수요관리도

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Demand Control Chart

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Abstract— The existing inventory managements bear a relation to forecasting or assumptions. So these methods become more complicated and more expensive systems as time goes. This paper developed a practical inventory system which is called DCC(demand control chart). DCC does not 'forecast' but 'control' the trend of demand without assumptions. According to the trend of sales, DCC adjusts an order quantity considering the capacity of shelf in a store. Specially, DCC is a useful method under FRID system. Besides, this paper introduces EPFR(Every Period Full Replenishment) policy for reducing stocks.

Index Terms—DCC(demand control chart), EPFR(Every Period Full Replenishment), DR(discount retailer), inventory, OOS(out of stock)

I. INTRODUCTION

There are many kinds of goods in a store, but the limited space of shelf affects customers' service levels. If a store has so many inventories, space of shelf is in short room. On the contrary, if a store has not enough inventory on hand, OOS(out of stocks) would be happen. The fear of losing market share due to OOS should be balanced with the reality of inventory holding costs. There is growing interest in "inventory management and sales management" in retailers. But it is hard to forecast the demand of future. These uncertainties lead to OOS or excess stocks. It is necessary to find an effective inventory management and a good forecasting method for future demand of customers.

This paper introduces EPFR(Every Period Full Replenishment) and DCC(demand control chart) for controlling inventory in terms of market. DCC does not 'forecast' but 'control' the trend of demand. This proposed method controls inventory without forecasting and assumptions. According to the trend of sales, we adjust an order quantity considering the capacity of shelf(= front store space). Section 2 and 3 describe the existing inventory systems and problems in the market of DR(discounter retailer)s, and introduce EPFR for solving these problems. Section 4 introduces the procedure of DCC in detail and DCC is applied to real data and random data. Finally, some conclusions and suggestions for further research are presented.

II. RELATIVE STUDY

A lot of inventory theories offer optimal order quantities, safety stock levels and inventory control procedures, given assumptions about demand, lead time and cost. An early example is the EOQ(economic order quantity) model which represents the theoretical optimum amount to order in each period. Inventory management at DRs is often based on EOQ principles. Each time the number of inventory decreases the below reorder point, suppliers replenish relative items at a fixed schedule of inventory system: "forecasted demand + safety stock" or "empirical judgment". Advanced inventory systems have shorten the interval among suppliers, retailers and customers, and have resolved many problems.

But as it is difficult to know about these values of assumptions, a forecasting method has been applied to inventory management system. Many researchers have developed various quantitative methods and judgmental methods for forecasting and the related papers are summarized by Smaros et.al[6]. Although a number of methodologies for judgmental and quantitative forecasts have been proposed to date, marketing traditionally relies on judgmental forecasting methods, such as managerial opinion, sales force composite, panel consensus, and market survey[5]. Namely it is important for people with contextual or domain information to incorporate the additional information into a final forecast. Edmundson et al[2] evaluated judgmental forecast performance of managers with three different levels of knowledge: having specific contextual information of the products, having domain knowledge of overall industry, having technical knowledge of forecasting methodologies. They found familiarity with specific products being forecast to be the most signification factor in improving forecast accuracy. Webby et.al.'s[7] paper is well written about dispute among statistical approaches and judgmental methods.

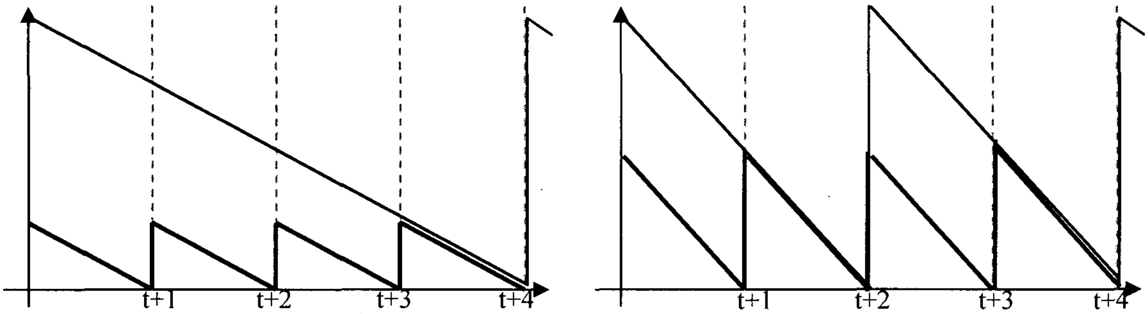
III. EVERY PERIOD FULL REPLENSHMENT(EPFR)

A. Every Period

Mostly DRs in Korea have been established VMI(vendor management inventory) systems under fixed

TABLE 1. Reorder point in E-mart

Day / Item	Mn	t	Wn	t	Fr	t	Sn	Mn	t	Wn	T	Fr	t	Sn	Mn	t	Wn	t	Fr	t	Sn
A									*		*					*					
B		*									*		*			*				*	
C																					
D		*		*							*							*			
E		*							*												
F											*					*					
G		*		*							*							*		*	
H											*										



(a) 4 periods vs 1 period (b) 2 periods vs 1 period

FIGURE 1. Comparison between periods and quantities

reorder points. VMI systems have contributed suppliers and DRs to improve customer service levels, inventory turnover and visualization. Theses systems are very strict. If any one of items is not replenished by the specific number of consecutive times of reorder, the item would be deleted from the order list of products on VMI. Besides, lead time at DR's is less short than any other market channels: receiving orders at pm. 4~5 and then delivering products by am. 11 o'clock in next day. The environment of DRs' market is described by Paik et al.[3, 4].

Suppliers deliver the required goods regularly from DRs. For example, E-mart, which is Korean DR company, usually has 3 reorder points in a week as like table 1: Mon-Wed-Fri or The-Thu-Sat. But erratic demands and unsuitable inventory policies result in inconstant service level as like excess stocks or OOS. Besides, lot size of item is so excessive and it takes a long time to sell items in a lot. At any case, it takes 3 months or more. Order quantities of mostly items are so excessive in comparison with demand rate and reorder point. Paik et.al[3] worked the relative problems.

TABLE 2. Comparison periods and quantity

Periods	2p vs. 1p		3p vs. 1p		4p vs. 1p	
Avg(#Inv)	2	1	3	1	4	1
Total Inventory	8	4	18	6	32	8

This paper proposes EPFR way. The principle of EPFR has been used in inventory model even if the principle is from doubtable source. Jong' book was addressed this principal simply[8]. Let each item is replenished every 4 periods and every periods as like figure 1. On this circumstance, it had better to deliver items every reorder points. The number of average inventory and total amount of inventory to a fourth of the amount of the former will be reduced. The results are as like table 2.

B. Full Replenishment

Supplier always replenishes as much as he sells every periods. Although the expenses associated with placing orders will be increased in inventory theory, the costs have been fixed at the market of DR. Suppliers pay the order costs in proportion to the selling every month, and these costs have nothing to do with how often placing orders.

For the efficient EPFR, it is necessary to pack various items in a box. But a packed box with mixed items is quite possible under RFID system. EPFR policy has a major merit which is to grasp the loss. If a MD(merchandiser), a person in charge of managing shelves, replenishes items under EPFR policy, he can always find the loss. The reason is that each shelf holds a specific amount of items constantly. This way can solve the previous problems as like table 3.

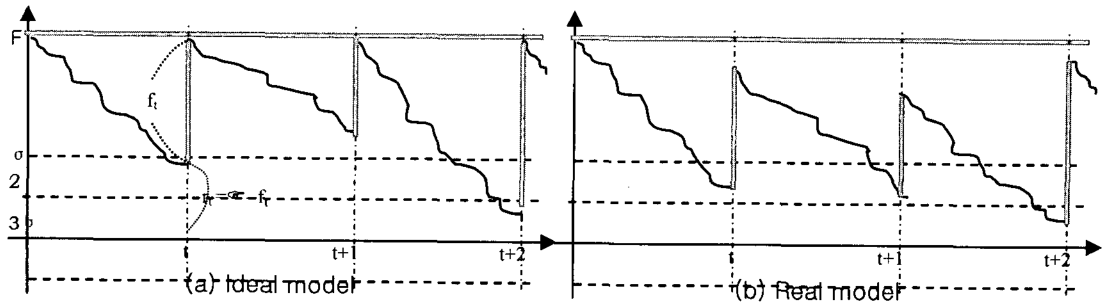


FIGURE 2. DCC Model

F : the replenishment line ($=f_t + r_t$) E : Base line(=zero line) σ : sensible line
f_t : the sales in period t (= the amount of the replenished items) r_t : the amount of stocks

TABLE 3. The benefit of EPFR

Problems of Existing system	EPFR
▪The discord between electronic stocks and real stocks.	°Find easily
▪The interrupt to place an order due to loss.	°No happen
▪Over work.	°Simplify work
▪The spending overtime for regular checking stocks.	°Unnecessary
▪Ineffective lot size.	°Suitable lot size
▪Hardly Hand over	°Easily take over
▪The difficulty of recognizing the trend of sales	°Improving

Ⅳ. DEMAND CONTROL CHART

A. Definition

A typical control chart is a graphical display of a quality characteristic that has been measured or computed from samples. Control chart is to quickly detect the assignable causes or process shifts. Control chart contains a center line that represents the average value of the quality characteristic and two lines which are called the upper control limit and the lower control limit. The principal of control chart is adapted to the new managing sales, and it is called DCC(demand control chart). The eventual goal of control chart is the elimination of variability in the process, but DCC copies with the variability in the demands without elimination(Table 4). DCC has a main line and multiple supplementary lines. These are called 'replenishment line' and 'sensible lines'. Control chart is to diagnosis the before process, but DCC is to 'manage' and 'prepare' than 'forecast' the next sales. DCC needs not to forecast but to replenish as amount of selling items. DCC manages the goal of sales and supports to propose an alternative about given circumstance.

DCC controls the order quantity according to residual quantity. In excessive stocks, DCC gets to reduce the order quantity. Reversely, DCC gets to increase them.

For an effective DCC, it needs to be a mutual good partnership among suppliers and retailers. Supplier analyzes the demand trend through DCC and delivers as amount of selling items. MDs find the loss with replenishing items and act as a solver. The graphical chart of DCC is like figure 2. Figure 2(a) is an ideal DCC model having no demand in replenishing. But there happens demand in lead time as like figure 2(b).

TABLE 4. Comparison DCC and CC

Factor	DCC	Control Chart
Variance	Confrontation	Elimination
Goal	Sales' management	Stable Process
Data	Remaining Stocks	Quality characteristic
Lines	Replenishment/ Sensible lines	Center/ Upper/ Lower control limit
Diagnosis	Sales' Variation	In control / Out of control
Approach	Empirical / Statistical	Statistical
Oriented	Short-term future	Past

B. Procedure

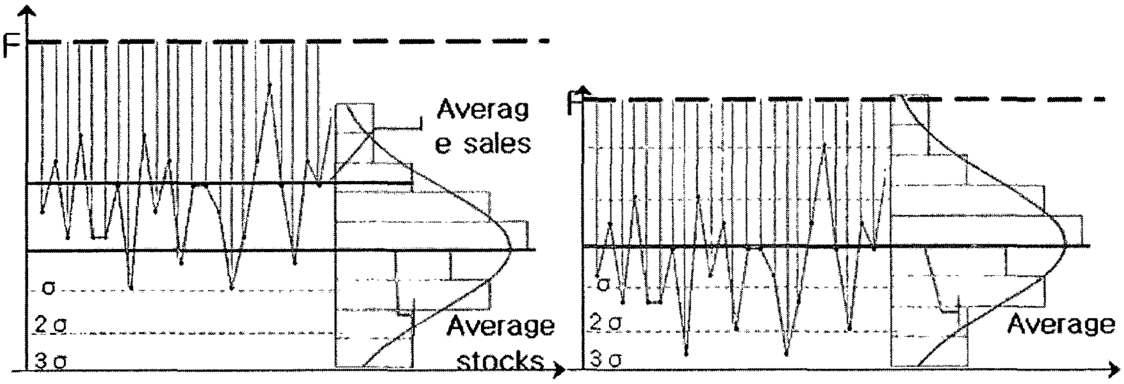
It is most important to decide the quantities of replenishment(F) in DCC. According to the decision of F, excess stocks or stock-outs is happened. There are 2 cases according to the quantity of replenishment. Fig 3(a) is shown with more stocks than he needs. In terms of marketing, piles of goods get to grow the appetite of customer's buying. So we must consider the capacity of the space of shelf-space. In this case, the role of sensible lines is alleviated. If the quantity is not filled by F after replenishing, we can guess the happened loss. Fig 3(b) is shown to replenish as much as the need.

[STEP 1] Collection fundamental data : T, N, μ, σ, δ

After deciding a sales strategy, we should find horizontal time(T), renewal time(N), average(μ,) and variance(σ) of sales, and the rate of OOS(δ). We can consider T as yearly, quarterly, monthly, weekly data. Besides, we need to reset average and variance every N times for reflecting the recent trend of sales. Usually, it is considered a quarter or a month as T, and a month or a week as N. It is recommended that data are grouped by daily. Because it is differences the trend of consumption by daily. In generally, it sells well on weekend. So it is possible to change original data into modified data with no trends as like Bedworth,D.D, and Bailey,J.E.[1].

[STEP 2] Decision a replenishment line: F

It is most important to decide the replenishment line. Line F could be compute as empirical methods or statistical methods.



(a) $\mu_f \neq \mu_r$ (b) $\mu_f = \mu_r$

FIGURE 3. Two type of DCC model

F = [space capacity of shelf, I x (# Average sales in a period) + $Z_\delta \sigma / \sqrt{n}$]

If the average sales per period are less then the capacity of shelf, you had better replenish them by F considering the shelf space. I is the rate of expectation for improvement sales. 'I = 1.2 means 20% of increasing sales more then the previous period.

[STEP 3] Setting sensible lines

It needs sensible lines so that DCC should perceive the demand changes whether to increase or not for preventing OOS and excess stocks. According to periods, sensible lines can be reset. Mostly goods have the trend of the times. It is recommended that data are grouped by daily. It is necessary to research the detailed sensible lines in the future.

A. Heuristic method (lot size, inventory, demand rate)

An opinion of actual worker is very important. Sanders et al[5] argued that specific products knowledge of retailer is significant factor in improving F[5]. When sensible lines are determined, you should have reflected marketing plan, lot size, and the specific product knowledge and so on. If variance is so large, heuristics method is recommended. For instance, a sensible line is considered as 'lot size' or '$\alpha \bar{x}$'.

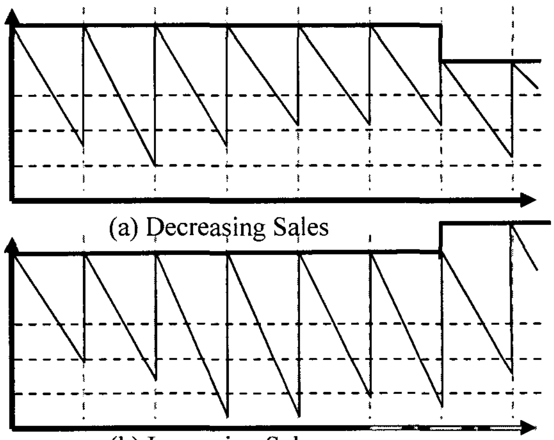
B. Statistical method

According to the inventory policy in one's company, you can set these lines. For example, d_1 is a% preservative line, d_2 is b% separate line, and d_3 is δ % rate of OOS. There are many methods in computing 3σ.

$R_i = |x_i - x_{i+1}|$,

3σ sensible line $=(\bar{x} + 2.66\bar{R} = D4\bar{R})$ or $(\bar{x} + 3\sigma)$

If σ is so much value, find the cause of variance and decide reasonable value as like fig 5.



(a) Decreasing Sales

(b) Increasing Sales

FIGURE 4. Increment/Decrement

[STEP 4] Analysis Trend

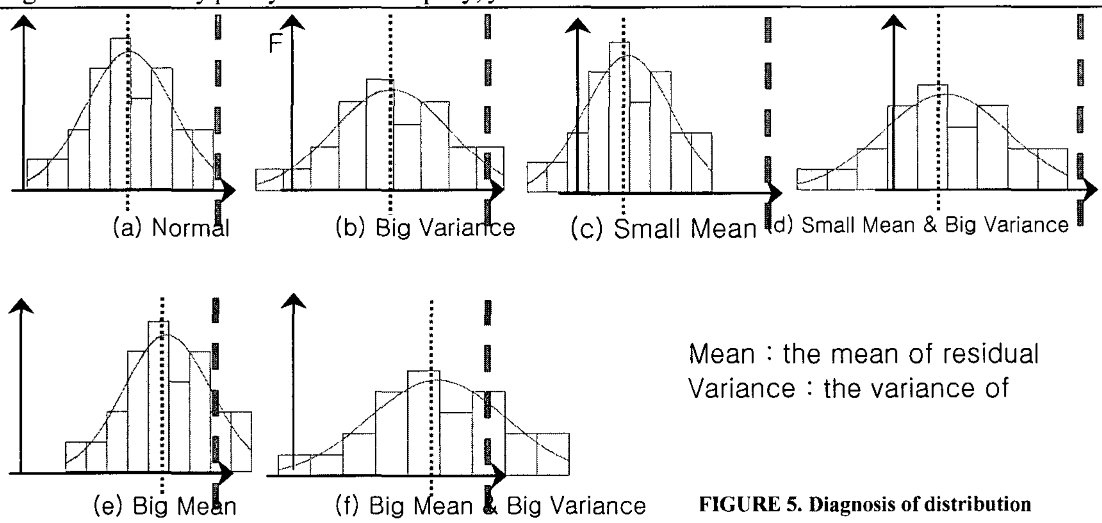


FIGURE 5. Diagnosis of distribution

Control chart is shown with 'run', 'trend', 'biased' and so on. DCC considers them as 'trend'. When an unexpected sale happens, it is necessary to find that the fluctuation in sales comes from the growing trend of sales or the chance causes. If the fluctuation brings about a chance cause, we usually need to have no concern. In the other case, more order quantities should be supplied. In statically, the probability of a point within 2σ-3σ is less 0.021. Else many cases are summarized as table 5. With free fluctuation scope from 3σ, F should be adjusted by $\lceil\sigma\rceil$ or $\lfloor\sigma\rfloor$: increase $\lceil D\rceil$ in stock-outs(fig 4 (a)) and decrease $\lfloor D\rfloor$ in excess stock(fig 4(b)).

Besides, sometimes it needs to adjust F value when the erratic demand is so much. At that time, we can not confront the fluctuation with ordinal methods. Fig 6(a) is normal condition. (b) means that the fluctuation of demand is heavy. So it needs to search the causes and to reset the sensible lines. (c) shows the sales continues to increase. Namely, stocks get to decrease. In this case, distribution is moved. (d) explains sales increase rapidly. After finding reasons, these values are readjusted with recent data. If F is so much high, the shape is as like (e). (e) is the opposite of (d).

[STEP 5] Control F value

If chance causes happen on SQC, we should remove the causes. On DCC, these causes are analyzed and are reflected to DCC; increasing or decreasing F value. With free fluctuation scope from 3σ, F should be adjusted as like bellows.

$F_t = F_{t-1} + D$, D : amount of increasing or decreasing.

There are many methods for deciding D value. This paper uses the average R_i. ($R_i = |x_i - x_{i+1}|$)

TABLE 5. Occurring Probability

Interval	μ~(+σ) <= 0.341	+σ~+2σ <=0.136	+2σ~+3σ <=0.021	Probability
# Points	0	0	1	0.021*
	0	2	0	0.019*
	1	1	0	0.046
	2	0	0	0.116
	3	0	0	0.040*

[STEP 6] Periodic Renewal

As time goes, the recent trend is so smooth that the sensibility of DCC would grow weak. So it is necessary to adjust D, μ, σ, F values reflecting recent demand every a given period(N)

V. CASE STUDY

In this section, DSS is applied to DIY(do it yourself) goods in DR(discount retailer)s: door lock, lightening, Multi-tab, tools etc. The real data from 02/1/1 to 02/12/31 are obtained from VMI(vendor management inventory)

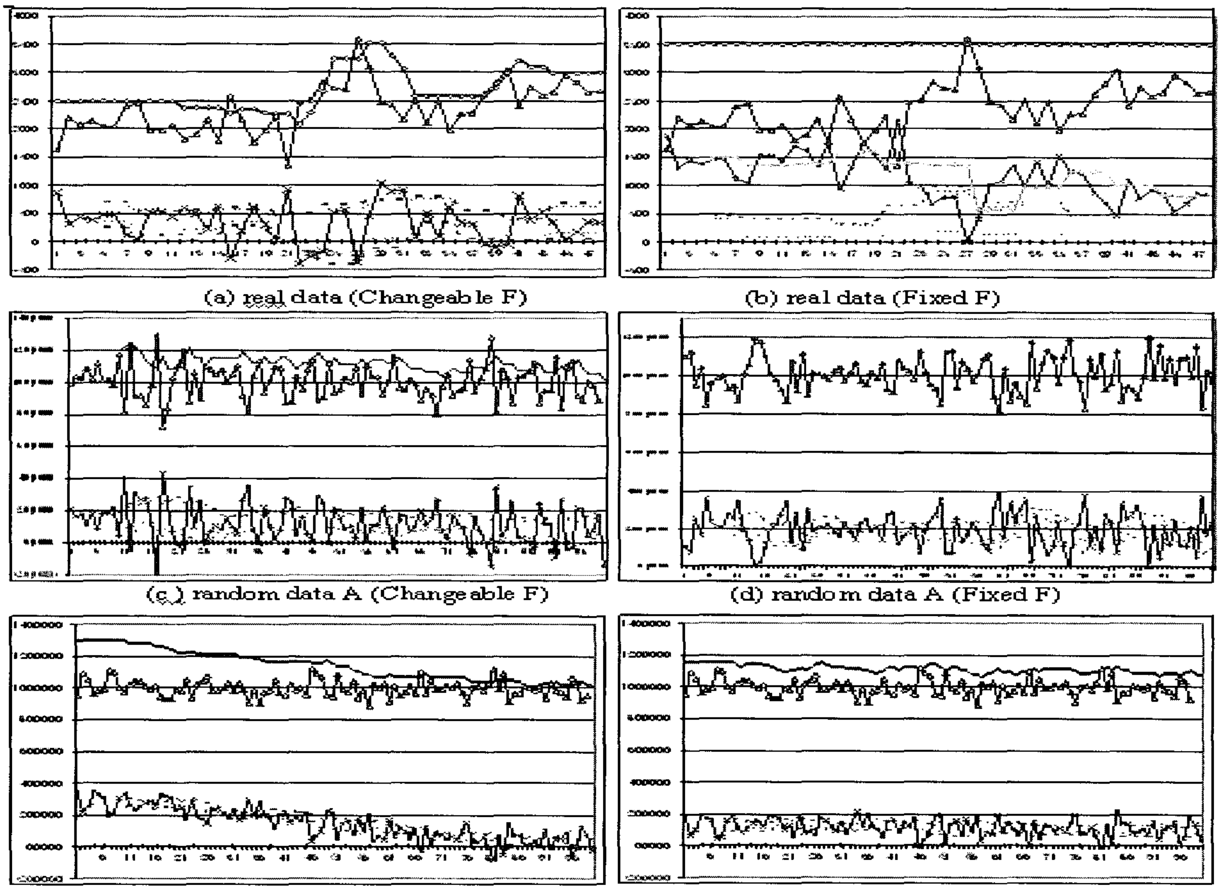


FIGURE 6. The result of simulation

systems of E-mart. Usually, the VMI systems of mostly DR give data within only 3 month to suppliers. So it is difficult to get daily data of each item. Many suppliers have no daily data per each item in a store because of spending much time, needing many workers, and increasing complexity. Besides, related clerks did not feel the necessity for collecting them, because clerks did not forecast items at DRs. So we generated random data in normal distribution with MiniTab SQC package.

The specification of data is as like table 6. Real daily data have the trend of sales. Usually the highest selling is on weekend[Paik2000]. So data are need to be separated daily. The result is shown good performance more then expectation as like fig 6. It is hard to specify the exact performance of DCC, but it is found that it is higher performance of DCC, its variance of data are smaller as like table 6.

After simulation, a problem is happened. If consecutive data differ greatly, the performance of DCC gets to be unstable for a time. Because amount of supplement are so small compared with a wide gab of data.

TABLE 6. Specification of data

	(a)	(b)	(c)	(d)	(e)	(f)
Init. F	2500	3500	120	150	115	130
Sens.L	±1.645	±1.645	±1.645	±1.645	±1.645	±1.645
$\bar{x}$	2,357	2,357	100	100	100	100
S	426.7	426.7	20	20	5	5
T, N	monthly	monthly	monthly	monthly	monthly	monthly
Out of Control	17%		15%		8%	
etc.	On continuous 2 decrease , F is increased as 2 times D					

Ⅵ. CONCLUSION

Generally, an effective inventory management bears a relation to forecasting. These methods become more complicated and more expensive systems as time goes. But it is impossible to know the trend of future. This paper developed the practical DCC firstly. DCC does not 'forecast' but 'control' the trend of demand. The proposed method controls inventory without forecasting and assumptions. Besides, this paper introduce the merit of EPFR(Every Period Full Replenishment) for reducing stocks and preventing the loss.

This paper finds that fluctuation of demand at DR is not large unexpectedly and the performance of DCC is well. The more the factors of variation will be find, the more it's performance is improved. DCC copes with demand of future about 80% or more. DCC has a good effect under fixed reorder point policy and regular replenishment way. The performance of DCC is affected by variance in data. So according as various situations, these values(sensible line, F, variance) should be controlled.

DCC is a useful method for short-term forecast and on real time inventory policy. In especially, DCC is a suitable tool under RFID system. Further works needs to research various applications, to remove the uncertain in data and to develop heuristic methods for the regulating of DCC.

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