Inventory Management for Irregular Shipment of Goods in Distribution Center

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Keywords: inventory control, supply chain management, distribution center, forecasting method.

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INVENTORYMANAGEMENTFORIRREGULARSHIPMENTOFGOODSINDISTRIBUTIONCENTER

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Inventory Management for Irregular Shipment of Goods in Distribution Center

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I. Introduction

The distribution center only ship merchandise after they receive direct orders from customers, who may be wholesalers, supermarkets or large-scale stores. The wholesalers then ship merchandise to retailers, who in turn sell the merchandise to consumers. The supermarkets and other large-scale stores, on the other hand, sell the merchandise directly to consumers. Generally, the sale of merchandise directly to ultimate consumers fluctuates widely according to the characteristics of the merchandise. For this reason, the amounts shipped from distribution center to their customers and the times of shipment also vary greatly. The commodity goods (Foods, confectionery, dairy products, such as public cosmetic pharmaceutical products) do irregular changes at the distribution center dealing with the general consumer goods. Therefore, the forecast of the shipment time and the shipment volume are difficult. It cannot be applied to the shipment of the commodity by the conventional inventory management techniques. For this reason, we have proposed a method of performing with the cumulative flow graph[1][2]. The irregular shipment characteristics of goods, we have proposed a theoretical formula that determines the order timing and order quantity. The cumulative inflow corresponds to the order quantity in inventory management. Here, it proposes three methods. 1) Power method, 2) Polynomial method[3] and 3) Revised Holt's linear method that forecasts data with trends that is a kind of exponential smoothing method. This paper compares the economics of the conventional

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method, which is managed by the experienced and three new proposed methods. And, the effectiveness of the proposal method is verified for the real distribution center.
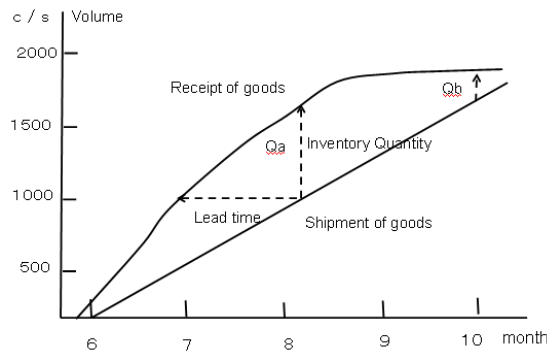
II. CUMULATIVE CURVE

Distribution center ship merchandise in direct response to orders from customers, be they wholesalers, supermarkets or other large-scale stores. The merchandise shipped from the distribution centers to wholesalers is then shipped by the wholesalers to retailers, as shown in Figure 1. Then the merchandise is sold by retailers to consumers. The merchandise shipped from distribution centers to supermarkets and other large-scale stores is sold directly to consumers at the supermarkets and those large-scale stores. Movement of warehouses and distribution center can be expressed by the cumulative flow curve. The cumulative flow curve is composed of the inflow, the outflow, and the processing line of the distribution center. Movement of the product can be represented by the inflow and outflow as shown in Figure 2[4][5]. Cumulative flow curve is a graph obtained by the cumulative value of the inflow and outflow of goods. Vertical interval of the cumulative line becomes the inventory volume and horizontal line becomes the lead time[6].
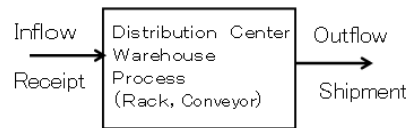
Fig. 1 : Relation between inflow and outflow in distribution center

Figure 2 shows a state in which store them in stock products in distribution centers there. Figure 2 shows cumulative flow curve by orders from customers, and are shipping the goods from distribution centers. Figure 2 also shows that the inventory quantity Qa is increasingly July and August. And, inventory quantity Qb has become less in October. Figure 3 shows the inventory quantity calculated from the inflow and outflow of the cumulative flow curve. Inventory levels in Figure 3 are changed to ship the order from the customer on a monthly. In the distribution center, processing time of machine transport number of forklift, man-hours of loading and unloading work, such as conveyor come determined by the amount of stock[7].

Fig. 2 : Cumulative flow curve at distribution center
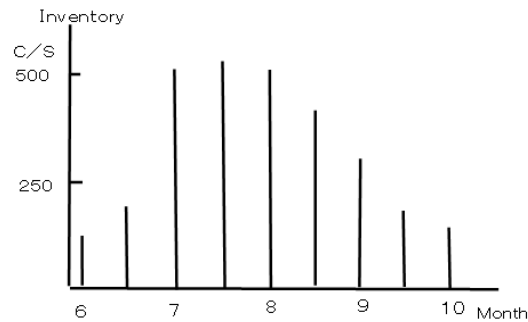
Fig. 3 : Amount of inventory to be changed every month

III. Characteristic of Shipment Data

The amount and the time of the products shipped from the distribution center to the supermarket, the large-scale retail stores, and the wholesale make a big change. The reason for change is because the direct product to ship is intended for consumer food, confectionery, dairy products, cosmetics, and pharmaceuticals. In the distribution center, product management, inventory management, shipment planning, delivery vehicle planning, labor management is difficult as compared to the production plant for the change of the product sales of shipping to large. Production planning and inventory control in the production plant can easily control for planning and management since the fluctuation is little[3]. There are various patterns in shipping time by customer. In one pattern, the time of shipments is concentrated at the beginning of month, whereas shipment time focuses at the end of a month in another pattern. In still another type of patterns, shipments are made almost every day. The shipment amount patterns also vary in a similar way to the shipping time patterns: large volume may be concentrated at the beginning of a month or at the end of month, or they can be almost same every day or differ every day. The shipping pattern can be classified as follows.

1) There are shipments every day, shipments to the normal distribution.
2) Shipment shall be concentrated at the beginning of a month.
3) There is a ship at the end of the month.
4) Those to be shipped to day irregular.
5) There is a shipping amount on the day of at the beginning of a month, shipment shall disappear from the end of the month.
6) There are shipments amount at the end of the month, that there is no ship of a beginning month.
7) The various combinations of shipping these patterns exist. Inventory management of goods with shipping such properties is difficult and is not available, such as reorder point method in the past. Therefore, the method for inventory control, shipment management, storage management using the cumulative flow curves in the distribution center is proposed.

IV. Relationship of Cumulative Inflow and Cumulative Outflow

Cumulative flow curve is made from the cumulative outflow and cumulative inflow as shown in Figure 4. In Figure 4, the top line of the graph represents the cumulative inflow, the lower line indicates the cumulative outflow. The vertical axis in figure 4 shows the amount of stock. The horizontal axis shows the date of arrival of goods. R1, R2, and R3 are the volume of inventories.

3. Li J., Kitaoka M., and Suzuki S, 2004, *Times series Analysis of Shipments and receipts for Distribution Center using GREY Theory and EIQ Table ICLS,246-252.*

Q1, Q2, and Q3 are the amounts of arrival of goods that the distribution center ordered the supplier.

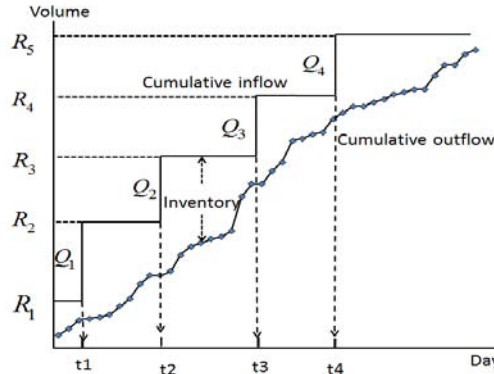The t1 of the horizontal axis represents the day of order quantity Q1 is in-stock.

Fig. 4 : The cumulative inflow and outflow curve and the inventory

The following relations are approved between volume of inventories R and amount Q of the order.

$$R_2 = R_1 + Q_1 \; ; \; R_3 = R_2 + Q_2$$
$$R_4 = R_3 + Q_3 \; ; \; R_5 = R_4 + Q_4 \tag{1}$$

The difference between the two graphs of the upper cumulative inflow and lower cumulative outflow is to the volume of inventories. The inventory control in the distribution center becomes a problem of deciding amount Q of the order.

V. Cumulative flow Curve of Shipping Characteristics

a) Cumulative shipments characteristics shipment characteristics

The data must be cumulative in order to draw the cumulative flow curves of the product for the irregular shipment characteristics. Cumulative flow curve can be controlled by the amount of quantity and timing of arrival[8]. However, it is not possible to control the shipment quantity and shipment time. Because this is an order from the customer, it is not possible to control freely. It is necessary to examine the pattern at the shipment amount and the shipment time according to the product. Three shipments of the kind of product and patterns at the shipment time are shown here as a typical example.
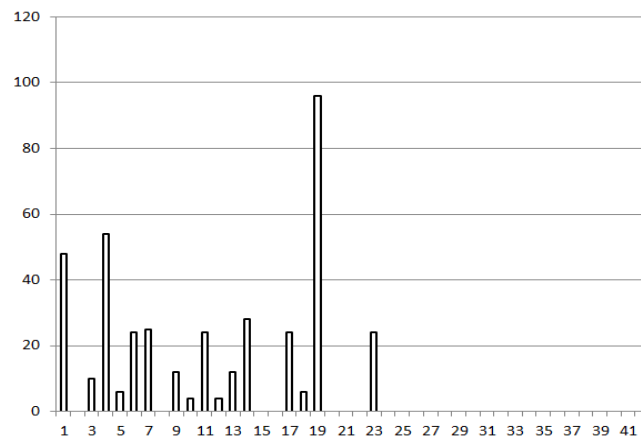

Fig. 5 : Shipping is concentrated in the beginning of the month (Item 1)

Ref

8. Abraham B. and Ledolter J, 2005, *Statistical Methods for Forecasting* (Wiley Inter-Science).

1) Figure 5 is a product it ships at the beginning of the month, and without the shipment until the end of the month. The shipment of the cumulative flow curve is shown in figure 6[8][9][10].
2) Figure 7 is a product it ships at the end of the month, and without the shipment until the end of the month. The shipment of the cumulative flow curve is shown in figure 8.
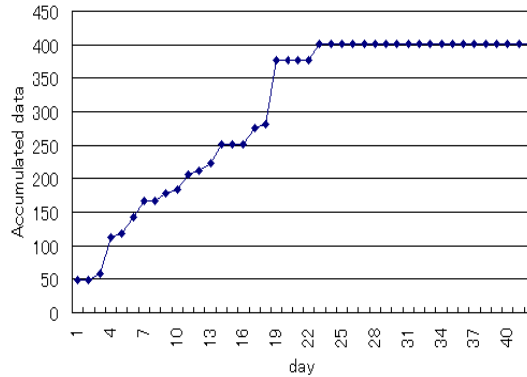3) Figure 9 is a product regularly shipped. The shipment of the cumulative flow curve is shown in figure 10.
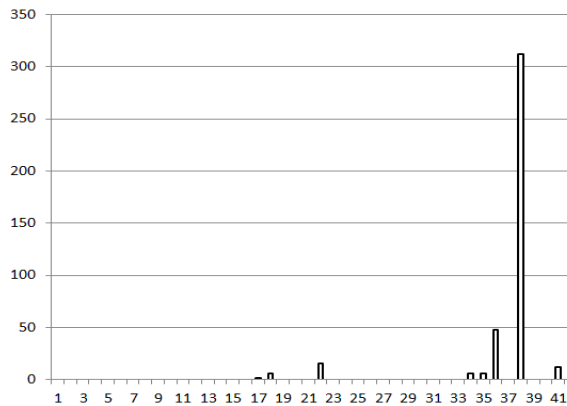

Fig. 6 : Cumulative flow curve for figure 3

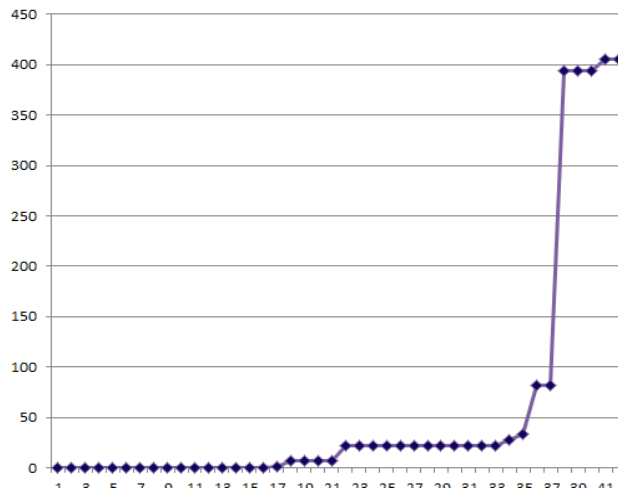*Fig. 7 :* Shipping is concentrated in the end of the month (Item 2)

Fig. 8 : Cumulative flow curve for figure 5

Ref

10. Donald W., 2003, Inventory Control Management (John Wiley&Sons).
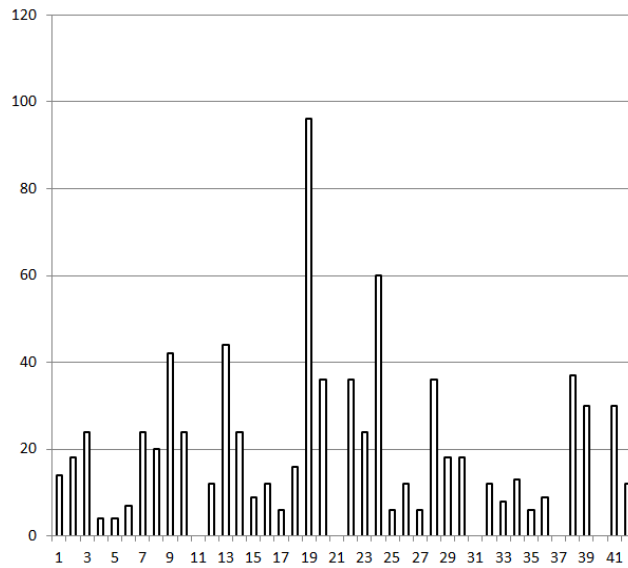

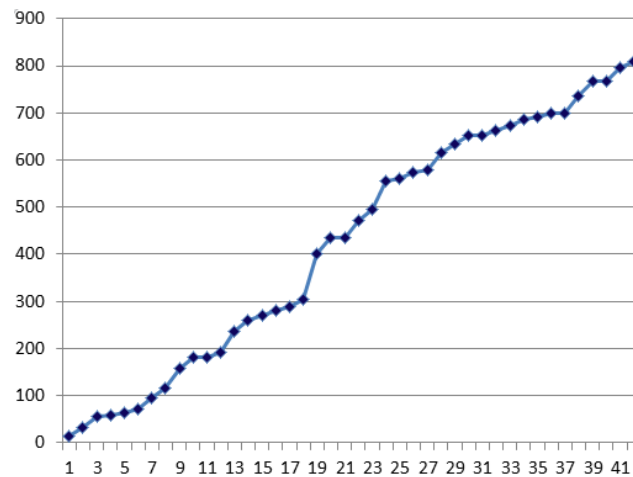*Fig. 9 :* The product is evenly shipped (Item 3)

Fig. 10 : Cumulative flow curve for fig 7

b) *Inventory control that uses cumulative flow curve in distribution center*

The current state of the inventory control that uses cumulative flow curve at the distribution center is examined here. Figure 11 is cumulative flow curve of item I4. The volume of inventories at this time is shown in figure 12, and the total of the volume of inventories becomes 12549. Cumulative flow curve of item 5 is similarly shown to figure 13. The volume of inventories is shown in figure 14. The total of the volume of inventories becomes 16507. The judgment whether this volume of inventories is a lot or is little cannot be judged because there is no technique of a scientific inventory management. However, because the shipment time and the shipment are irregular. It becomes possible to stock a lot of inventory in the distribution center[8][9][10].
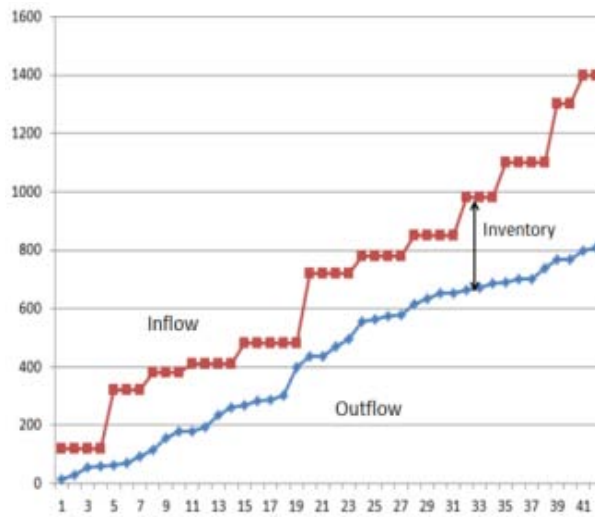
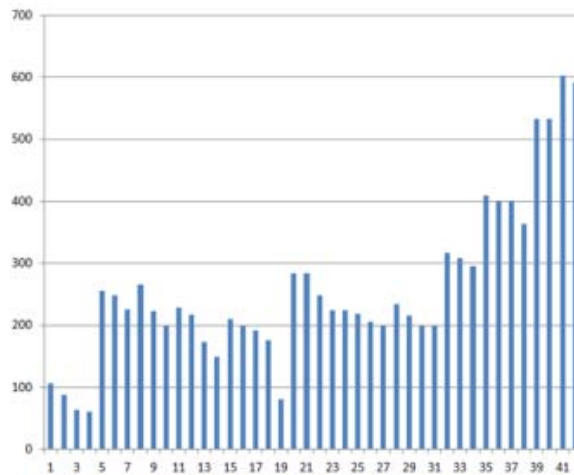*Fig. 11 :* Cumulative flow curve of Item I4
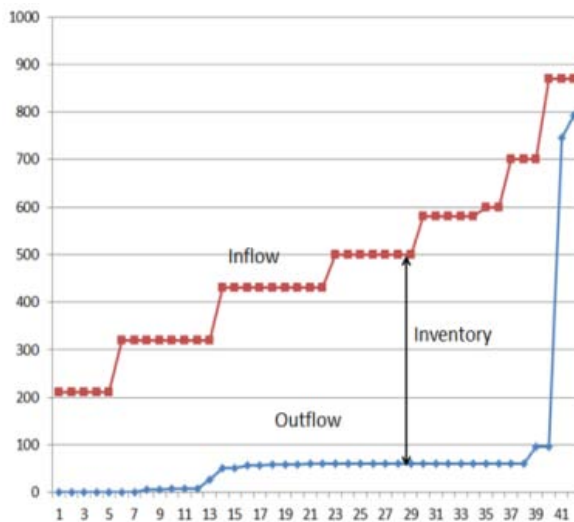
Fig. 12 : Volume of inventories of Item I4

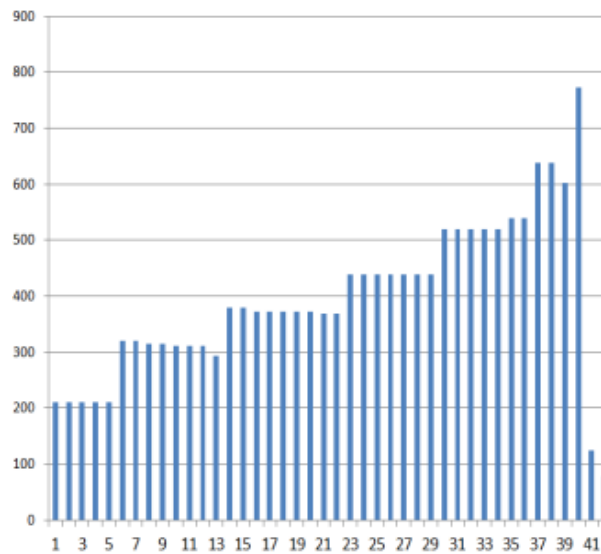*Fig. 13 :* Cumulative flow curve of Item I5

Notes

Fig. 14 : Inventory volume of Item I5

c) Inventory control for irregular demand

The formula of Economic Order Quantity is used for the inventory control. The EOQ calculation is the most important analysis of inventory control. We start with a basic model that makes a number of assumptions.

1) The quantity demanded is known exactly and continuous and is constant over time;
2) All costs are already known exactly and do not vary;
3) No shortage is allowed, and lead time is zero.

However, the formula of the EOQ cannot be applied to irregular shipment time and the shipment. The EOQ formula becomes the assumption that the amount of the demand is constant succession. However, the amount of the order and the order time in distribution center are irregular. For this reason, the EOQ equation prerequisites are greatly different. Therefore the formula of the EOQ cannot be applied. The inventory control of such irregular demand is generated in the inventory control of the spare parts of the mechanical equipment. The failure of the mechanical equipment occurs only unusually. It becomes so-called intermittent demand. The order quantity is calculated by using the shortage probability also for such inventory control on the assumption of normal distribution. However the distribution center shipping time is irregular, and shipment volume is also irregular. Moreover, the order for a lot of amounts is irregularly generated in the distribution center. For this reason it cannot be solved by conventional inventory control techniques. Here it is necessary to the new inventory control techniques.

VI. Cumulative Inflow Curve and Volume of Inventories

a) Decision of cumulative inflow curve

The inventory control is carried at the distribution center is a method by a past experience and intuition. In Figure 11 is the cumulative flow curve for item I4 and the Figure 12 is the volume of inventories. Figure 13 is the cumulative flow curve for item I5 and the Figure 14 is the volume of inventories. It is necessary to ship the amount (Outflow) of cumulative outflow by the order from the customer. Then, we can control at the distribution center is only an amount of the cumulative inflow from the vendor. The cumulative inflow (Inflow) Q shown in the upper row of figure 4 shows the amount of received of goods from the vendor. The problem is the method of deciding amount

(Inflow) of the cumulative inflow curve in figure 4. It is necessary to decide the method how the time of received of goods and the amount of cumulative inflow. The volume of inventories can be reduced by efficiently doing the amount of received of goods and time of received of goods. The relation of the cumulative inflow amount ¿ amount of the cumulative outflow is approved from figure 4. The volume of inventories becomes the difference between the amount of cumulative inflow and the amount of the cumulative outflow. It proposes a new method of controlling the amount of the cumulative inflow to reduce the volume of inventories. When the difference is reduced, the volume of inventories is minimized. To reduce the volume of inventories, it proposes a new method here about time and inlet flow Q of the order to the amount of the accumulation inflow, that is, the vendor. When this difference is reduced, the volume of inventories is minimized. To reduce the volume of inventories, it proposes a new method here about time and inlet flow Q of the order to the amount of the accumulation inflow, that is, the vendor[11].

b) Inventory control by cumulative flow graph

Cumulative flow graph puts out the order with t01 as shown in Figure 15. The commodity arrives to tR1. The lead time at this time becomes tR1-t01. However, the commodity handled here is a general consumption material. Therefore, it will be delivered the next day when ordering. Therefore, it is thought that there is no lead time. Amount Q of the order is assumed to take the periodic reordering method. The reorder cycle is assumed to be TC. Amount Q of the order will be decided with forecasting of the actual data. The forecast period becomes TC. The forecasting value is calculated for actual data of Figure 15. At this time, the safety stock SS is put in the forecasting value or the safety stock is separately installed.
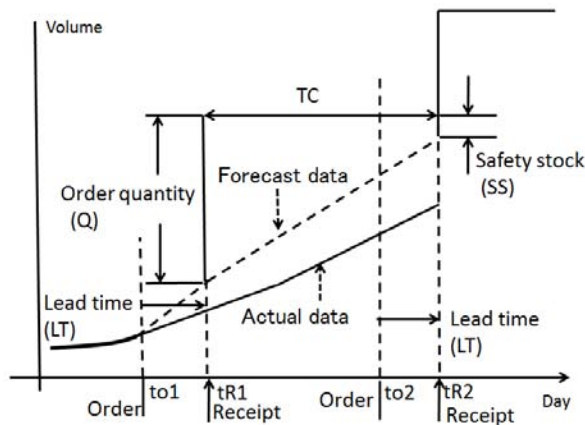

Fig. 15 : Order quantity of accumulative

In this research paper, the method of demand forecasting to validate the two methods according to the Holts exponential smoothing method and power approximation, polynomial approximation[11].

c) Order quantity of cumulative inflow by power and polynomial method

The forecast period is assumed to be TC. The forecast shows period p cycle TC by n. The predictive value becomes amount Q of the order. Amount Q of the order uses the forecast value by the exponential approximation and the polynomial approximation. The forecast time is assumed to be x. Stock shortage is caused when the forecast value is small. Therefore, the safety value $P\sigma$ of the upper bound is given to the forecast value. The expression of the forecast is calculated by using the past data. It forecasts p

period ahead by the expression of the forecast of the past data of n period. As a result, the forecast by the power and the polynomial forecast becomes the next expression[8][9][10].

$$\hat{x}\,(t+p) = A(t+p)^B + p\sigma$$

$$\hat{x}\,(t+p) = A_1 + A_2(t+p) + A_3(t+p)x^2 + p\sigma \qquad (2)$$
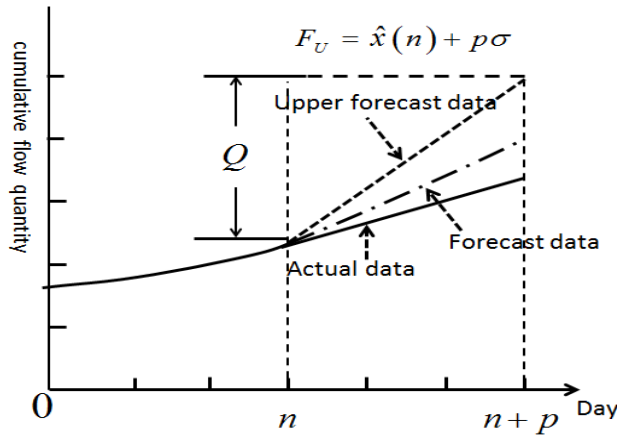

Fig. 16 : Forecast for order quantity

It applies to the commodity of Item3 shown in figure 9 to verify the proposed forecast method. The cumulative curve of Item3 becomes figure 10.

[Numerical Example 1]

(1) Power forecast method

It forecasts to the shipment data of eight days in the past by the Power method. The expression of the forecast becomes as follows.

$$\hat{x}\,(t) = 15.843 \cdot t^{0.9282} + p\sigma \qquad (3)$$

Order quantity adds and calculates safety stock Pσ in the expression of the forecast. As a result, order quantity became 82. Next, the prediction error occurs between a predictive value and actual value as shown in figure 17. Table 1 has shown the volume of inventories. The total of the volume of inventories becomes 158.

Table 1 : Inventory and order quantity with power method

week	8	9	10
Inventory	82	40	16
week	11	12	Total
Inventory	16	4	158

8. Abraham B. and Ledolter J, 2005, *Statistical Methods for Forecasting* (Wiley Inter-Science).
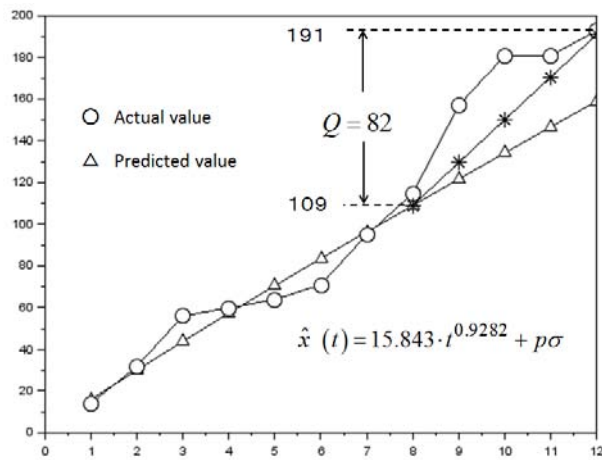
Fig. 17 : Power forecast of demand and order quantity

(2) Polynomial forecast method

In the same way as the power method to calculate it forecasts by polynomial to the shipment data of the past eight days. The expression of the forecast becomes as follows.

$$\hat{x}\ (t) = 8.5893 + 11.196 \cdot t + 0.1726 \cdot t^2 + p\sigma \tag{4}$$

Order quantity is calculated by adding the safety stock Pσ in the equation of prediction. As a result, order quantity became 108. Figure 17 has shown an expression of the forecast and actual data. Figure 17 has shown the relation between the safety stock and the volume of inventories when Order quantity is 100. Table 4 has shown the volume of inventories. The total volume of inventories becomes 218.

Table. 2 : Inventory and order quantity with polynomial method

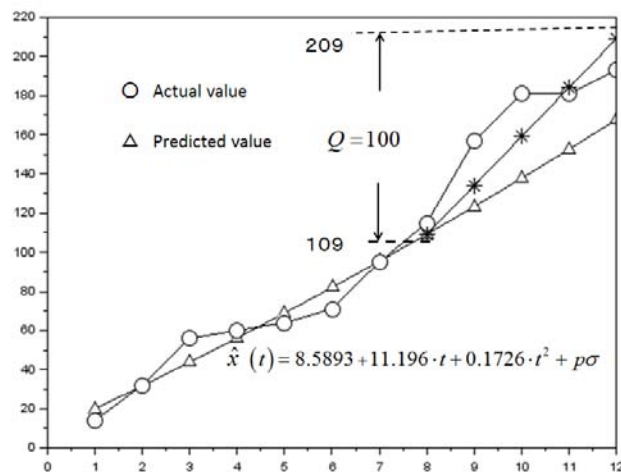| week	8	9	10
Inventory	94	52	28
week	11	12	Total
Inventory	28	16	218

Fig. 18 : Polynomial forecast of demand and order quantity

d) Order quantity of cumulative inflow by Improved Holt's linear method

Linear exponential smoothing is found using two constants, α and β, and three equations. The equation is given as follow[8][9][10].

$$
\begin{aligned}
L_t &= \alpha \cdot Y_t + (1-\alpha)(L_{t-1} + b_{t-1}) \\
b_t &= \beta(L_t - L_{t-1}) + (1-\beta)b_{t-1} \\
Q_{t+k} &= L_t + b_t k + Z_t k
\end{aligned}
\tag{5}
$$

L_t denotes an estimate of the level and b_t denotes an estimate of slope of the time series at time t.

L_t adjusts for the trend of previous period. b_{t-1} by adding it to the last smoothed value, L_{t-1}. Equation b_t the updates the trend, which is expressed as the difference between the last two smoothed values.

The trend is modified by smoothing with β the trend in the last period $(L_t - L_{t-1})$, and adding that to the previous estimate of the trend multiplied by $(1-\beta)$. Finally Q_{t+k} is used to forecast ahead. This equation is different for Holt's linear method. The trend b_t is multiplied by the number of periods ahead to forecast k, and added to the base value of L_t [11].

[Numerical Example 2]

The predictor equation of Holt was calculated by using data here for eight weeks. Figure 19 shows the procedure for requesting the amount of the accumulation inflow from the forecast type of Holt of Item I1. The forecast value of t=8 and k=4 is calculated as α=0.8 and β=0.08. The forecast value of the seventh week becomes Q=67. In graph, triangle indicates the predicted value round is in the actual value. Table 7 shows the volume of inventories at this time.

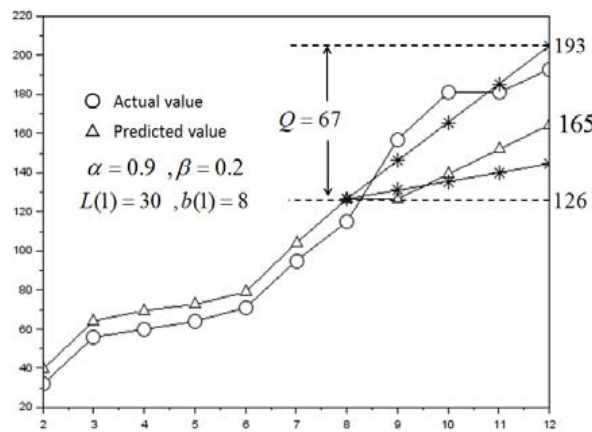
Fig. 19 : Forecast of demand and order quantity

Table. 3 : Inventory and order quantity with improved Holt's method

week	8	9	10
Inventory	78	36	12
week	11	12	Total
Inventory	12	0	138

V. Comparison between Current method and Improvement Method

The volume of inventories of three proposed methods and current methods are compared. Table 4 is a method by the experience of the current method. The volume of inventories is examined for five week. The volume of inventories in the stock control managed in the distribution center experiencing becomes 1180. Compared to other methods of Table 5, the current management methods is clear that the amount of inventory is large. The improved Holt's method[7][8] is the most excellent clearly from Table 5. Because other forecasting methods are used power and straight line, the demand that fluctuates not adapted. For this, the prediction error grows. Power method is more excellent than the polynomial method because there are a lot of quantity safety stocks. The volume of inventories changes by setting the safety stock. Therefore, it is difficult to judge which of these two methods is excellent.

Table. 4 : Inventory quantity for current method

week	8	9	10
Inventory	275	233	209
week	11	12	Total
Inventory	239	227	1183

Table. 5 : Comparison between current method and proposed method

	Inventory quantity
Current method	1183
Power method	158
Polynomial method	218
Improved Holt's method	138

VI. Conclusion

Up to now, the method of theoretically computing the order quantity in the cumulative flow curve has not been proposed. This paper proposed the method of deciding the order quantity of the inventory control by the cumulative flow curve. Three proposed methods are shown in the calculation of the order quantity. The time and volumes of the shipments from the distribution center to the customers are irregular. With the cumulative flow curve, it is possible to inventory control of products that the irregular shipping. To provide useful forecasts of such irregular shipping times and volumes, a method utilizing the power, polynomial method and improved Holt's method are presented. The volume of inventories of three proposed methods and current methods are compared. By applying the cumulative flow curves, it is clarified that the inventory control is possible for irregular shipment products.

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Notes