

Evolution of Automatic Ordering System in Retail Market : Analyzing Inventory Data

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Abstract

The purpose of this paper is to reveal two problems in the existing inventory systems in retail market, and to suggest a Two-Bin System under Automatic Ordering System considering only base-stock.

Large retailers already have a sophisticated inventory system based on an automatic ordering principle. However, why does the out-of-stock (OOS) happen in large discount stores in spite of having a good inventory system? This paper suggests two systems after finding the root causes concerning the previous question. For evaluating the performance of each system, the random 200 data set in each sample group was generated from MINITAB 16 and obeyed the Poisson distribution.

The existing inventory system in retail market cannot help generating OOS due to indwelling contradiction in itself. The reasons are the ordering deadline and the relationship between ordering quantity and base stock. This paper also demonstrates that these previous studies on inventory fall into the closed loop. Also the paper shows that the performance of the replenishment policy was better than traditional methods dealing with ordering quantity and base stock.

Keywords: *Inventory management, Supply chain management, Retail, Automatic ordering system*

1. INTRODUCTION

Recently, there have been drastic changes in the retail market. For examples, many leading retail companies have researched new business format such as SSM (super supermarket) and SVS (smart virtual store), and have extended their market through M&A (merge & acquisition). Not only they accomplished their external development, they have made strong efforts to develop their own technologies which are FRID (frequency identification), CPFR (collaborative planning/ forecasting/ replenishment), CTP (capable-to-promise), ASN (advanced shipping notice), DBR (drum-buffer-rope) and so forth. So the retail supply chain is getting slimmer and has an efficient distribution structure. Specially, large retailers like Wal-Mart and Carrefour have a sophisticated inventory system based on an automatic ordering principle. In this paper, the inventory system is called 'automatic ordering system (AOS)'. Large retailers deal with hundreds of thousands of items and have tens to thousands of stores. So it is important for them to manage many

inventories efficiently and to have an efficient inventory system.

AOS has been considered as a suitable and excellent inventory ordering method for large retailers. AOS commonly places an order automatically when the residual stocks reach a specific level of safe stock, and then the quantities of each order are replenished in each store on a fixed cycle. So the reorder point (r) and the order quantity (Q) / the replenished level (S) are very important parameters on AOS. However, why out-of-stock(OOS) happens in large discount stores in spite of having a good inventory system as AOS and an efficient distribution structure with 'high frequency-small volume'? How is the performance of AOS improved for preventing OOS? In other words, in spite of having the effective inventory system in efficient retail supply chain, why do large retailers have some problems with OOS and excessive stock? Ultimately, we can have a question of whether large retailers have built the advanced inventory management system.

Many researchers take it for granted that AOS is an efficient ordering method. However, the existing AOS has no choice but to generate the OOS due to indwelling contradiction in itself, even though AOS may be done.

The purpose of this research is to show two major problems on the existing AOS in retail market and to suggest an alternative for managing inventory which is 'Two-Bin system under AOS (2BinAOS)'. That is not to manage inventory but sales. This paper shows that OOS will happen inevitably on the existing AOS as long as the ordering deadline exists.

This paper is organized into several sections. The major principles of inventory and the related works are introduced in section two. Section three introduces some problems resulting from the ordering deadline, and the relation between variables (r and Q). In section four, two advanced AOS methods which will be able to be researched for solving the finding problems are suggested. Although the performances of these proposed methods are better than the existing AOS, this paper would like to attach the 'Pseudo-' into these methods since these suggested methods are not the final goal of this research. The suggested methods are simulated and evaluated with much data in section five. Section six demonstrates that the present approaches dealing with order quantity and safety stock have limitation and are the closed-loop of inventory methods, and suggests the implication of 2BinAOS which is another approach dealing with no controlling stocks but managing sales. Finally, the various results of empirical analysis on these systems and conclusions are summarized in section six and seven.

2. RELATED RESEARCH

Although all members in a supply chain are putting so much effort to reduce inventory, they need to hold these inventories in order to prohibit OOS and unexpected problems. So many researchers have published frequently on their research findings about inventory management. Williams and Tokar (2008) examined related papers published in the last 30 years from four famous journals. From their results, 56 percent belong to the inventory models (traditional inventory management as Q-system and P-system), the others focused on examining inventory management through collaborative models. Also, Gupta *et al.* (2012) summarized related papers in chronological ascending order and proposed the framework of selection of suitable inventory policy/model, but they did not verify the validity of the inventory models and just summarized the previous related studies. Surprisingly, the main principles of inventory management from many complicated articles can be classified into two basic models. The models are the (Q, r) inventory control model introduced by Harris (1913) and the (S, T) model described by Hadley and Whitin (1963). Most of hybrid models are derived from two models. The (Q, r) model (or Q-system) places an order of the calculated quantity (Q) whenever the residual stock drops down to a designed reorder point (r) and entails

continuous stock review annoyingly. The (S, T) model (or P-system) replenishes a preset point (S) at regular intervals (T) and must set a buffer (or safety) for reserving reasonable quantity greater than average usage rate during a lead time. Buxey (2006) expressed the pros and cons of two models in detail. Gupta *et al.* (2012) addressed most of the hybrid models are based on two models according to eight inventory parameters: ordering/ procurement/ replenishment cost, holding/ carrying cost, review period, reorder point, demand, shortage cost, lead time and unit price/ item cost. One of these hybrid models is a hybrid 'minimax' model or AOS which utilizes periodic review in tandem with a preset reorder point (Williams and Tokar, 2008).

Generally, the inventory management problem deals with the determining two parts; order quantity and reorder point (Verma, 2006). Finally, most of studies are combination of two models and assumptions on eight inventory parameters what Gupta *et al.* (2012) said. However, due to these assumptions, it is a serious gap between theory and practice. Although many papers have existed, by and large the role of technologies in these papers has been ignored in many companies (Williams and Tokar, 2008). It may be so, recent research on inventory has more focused on examining inventory management through collaborative models in a supply chain. Seeing an inventory management problem in view with supply chain management (SCM), it is natural to have the extension of collaboration among members in a supply chain. In order to improve the collaboration, much information through VMI (vendor managed inventory) should be shared by partners in supply chains. Sahin and Robinson (2005) addressed that information sharing and coordination can reduce these related inventory costs and the experimental results from 2.33% to 47.58%.

In retail market, OOS is an important factor since OOS ends up reducing sales and degrading the performance of inventory system. OOS results from loss, the gap between real stock and electronic stock data, poor management and so forth. Retailer's goal would reduce OOS to zero and set an inventory process where inventory is replenished daily as it sells (Ayad, 2008). The European grocery industry also considers OOS as the third most important issue after shorter queues and more promotions (ECR Europe 2003). It is not easy to measure the amount of OOS because of enormous types of items and unknown demand for the future. Ayad (2008) addressed that worldwide OOS levels were at an average 8 percent and OOS of promoted items hover at 16 percent. Corsten *et al.* (2003) showed that major causes of OOS are the failure to place order (33%), the failure to replenish (22%), and to correctly forecast demand (18%). Also Hardgrave, *et al.* (2008) revealed that the loss due to the OOS problem is about 3.4% of revenue of sellers and 2.6% of revenues of suppliers. Clearly, there are OOS frequently in a store, and we must avoid them.

AOS utilizing VMI has been developed to generate an exact ordering data while simultaneously rationalizing inventories and reducing waste. Most of studies on AOS did not focus on the principle of inventory but the collaboration and the integration of various functions. As for previous studies, researchers had two terms confused with 'automatic replenishment system (ARS)' (Stank *et al.* 1999; Daugherty and Myers, 1999; Sabath *et al.*, 2001; Ayad, 2008) and 'automatic ordering system (Kiesmüller and Broekmeulen, 2010; Paik and Park, 2010)'. From the terminology of AOS and ARS, goods are not replenished automatically in the real market. Even if an order is placed, goods are not able to be replenished due to inadequate delivery or supplier's situation. However an order must be placed automatically whenever stock levels drop down at a specific level. Paik and Park(2010) pointed out the difference between 'replenishment' and 'supply', and suggested that 'supply' is more the expression than 'replenishment' for describing the existing retail environment. This paper studies AOS for preventing OOS in detail and proposes the advanced AOS adapted to real retail market.

3. AOS FEATURES

A large discount store deals with more than tens of thousands of items and these are coming from more than hundreds of stores in large retail company. From the website of Wal-Mart, there are about 120,000 items in a discount store and 11,000 stores in 27 countries in the first of 2014 year. As a result, they have no choice but to employ AOS in their stores. However, the life of many items grows shorter, the customers' needs are changeable easily, and it is hard to forecast the demand of items because of frequent promotions as well as uncertain future. In this environment, exact 'Q' and 's' in the (Q, s) model are impossible to be solved in any systems. As previously stated, the inventory management problem deals with order quantity and reorder point (Verma, 2006). Even though we cannot obtain the exact solutions on real time, we need to have these reasonable solutions. When you use inadequate 'Q' and 's', the performance of the inventory system will be not good. Generally, Safety stock is a level of extra stock that is maintained to mitigate risk of OOS, and reorder point(r) is the level of stock which triggers an action to replenish. Also reorder point should reflect safety stock. However, in discount stores (or AOS), the reorder point has a slightly different meaning. Reorder point in a discount store should contain not only demand within lead time but also goods on display. In the meaning of this paper, let this paper call 'reorder point' on AOS 'base stock'. It is explained below how important 'Q' and 's' are on AOS.

Table 1. The relation between Q and s

Reorder point	Order Quantity	Results
's' is big	Q is small	OOS happens periodically
	Q is big	Long the interval between reorder points. Excess inventory.
's' is small	Q is small	OOS happens frequently
	Q is big	OOS happens periodically
's' is suitable	Q is small	OOS happens periodically
	Q is big	Long the interval between reorder points. Excess inventory.

A. Excessive stock and OOS happen due to unreasonable Q and s.

Unreasonable order quantity (Q) and base stock (s) brings stock level to be excessive stock or OOS. Namely, OOS may happen in a store, albeit holding enough large 'Q' or 's'. From table 1, order quantity or base stock from the inventory system would make a skimpy residual stock into OOS in a store. Although big or reasonable 's' is set, small 'Q' gives rise to OOS periodically whereas big 'Q' leads to long interval time. Contrary to that, when big or reasonable 'Q' is fixed, inventory level could lead to OOS or excess stocks according to 's' value. The relation between 'Q' and 's' is summarized in figure 1 and table 1. Figure 1 is simulated with random demand data for 100 showing the relationship for each of 'Q' and 's'. Therefore it is very important to determine reasonable 'Q' and 's' at the same time. If retailers used the existing AOS without reasonable 'Q' and 's', they would give rise to more stock than needs for preventing OOS, and OOS will happened well. Actually, most retailers used to decide 'Q' and 's' randomly because of having hundreds of thousands of items and not knowing the demand of each item.

B. Excessive stock and OOS happen due to ordering deadline

Most people misunderstand that large discount stores have small quantities of base stock as figure 2(a), and the saw-toothed in figure 2(a) is a typical AOS model which looks like (Q,r) model. However this paper finds that AOS has a structural problem such as OOS and overstock, and that the major reason for the

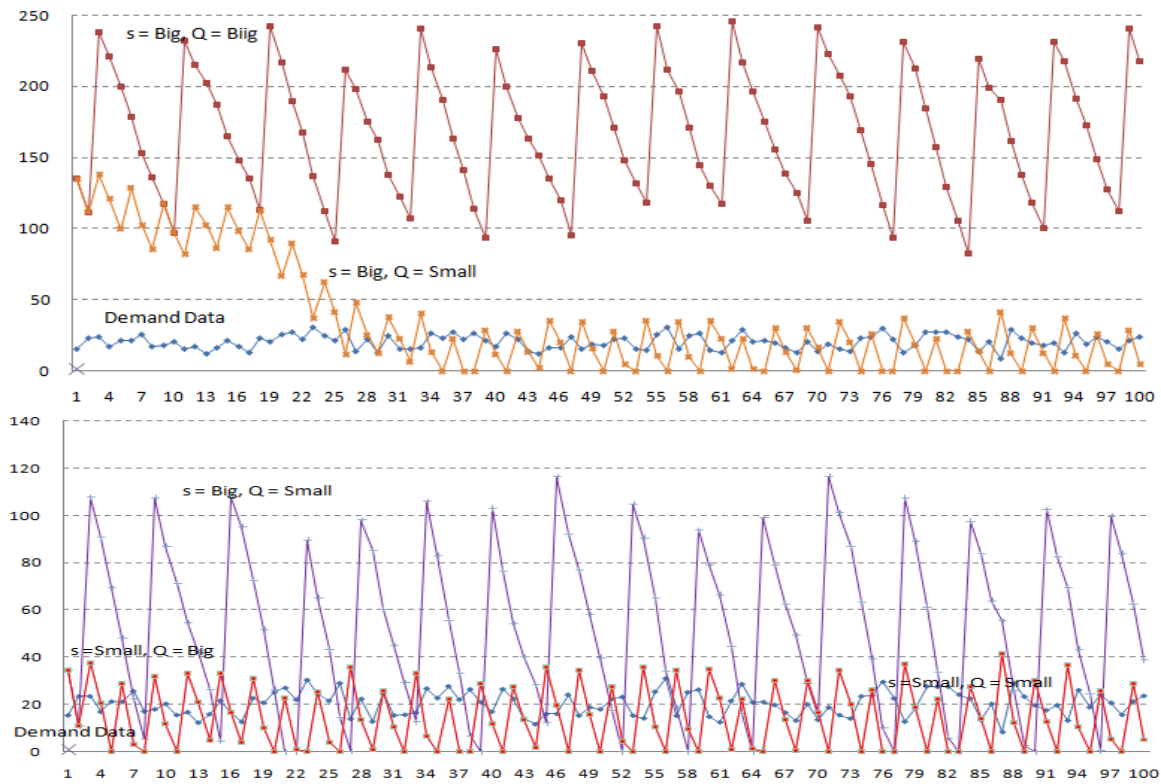


Figure 1. The relational chart between ‘s’ and ‘Q’

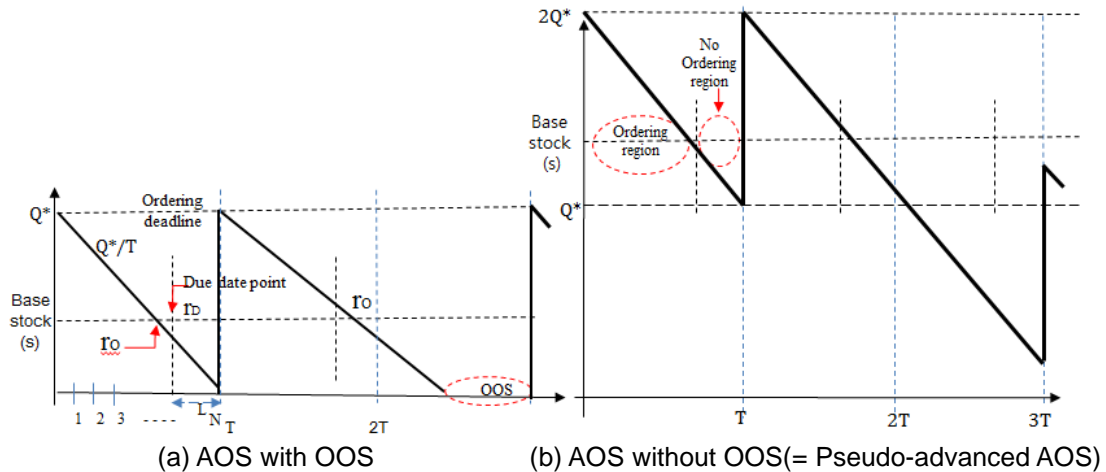


Figure 2. The model of the existing AOS

problem is the ordering deadline. In large discount stores, orders can be placed only when the remaining stock level meets two conditions: a preset base stock and a preset ordering deadline (Fig 2(a)). In figure 2, if an order is placed after the ordering deadline, the order quantity cannot be supplied to a store at this time. Only when an order is placed before the ordering deadline, an order is delivered into a store. Although many stocks are piled up in a store and reasonable ‘Q’ and ‘s’ are calculated, the existing

AOS gives rise to OOS. The bigger problem is to much happen this situation in a store. As I mentioned earlier, large retailers deal with hundreds of thousands of items. Each items has the different demand rate. However, retailers place orders the need items at the same time regardless of demand rate. So base stock in a

store must be prepared not only for the need demand amount during lead time, but also for the need quantity of the next period like figure 2(b). Finally, AOS for avoiding OOS results in excessive stocks due to big 's'.

4. TWO PSEUDO- ADVANCED AOS METHODS

For solving the previous problems concerning OOS and two factors (Q and s), two alternatives which will be able to be researched are designed in this section. Although the advanced AOS methods are better than the present AOS, we attached the 'Pseudo-' into these methods. The reason for designing two advanced methods is to show the closed-loop of previous inventory methods.

1) Pseudo-advanced AOS

OOS has arisen inevitably under the existing AOS with unreasonable 'Q' and 's'. So it is important to decide adequate 'Q' and 's' simultaneously. As previously mentioned, an order will be generated in the first period when stock level drops down before a due date point (r_D) like figure 2. But in the second period, stock level drops down after ' r_D ', and then an order is not placed at that time. Accordingly, the probability to happen OOS gets very high in the next period. Namely, to manage AOS is to solve both the order quantity and the base stock at the same time.

A. Optimal order quantity (Q^*)

In this paper, the assumption of demand obeys the Poisson distribution (Archibald, 2007; Graves, 1996; Verma, 2006). In order to examine the performance of the proposed and the existing systems this paper assumes the demand obeys the Poisson distribution. However the introducing methods are not extremely sensitive about the distribution because of preparing enough stock on the basis of demand rate.

X, D: Random variables

X_i : Demand at time i, $i = 1, 2, \dots$,

$X_i \sim$ independent identically distributed

D_j : Demand of period j,

$D_j = X_1 + X_2 + \dots + X_N$

N: Constant as times in a period.

D_L : Demand for lead time (L).

Q^* : Optimal order quantity

L: lead time from placing an order to supplying items

Q_{LOT} : Actual order quantity considering lot size in a box.

As X is an independent identically distributed variable, the average and variance of D is the below.

$D_j = X_1 + X_2 + \dots + X_N$, $X \sim$ Poisson (μ)

$E(D) = E(X_1 + X_2 + \dots + X_N) = E(X_1) + E(X_2) + \dots + E(X_N) = N\mu$

$Var(D) = Var(X_1 + X_2 + \dots + X_N) = Var(X_1) + Var(X_2) + \dots + Var(X_N) = N\mu$

$Q^* = N\mu + k \sqrt{N\mu}$ (1)

k=2, when significant level is 1.1%

k=3, when significant level is 0.07%

B. Base stock (s)

In case of $r_o < r_D$, an order is placed. On the contrary $r_o > r_D$, it needs to preserve the amount of base stock for preparing the required amounts in the next period.

$$E(s) = E(D) + E(D_L) \leq Q^* + Q^* (L/N) = Q^* \times (1+L/N) \leq (N\mu + k\sqrt{N\mu}) \times (1+L/N) \quad (2)$$

Base stock from function (2) looks like figure 2(b). Namely, ‘Q’ is solved as ‘the amount of demand in next period, and ‘s’ as ‘the required demand during the lead time and the next period in the case of not placing an order’ as figure 2(b) shown. In addition, in case Q^* is not equal to Q_{LOT} , Q_{LOT} cannot help being used instead of Q^* . Although the optimal order quantity (Q^*) can be obtained, the supplier has to send the order quantity by the box (or lot size). For example, if a box contains 10 items in spite that Q^* is 5 items, the supplier has to send 10 items. We should consider the actual order quantity.

- $Q_{LOT} > Q^*$, Supply ‘ Q_{LOT} ’ every $[(Q_{LOT} / Q^*)]$ period (3)

- $Q_{LOT} < Q^*$, Supply ‘ $[(Q^* / Q_{LOT})] \times Q_{LOT}$ ’ every period (4)

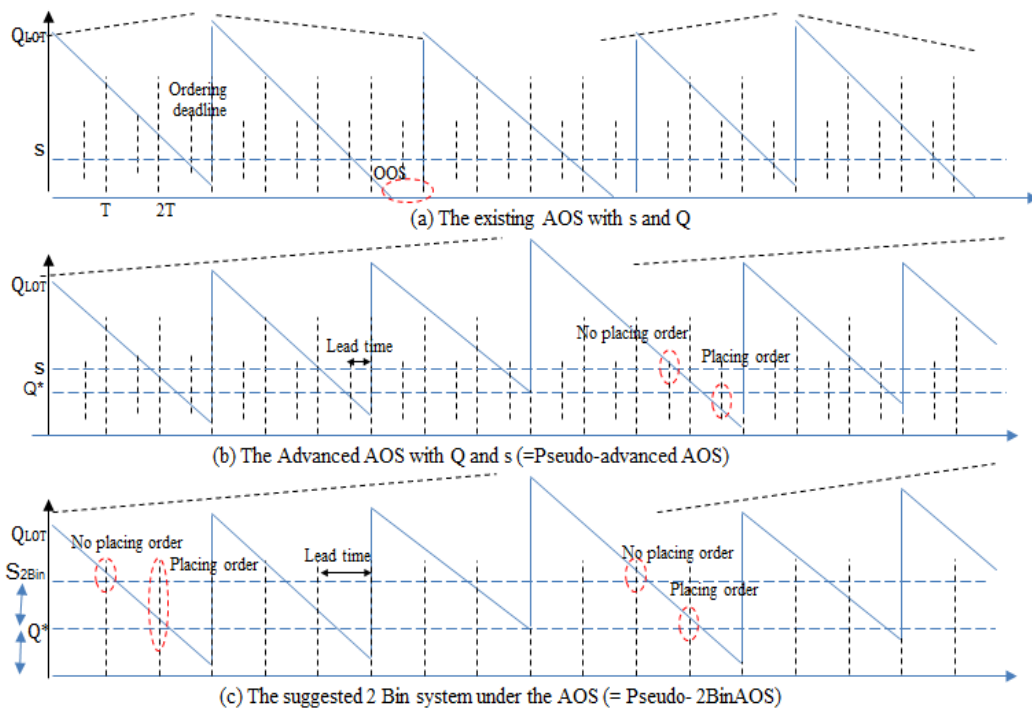


Figure 3. The charts of the AOS, Pseudo-advanced AOS and Pseudo-2BinAOS

When Q_{LOT} is more than Q^* , Q_{LOT} is supplied periodically as equation (3). If the accumulated residual amount gets to be more than Q^* , Q_{LOT} is not sent. On the contrary to that, the several times of Q_{LOT} from equation (4) are sent every period.

2) Pseudo-Two Bin System under the AOS (Pseudo-2BinAOS)

The existing AOS and Pseudo-advanced AOS have to prepare the amount of stock for at least two periods, according to the customer’s demand as in figure 3(a) and 3(b). However, the fixed Q^* is useless in

the real market due to the variable demand and discrepant order size. Being it is hard to obtain Q^* of each item every period, we cannot help dealing with only base stock which is similar to the ‘Two-Bin system’. There are some differences between Pseudo-advanced AOS (or AOS) and Two-Bin system. Two-Bin system is explained below.

- The ordering deadline is unnecessary.
- Two-Bin system does not need to wait until the ordering deadline like AOS. In the Two-Bin system, as soon as a bin of both is empty, an empty bin is made out of replenishment.
 - Lead time after placing an order is longer than Pseudo- advanced AOS.
- Pseudo-advanced AOS must supply Q_{LOT} within the lead time, but Two-Bin system sent Q_{LOT} by the next period like figure 3(b) and figure 3(c). Longer lead time means to have enough time to prepare the received order.
 - Less factors are considered than Pseudo- advanced AOS
- Pseudo-advanced AOS considers both factors (Q and s), but Two-Bin system takes into account only ‘a bin’ and is more simple method. Also Pseudo-advanced AOS needs to consider more time (lead time + Q) for the future than Two-Bin system (only next period). So there are more uncertain factors in the Pseudo-advanced AOS.

In this paper, it suggests another method called as Pseudo-2BinAOS. The suggested Pseudo-2BinAOS is slightly different from the original Two-Bin system. In the original Two-Bin system, items will be replenished regardless of placing orders, whenever a bin of both is empty. But the replenishment can be executed every period in Pseudo-2BinAOS like figure 3(c).

The principle of Pseudo-2BinAOS is to supply the preset quantity when the residual stock goes down to a specific level. It is assumed that a bin is checked at the end of period t and the replenishment is done by the start of period $(t+1)$. In Pseudo-2BinAOS, when two bins are not full of items at the end of period t , the order is placed at the end of period t and the order quantity will be supplied at the first of the period $(t+1)$ as figure 3(c) shows. So the base stock (s_{2Bin}) of Pseudo-2BinAOS needs the amount during $(2N-1)$ times and we must check the residual stock as two bins. The base stock of Pseudo-2BinAOS can be solved as below.

$$\begin{aligned}
 d_j &= X_1 + X_2 + \dots + X_N, \\
 d_{2Bin} &= X_1 + X_2 + \dots + X_N + \dots + X_{2N-1}, \\
 E(D_{2Bin}) &= E(X_1 + X_2 + \dots + X_{2N-1}) \\
 &= E(X_1) + E(X_2) + \dots + E(X_{2N-1}) = (2N-1)\mu \\
 \text{Var}(D_{2Bin}) &= \text{Var}(X_1 + X_2 + \dots + X_{2N-1}) = \text{Var}(X_1) + \text{Var}(X_2) + \dots + \text{Var}(X_{2N-1}) = (2N-1)\mu \\
 s_{2Bin}^* &= (2N - 1)\mu + k\sqrt{(2N - 1)\mu} \tag{5} \\
 k=2, & \text{ when significant level is 1.1\%} \\
 k=3, & \text{ when significant level is 0.07\%}
 \end{aligned}$$

The retailer has only to solve the s_{2Bin} value, and to check it every period. After the base stock for two periods (s_{2Bin}^*) is examined at the end of the period (t) , suppliers only need to supply Q^* or Q_{LOT} at the first of the next period $(t+1)$ whenever residual stock is less than s_{2Bin}^* . At this moment, suppliers need not wait for orders from retailer.

5. SIMULATION

The random 200 data set in each sample group obeys the Poisson distribution and are generated by

MINITAB 16. The average of each data group is 2, 4, 5, 6, 8, and 10. Some researchers revealed that consumers’ demand was not unstable unless promotion was done (Disney and Towill, 2006; Taylor and Fearnle, 2009; Paik and Park, 2010) and showed that the pattern of customers’ demand in sausages and cheese was comparatively stable based on a year of real data(Taylor and Fearnle, 2009). Their paper showed that the end consumer demand was the least variable feature (± 11 percent). Eroglu *et al.* (2011) researched their work with the demand rate of 0.71 ~ 1.71(units/day), and the dealt with data in Paik and Park (2010) was less than 10 units in a period. So this paper generated these data whose averages are less than 10 units in a day. The lead time was set at two days and the interval of period at four days. In general, U.S. companies supplying goods to Wal-Mart distribution center must deliver within a four-day window. The simulation of Pseudo-advanced AOS and Pseudo-2BinAOS can be easily programmed by Excel.

Table 2. Values of parameters in Simulation

Factors		POISSON(2)	POISSON(5)	POISSON(10)
Q	by Equation (1)	14	29	53
s1	L=1, by Equation (2)	18	37	66
s2	L=2, by Equation (2)	21	44	79
s2Bin	by Equation (5)	22	47	87
let, k=2, N=4				

Table 3. Results of these methods

		AOS						Pseudo-advanced AOS (L=1)		Pseudo-advanced AOS (L=2)		Pseudo-2BinAOS					
		Small (1/2) S		S		Big 2S		Avg Stock	OOS rate	Avg Stock	OOS rate	Avg Stock	OOS rate	Avg Stock	OOS rate	Imprv_rate1	Imprv_rate2
		Avg Stock	OOS rate	Avg Stock	OOS rate	Avg Stock	OOS rate										
POISSON (2)	Resonable Q	9	11.5%	18	0.0%	27	0.0%	19	0.0%	19	0.0%	19	0.0%	0%	0%		
	Big 2Q	15	7.5%	34	0.0%	45	0.0%	25	0.0%	24	0.0%	26	0.0%	-4%	-8%		
	more Big 4Q	29	1.0%	48	0.0%	60	0.0%	39	0.0%	39	0.0%	34	0.0%	13%	13%		
POISSON (5)	Resonable Q	15	13.5%	33	0.0%	52	0.0%	34	0.0%	37	0.0%	30	0.0%	12%	19%		
	Big 2Q	28	3.0%	42	0.0%	60	0.0%	44	0.0%	47	0.0%	42	0.0%	5%	11%		
	more Big 4Q	52	2.0%	67	0.0%	87	0.0%	68	0.0%	71	0.0%	66	0.0%	3%	7%		
POISSON (10)	Resonable Q	24	20.5%	59	0.0%	97	0.0%	56	0.0%	57	0.0%	48	0.0%	14%	16%		
	Big 2Q	48	12.0%	86	0.0%	121	0.0%	83	0.0%	86	0.0%	73	0.0%	12%	15%		
	more Big 4Q	103	4.5%	140	0.0%	174	0.0%	130	0.0%	140	0.0%	121	0.0%	7%	14%		
Avg		35.9		58.6		80.3		55.3		57.8		51.0		7%	10%		

The intent of this simulation is that any one of three systems, which are traditional AOS, Pseudo-advanced AOS with s and Q, and Pseudo-2BinAOS, makes inventory commitment more efficient in a real environment. For this simulation, each parameter is summarized in table 2. The results are as follows.

First, it is shown each of their performances according to ‘Q’ and ‘s’ in the table 3. As it is already known, short lead time (L=1) can lead to be better solution more than if lead time is two. But laborers will get to be busy in case of short lead time. On the right-hand side in the table 3, there is a significant difference between Pseudo-2BinAOS and Pseudo-advanced AOS in terms of average stocks. The average stock of Pseudo-2BinAOS can be reduced about 7~10 percent than Pseudo-advanced AOS. Besides, Pseudo-2BinAOS, considering only one factor (s_{2Bin}), is a more simple and practical method than Pseudo-advanced AOS with L=2 considering two factors (Q and s). That is why the ordering deadline is. Pseudo-2binAOS checks the base stock at the end of period ‘t’ and can afford to prepare orders leisurely owing to delivering items until the next period. On the other hand, Pseudo-advanced AOS checks at ‘t-L’ whether orders are placed or not, and then must supply items within ‘L’ immediately.

Second, it is hard to always adjust ‘Q’ and ‘s’ of all items. So it is usual to fix the factors (Q,s) regardless of demand. Table 4 shows how many stocks are piled up according to various demands under an arbitrarily chosen ‘Q’, ‘s_{2Bin}’, or ‘s’. According to equations (1) to (5), each parameter is set as the optimal solution of Poisson (6): Q=34, s=51, s_{2Bin}=55.

Table 4. The performance of Pseudo-2BinAOS regardless of Q

Fixed Q,s,s _{2Bin}	Poisson (2)		Poisson (4)		Poisson (6)		Poisson (8)		Poisson (10)	
	Avg Stock	OOS rate	Avg Stock	OOS rate	Avg Stock	OOS rate	Avg Stock	OOS rate	Avg Stock	OOS rate
Pseudo-advanced AOS (L=2)	58	0.0%	50	0.0%	44	0.0%	30	3.5%	13	26.5%
Pseudo-2BinAOS	57	0.0%	49	0.0%	41	0.0%	28	3.5%	12	28.0%

On the whole, Pseudo-2BinAOS is more efficient than Pseudo-advanced AOS. However if the demands exceed the limit of both system capacities, the performance of Pseudo-2BinAOS goes down more sharply than Pseudo-advanced AOS. For the good performance of Pseudo-2BinAOS, it needs an effective size of base-stock according to average daily demands (μ) and ordering frequency (N). From equation (6) or (6-1), we can obtain various sizes as indicated below.

$$s_{2Bin}(\text{Base Stock}) = (2N-1) \mu + k\sqrt{(2N-1)\mu} \tag{6}$$

Let, $y = (2N-1) \mu$, $k=2$.

$$s_{2Bin}(\text{Base Stock: B}) = y + 2\sqrt{y} \tag{6-1}$$

$$B^2 - 2By + y^2 = 4y, \quad y^2 - 2By - 4t + B^2 = 0$$

By quadratic discriminate equation,

$$y = (B+2) \pm 2\sqrt{(B+1)} \tag{7}$$

B is not negative

Table 5 is summarized on the basis of function (7). For example, if a supplier delivers items every 10 days, and all average daily demand are less than one unit, you can set the bin-size of items at thirty. Table 5 can be adjusted according to a retailer’s situation and utilized in the decision support system for the inventory level.

Table 5. Bin-size according to average daily demands

S _{2Bin} \ N	every 2 days	every 4 days	every 7 days	every 10 days
10	≤1.79	≤0.76	≤0.41	≤0.28
20	≤4.28	≤1.83	≤0.98	≤0.68
30	≤6.95	≤2.98	≤1.6	≤1.10
40	≤9.73	≤4.17	≤2.25	≤1.54
50	≤12.57	≤5.39	≤2.90	≤1.98
100	≤27.30	≤11.70	≤6.30	≤4.31
150	≤47.47	≤18.20	≤9.80	≤6.71
200	≤57.88	≤24.81	≤13.36	≤9.14

Value is daily demand, lead time = 2 days, k=2

6. IMPLICATION AND CONCLUSION

1) Managerial Implication

Traditionally, inventory management is the activities to maintain the optimal number or amount of each item while minimizing the total cost of inventory. If it is possible, efforts are made so that the inventory level gets to be equal with the customers' demand in order to prohibit the loss of sales. However, most of the solutions on ordering quantity and base stock avail many companies little. Because, it is hard to obtain Q^* of each item every period, and the obtained Q^* is not equal to Q_{LOT} . These problems eventually lead to the dissonant relation with 'Q' and 's', and then the helpfulness solutions make to return to the original problem. Also daily demand in a discount retail store is very small as mentioned early (Eroglue, *et al.*, 2011; Paik, 2008). As the amount in a box (or lot size) are so big in comparison with the economic order quantity, the amount of ordering gets to be unreasonable Q. Finally, the previous approaches with order quantity and base stock have limitations and falls into the closed-loop of inventory methods as in figure 4.

Moreover, the traditional economic order quantity (EOQ) does not fit the retail market. Usually, total inventory cost functions are basically categorized into two areas: ordering cost and holding (carrying) cost like shown in figure 5(a). In terms of ordering cost, the more delivering quantities at one time, the less ordering costs per unit, and the more deliveries, the more the ordering costs. That statement is just academically right. However the environment of the market has changed. In the retail market, delivery vehicles are operating frequently and regularly, and the fee is calculated by boxes of items. Namely, if the total number of boxes is the same, the ordering cost is the same regardless of how often they are sent. The functions of ordering cost and total inventory cost have changed, and it does not exist in the traditional economic order quantity (EOQ) likes figure 5(b). After all, the fewer inventory quantities, the fewer total inventory costs.

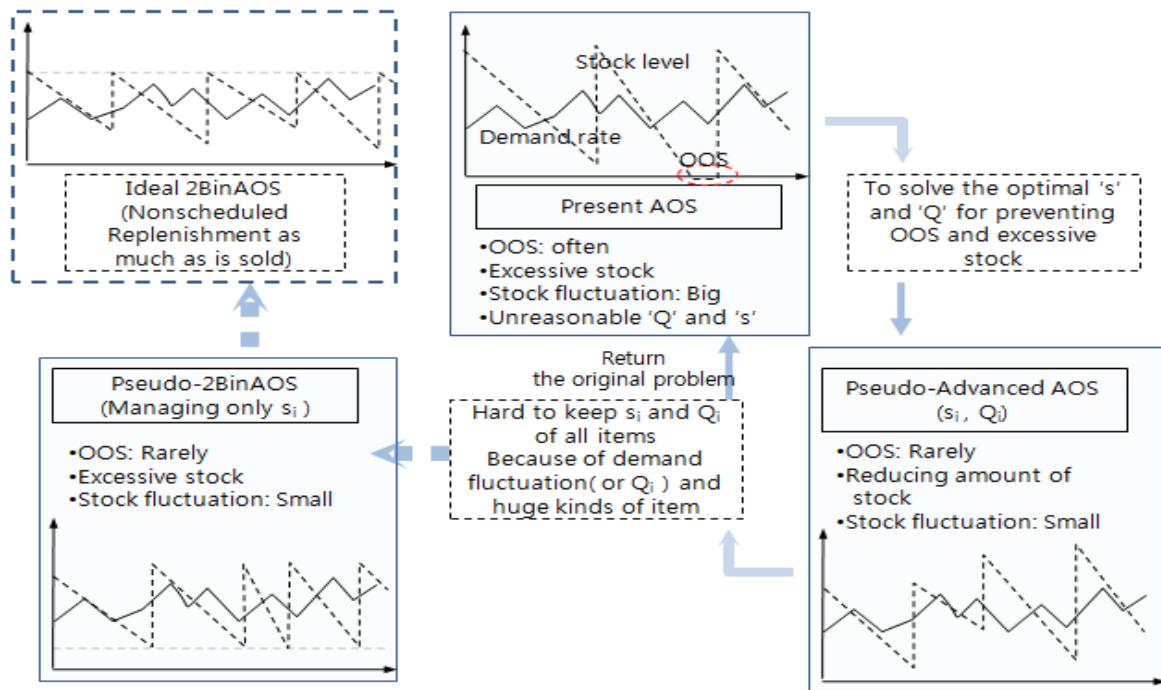
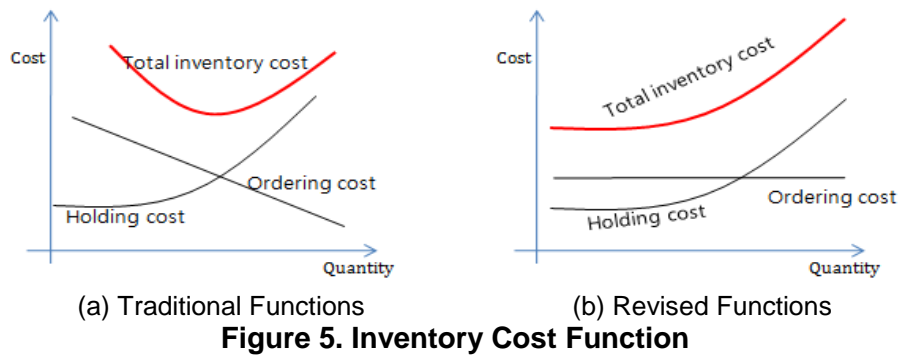


Figure 4. The Closed-loop of Inventory Management



In retail stores, controlling 'Q' in the EOQ model seems to be unnecessary work as before. It needs another approach. The principle of Pseudo-2BinAOS is to supply the quantity when the residual stock goes down to a specific level according to the demand rate or product category. More precisely, Pseudo-2BinAOS is more likely not to deal with 'Q' and 's' but to manage sales (or base stock). Also, this paper showed in the previous section that the performance of the managing sales (Pseudo-2BinAOS) was better than managing stocks (Pseudo-advanced AOS). If the focus of Pseudo-2BinAOS is changed from 'stocks' to 'sales', Pseudo-2BinAOS will become an advisable 2BinAOS.

However, albeit the replenishment ordering policy as in 2BinAOS has a low risk of OOS, 2BinAOS still has much more stock than needed because of the ordering lot size. If 2BinAOS replenishes as much as is sold at any time without waiting for orders, this method will be the ideal 2BinAOS model on the left-hand side in the figure 4. The ideal model was already shown in many textbooks. To realize the ideal model, we can apply to a Wi-Fi inventory system as a RFID-enabled system which automatically captures the replenishment signal when the bin is empty.

2) Conclusion

Many studies on inventory management have focused on academic theory rather than practical use. Many logistics researchers have established the values of 'Q' and 's' on various inventory models under a specific situations and assumptions. However most of the solutions did not lead to satisfactory results when the solutions were applied in real systems. Also inappropriate solutions bring the solved problem back to the original problem again.

This paper studied inventory challenge and focused on real problems of large retailers. Regardless of considering various demand rates, vast kind of items, retailer's deadlines and suppliers' lot size, the suggested system (2BinAOS or Pseudo-2BinAOS) can be utilized in the real market. Although this paper assumed the demand obeys the Poisson distribution in order to evaluate the proposed system, 2BinAOS is not very sensitive about the distribution because of the suggested size of a bin on the basis of demand rate. 2BinAOS can provide a valuable framework for avoiding OOS and increasing sales while reducing inventory levels. Above all, this paper shows that the performance of the replenishment policy is better than traditional methods dealing with ordering quantity and base stock and these previous methods fell into the closed loop of inventory research. If the ordering deadline could be omitted from the existing retail environment, 2BinAOS will become an ideal model. Namely, the replenishment by the amount sold without receiving any orders can lead to less OOS and less stocks. For further studies, it is necessary to do 'ordering odd lot' to conduct an ideal model.

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