrt{t_{j+1} - t_j} \tag{5}$$

- t : Number representing a date in the target period
- t_j : Number representing the day when j th order is done
- $S_{est}(t)$: Estimated number of stocks in the day t [unit]
- S_{0j} : Number of safety inventory for period j [unit]
- $O_{est,j}$: Estimated quantity of order for period j [unit]
- $\hat{d}(t)$: Cumulative forecast sales value up to date t [unit]
- k : Sefety coefficient
- σ : Standard deviation of difference between past sales data and regression equation [unit]

B.4 Select m and t_1~t_m which minimize the sum of storage cost and order cost : To select m and t_1~t_m so that the sum of C_S and C_O is minimized.

2.4. Demand forecast error feedback

The purpose of demand forecast error feedback is to prevent the accumulation of errors and to bring the number of period-end inventories close to the number of safety stocks. Figure5 is a conceptual diagram which shows the effect of the demand forecast error feedback. If the demand is small relative to the forecasted demand as shown in Fig. 5, the period-end inventory quantity gradually deviates from the safety stock number unless forecast error up to then is taken into consideration, the inventory quantity will gradually increase. Therefore, in order to prevent the accumulation of forecast errors, it is necessary to reflect the demand forecast error in the previous ordering period in the order quantity.

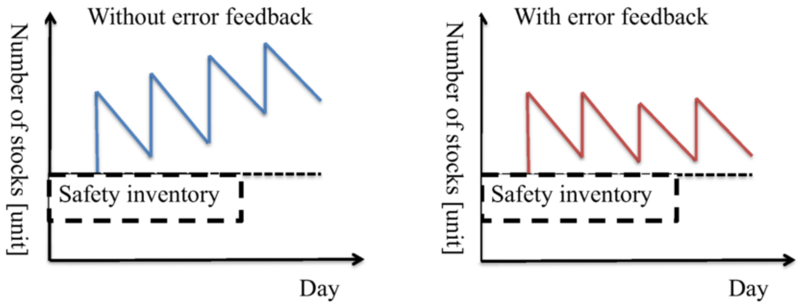

Figure 4. Effect of the demand forecast error feedback.

In actual inventory operation, there is an order lead time from the ordering until the goods are delivered to the warehouse. The sales forecast error feedback reflects the prediction error that occurred between the previous order and the next order in the next order quantity. It is formulated as follows.

$$S(t) = S(t_j - 1) + O(t_j) - \{d(t) - d(t_j - 1)\} \quad (t_j \le t < t_{j+1}) \tag{6}$$

$$O(t_j) = \hat{d}(t_{j+1} - 1) + S_{0j} - \{\hat{d}(t_j - 1) + S_{0j-1}\} + E_{j-1} \tag{7}$$

$$\mathrm{E}_{j-1} = d(t_j - L) - \hat{d}(t_j - L) - \{d(t_{j-1} - L) - \hat{d}(t_{j-1} - L)\} \tag{8}$$

– S(t) : Number of stocks after the day t [unit]
– $O(t_j)$: Quantity of order for period j [unit]
– d(t) : Qumulative demand up to date t [unit]
– E_{j-1} : Error to feedback to the order quantity [unit]
– L : Order lead time [day]

3. Case Study & Discussions

3.1. Data Overview

This research is a part of joint research project with an EC company, and is based on actual data provided by the company. The types of data used in this research are as follows.

1. Item master
2. Sales data
3. Arrival data
4. Planned price data

The item master is the data such as item number of product, product name, manufacturer, product category, number entry, handling start date and so on. The sales data is daily sales data of the product, and is data such as item number, order receiving date from the customer, shipping date to the customer, shipping warehouse, sales quantity, selling price and the like. The arrival data is the daily arrival data of the product, and it is data such as the item number, the arrival date from the supplier, the arrival amount and the arrival warehouse. The planned price data is schedule data of selling price for each product and is used for sales forecasting. In this research, it is assumed that planned price data up to one month ahead can be obtained at any time. In other words, when practicing the method of this research, it is necessary to set a price strategy up to one month ahead of the target product. In this case study, the selling price of the sales data during the prediction target period is regarded as the planned price and used for prediction.

This model is applied to item A and the result is compared with that of conventional method. The item A is 2L PET bottled drink, X company sells it in 3-piece set and 9-piece set. 3-piece set are B to C, 9-piece set are handled in both B to B and B to C, so the trend of sales is totally different. Therefore, sales forecasts are separately made for 3-piece set and 9-piece set, and then sales forecast values for 3-piece set and 9-piece set are added together to make sales forecast value for product A.

3.2. Prerequisites

3.2.1. Target period

The period of the sales data used for formulating the prediction formula is set to 60 days, and the target period of the prediction and inventory estimation simulation is set to the next 30 days.

3.2.2. Storage cost

In this research, the stock cost per day is assumed to be 2.3 [yen / m^3 / day]. Since the size per unit of item A is 2.89×10^{-3} [m^3], storage cost per month for item A is H = 7.18 [yen / unit / month].

3.2.3. Order cost

In this research, the cost for one order is assumed to be E = 4,000 [yen / order].

3.2.4. Safety coefficient

In this research, the safety coefficient k used for calculating the safety stock is set to k = 4. If k = 4, a missing item will not occur if the prediction error is up to 4σ.

3.3. Demand forecast

Table 1 shows the correlation coefficient R of each regression formula of the product A.

Table 1. Correlation coefficient R of each regression formula.

Regression type	3-piece set	9-piece set
Linear	0.96	0.64
Quadratic	0.96	0.64
Exponential	0.96	0.65

Regarding the 3-piece set, any regression formula is the same for 2 significant digits. When comparing by increasing the significant digits, since the value of the quadratic regression is slightly high, in this case, the quadratic regression is selected. In 9-piece set, exponential regression showed the highest R value. Therefore, exponential regression equation is selected for 9-piece set.

Figure7 shows a graph of the sales forecast / forecast average and actual sales/ actual sales average of the total of 3-piece set and 9-piece set.

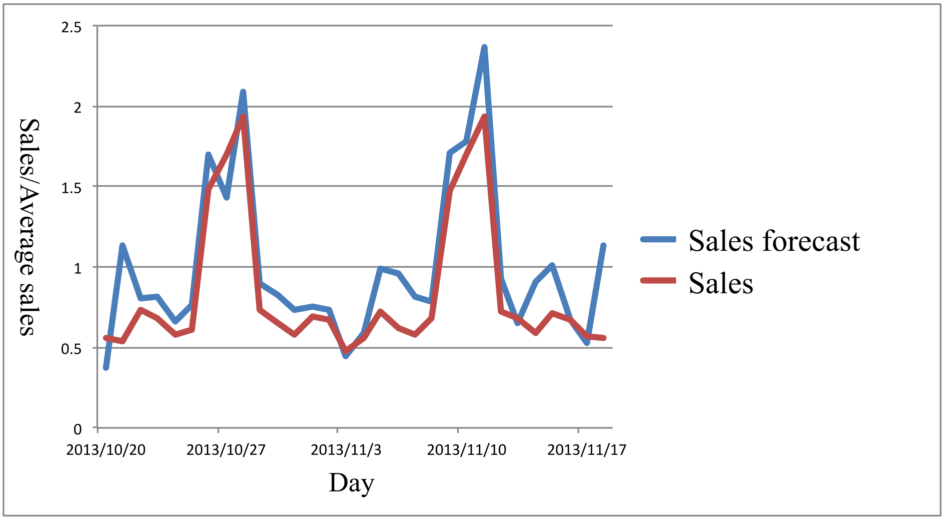

Figure 5. Result of demand forecast of 3-piece set + 9-piece set.

Table 2 shows correlation coefficients between sales forecast values and actual sales values. The correlation coefficient between the predicted value and the actual value in the 3-piece set is as high as 0.99. The 9-piece set had a correlation coefficient of 0.72, which was lower than that of the 3-piece set. The correlation coefficient of the total of 3-piece set and 9-piece set is 0.92, which is improved from 9-piece set.

Table 2. Correlation coefficient R of 3-piece set, 9-piece set and sum of them.

-	3-piece set	9-piece set	3-piece set + 9-piece set
R	0.99	0.72	0.92

3.4. Order timing determination

Figure6 shows relationship between the order number and the total cost. Figure6 shows that the total cost is the smallest when the ordering number is 11, and the cost is 11,300 yen at that time.

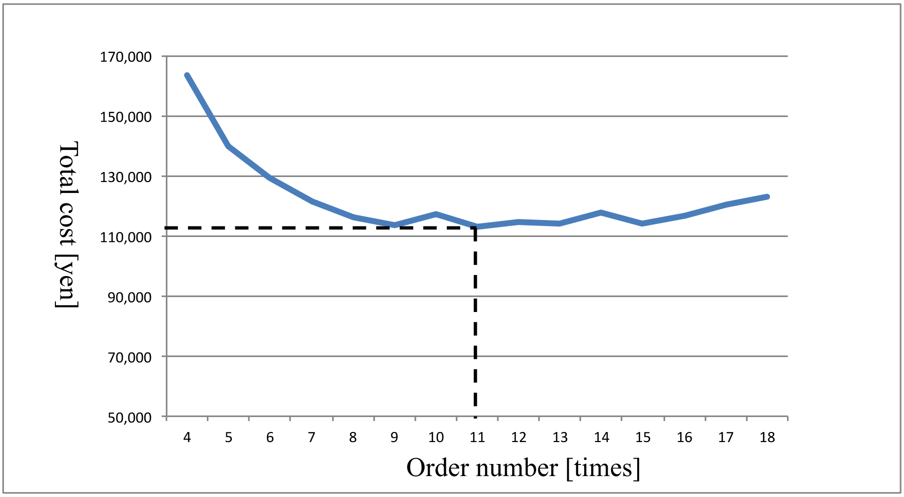

Figure 6. Relationship between the order number and the total cost.

3.5. Comparison with conventional method

Figure7 shows that the proposed inventory method has made it possible to lower the maximum stock compared to regular order (3days).

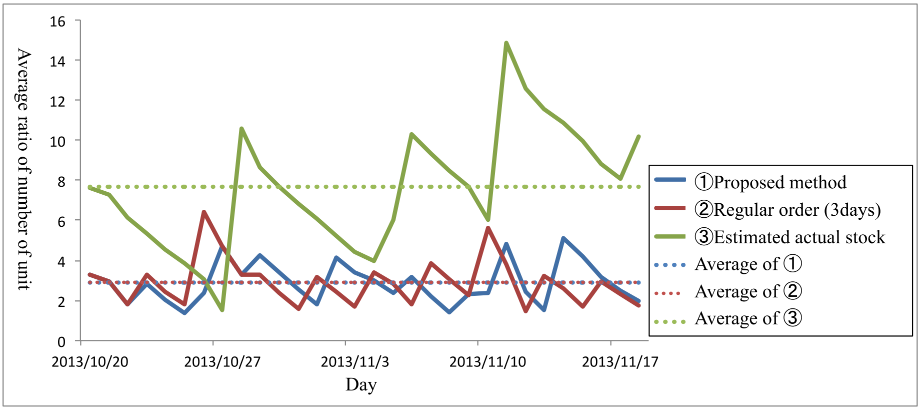

Figure 7. Average ratio of inventory of each inventory method.

Table 3 shows the reduction rate of various indices. The proposed method were able to reduce the total cost by 10% from that of the regular order. Despite not reducing the average stock $S_{Average}$, the maximum stock S_{Max} has been reduced by 20%. This indicates that inventory cost can be suppressed by determining the ordering timing considering the planned price.

Table 3. Correlation coefficient R of 3-piece set, 9-piece set and sum of them.

Reduction rate of the proposed method	Proposed method / Regular order (3days)
$S_{Average}$	0 %
S_{Max}	20 %
C_I	20 %
C_o	-10 %
C_{Total}	10 %

4. Conclusion

In this paper, inventory management method with demand forecast is developed. In the case study of item A, it is shown that the proposed method can reduce the total cost by 10% over the regular ordering method. These fact shows the effectiveness of the proposed method and the possibility of control of inventory volume through price adjustment. In the future research, I will apply this method to large numbers of SKUs to show this method is effectiveness.

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References

[1] Ministry of Economy, Trade and Industry, *On the Publication of the Results of the Foundation for Heisei 24 Economic and Social Infrastructure in Japan* (Market Research on Electronic Commerce) (Abstract of Survey Results), 2013.
[2] Sakata Warehouse Co., *Logistics Review*, 2007.
[3] H. Patil and B.R. Divekar, Inventory management challenges for B2C e-commerce retailers, *Procedia Economics and Finance*, Vol. 11, 2014, pp. 561-571.
[4] K. Keita, *Optimization method for procurement logistics taking both logistics and warehouse costs into account, thesis*, University of Tokyo, Department of Engineering Systems Innovation, 2009.
[5] Y. Li, M. Lu and B. Liu, A two-stage algorithm for the closed-loop location-inventory problem model considering returns in e-commerce, *Mathematical Problems in Engineering*, 2014, http://dx.doi.org/10.1155/2014/260869.
[6] H. Kyoji, Optimization of safety inventory quantity in periodic ordering method, *Shogaku-ronshu*, Vol. 76, 2008, No. 4.
[7] De-Bi Tsao, *A Method of Safety Stock Calculation Utilizing Forecasting Errors*, Japan Industrial Management Association, 2000.
[8] A. Niwa, Economic lot size model when demand changes M times during the planning period, *Journal of the Operations Research Society of Japan*, Vol. 20, No. 4, 1977.